Inter-Domain Routing
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# North-Bound Distribution of Link-State and TE Information using BGP
# draft-ietf-idr-ls-distribution-05

## Abstract

In a number of environments, a component external to a network is called upon to perform computations based on the network topology and current state of the connections within the network, including traffic engineering information. This is information typically distributed by IGP routing protocols within the network

This document describes a mechanism by which links state and traffic engineering information can be collected from networks and shared with external components using the BGP routing protocol. This is achieved using a new BGP Network Layer Reachability Information (NLRI) encoding format. The mechanism is applicable to physical and virtual IGP links. The mechanism described is subject to policy control.

Applications of this technique include Application Layer Traffic Optimization (ALTO) servers, and Path Computation Elements (PCEs).

## 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

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

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## Table of Contents

## 1. Introduction

The contents of a Link State Database (LSDB) or a Traffic Engineering Database (TED) has the scope of an IGP area. Some applications, such as end-to-end Traffic Engineering (TE), would benefit from visibility outside one area or Autonomous System (AS) in order to make better decisions.

The IETF has defined the Path Computation Element (PCE) [RFC4655] as

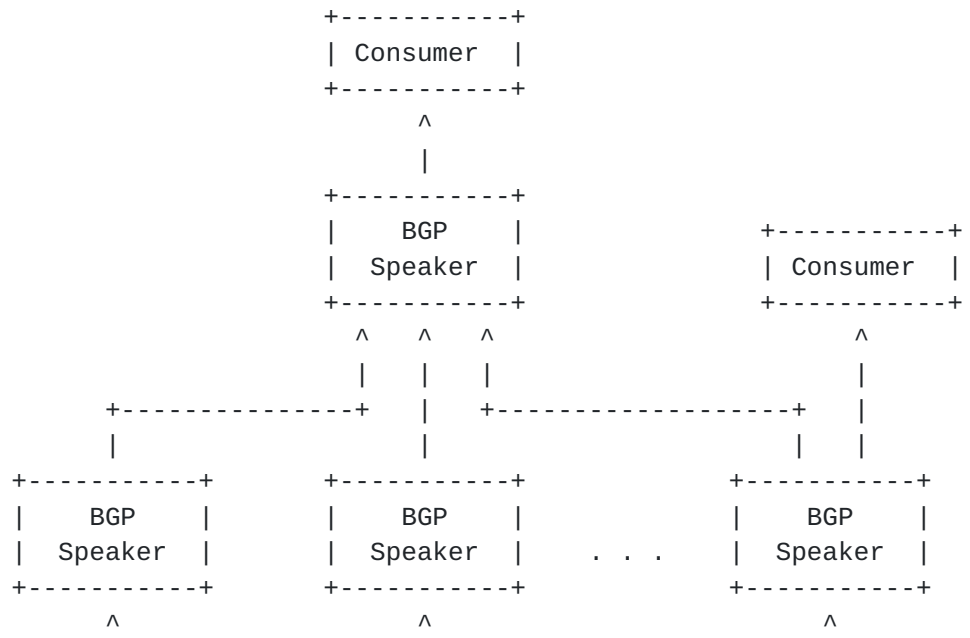
a mechanism for achieving the computation of end-to-end TE paths that cross the visibility of more than one TED or which require CPU-intensive or coordinated computations. The IETF has also defined the ALTO Server [RFC5693] as an entity that generates an abstracted network topology and provides it to network-aware applications.

Both a PCE and an ALTO Server need to gather information about the topologies and capabilities of the network in order to be able to fulfill their function.

This document describes a mechanism by which Link State and TE information can be collected from networks and shared with external components using the BGP routing protocol [RFC4271]. This is achieved using a new BGP Network Layer Reachability Information (NLRI) encoding format. The mechanism is applicable to physical and virtual links. The mechanism described is subject to policy control.

A router maintains one or more databases for storing link-state information about nodes and links in any given area. Link attributes stored in these databases include: local/remote IP addresses, local/remote interface identifiers, link metric and TE metric, link bandwidth, reservable bandwidth, per CoS class reservation state, preemption and Shared Risk Link Groups (SRLG). The router's BGP process can retrieve topology from these LSDBs and distribute it to a consumer, either directly or via a peer BGP Speaker (typically a dedicated Route Reflector), using the encoding specified in this document.

The collection of Link State and TE link state information and its distribution to consumers is shown in the following figure.




IGP
IGP
IGP

A BGP Speaker may apply configurable policy to the information that it distributes. Thus, it may distribute the real physical topology from the LSDB or the TED. Alternatively, it may create an abstracted topology, where virtual, aggregated nodes are connected by virtual paths. Aggregated nodes can be created, for example, out of multiple routers in a POP. Abstracted topology can also be a mix of physical and virtual nodes and physical and virtual links. Furthermore, the BGP Speaker can apply policy to determine when information is updated to the consumer so that there is reduction of information flow form the network to the consumers. Mechanisms through which topologies can be aggregated or virtualized are outside the scope of this document

## 2. Motivation and Applicability

This section describes use cases from which the requirements can be derived.

### 2.1. MPLS-TE with PCE

As described in [RFC4655] a PCE can be used to compute MPLS-TE paths within a "domain" (such as an IGP area) or across multiple domains (such as a multi-area AS, or multiple ASes).

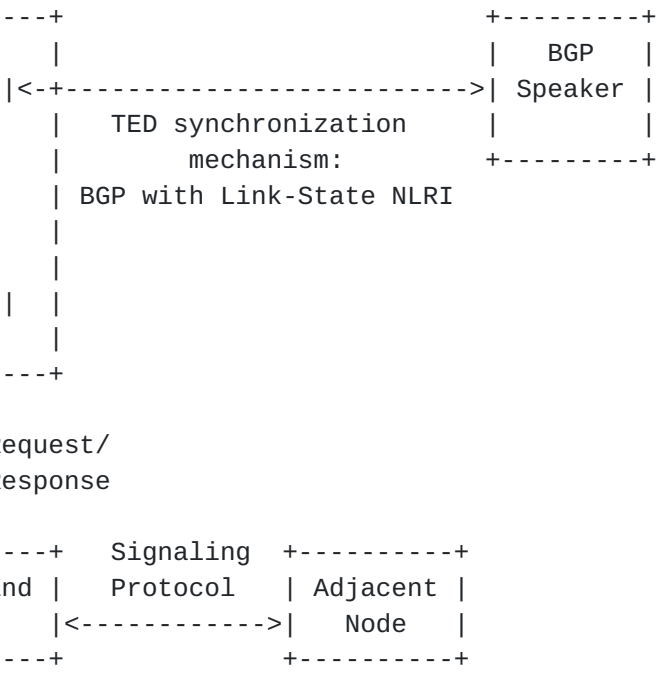
- Within a single area, the PCE offers enhanced computational power that may not be available on individual routers, sophisticated policy control and algorithms, and coordination of computation across the whole area.

- If a router wants to compute a MPLS-TE path across IGP areas its own TED lacks visibility of the complete topology. That means that the router cannot determine the end-to-end path, and cannot even select the right exit router (Area Border Router - ABR) for an optimal path. This is an issue for large-scale networks that need to segment their core networks into distinct areas, but which still want to take advantage of MPLS-TE.

Previous solutions used per-domain path computation [RFC5152]. The source router could only compute the path for the first area because the router only has full topological visibility for the first area along the path, but not for subsequent areas. Per-domain path computation uses a technique called "loose-hop-expansion" [RFC3209], and selects the exit ABR and other ABRs or AS Border Routers (ASBRs) using the IGP computed shortest path topology for the remainder of the path. This may lead to sub-optimal paths, makes alternate/back-up path computation hard, and might result in no TE path being found when one really does exist.

The PCE presents a computation server that may have visibility into more than one IGP area or AS, or may cooperate with other PCEs to perform distributed path computation. The PCE obviously needs access to the TED for the area(s) it serves, but [RFC4655] does not describe how this is achieved. Many implementations make the PCE a passive participant in the IGP so that it can learn the latest state of the network, but this may be sub-optimal when the network is subject to a high degree of churn, or when the PCE is responsible for multiple areas.

The following figure shows how a PCE can get its TED information using the mechanism described in this document.



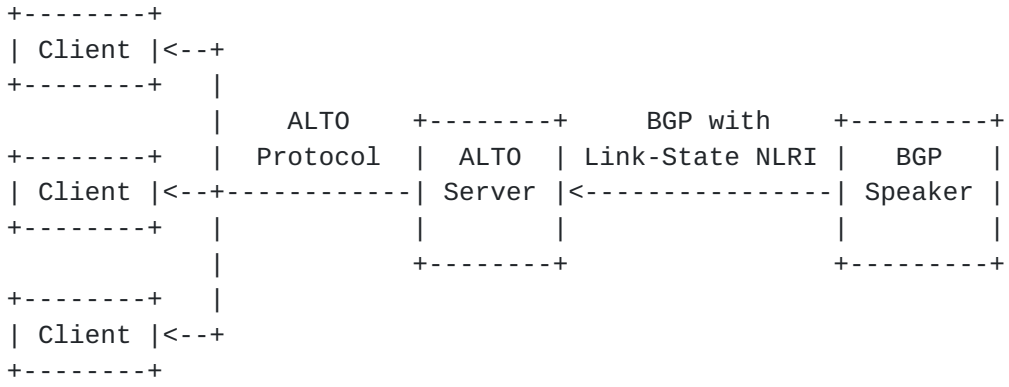

The mechanism in this document allows the necessary TED information to be collected from the IGP within the network, filtered according to configurable policy, and distributed to the PCE as necessary.

## 2.2. ALTO Server Network API

An ALTO Server [RFC5693] is an entity that generates an abstracted network topology and provides it to network-aware applications over a web service based API. Example applications are p2p clients or trackers, or CDNs. The abstracted network topology comes in the form of two maps: a Network Map that specifies allocation of prefixes to Partition Identifiers (PIDs), and a Cost Map that specifies the cost between PIDs listed in the Network Map. For more details, see [I-D .ietf-alto-protocol].

ALTO abstract network topologies can be auto-generated from the physical topology of the underlying network. The generation would typically be based on policies and rules set by the operator. Both prefix and TE data are required: prefix data is required to generate ALTO Network Maps, TE (topology) data is required to generate ALTO Cost Maps. Prefix data is carried and originated in BGP, TE data is originated and carried in an IGP. The mechanism defined in this document provides a single interface through which an ALTO Server can retrieve all the necessary prefix and network topology data from the underlying network. Note an ALTO Server can use other mechanisms to get network data, for example, peering with multiple IGP and BGP Speakers.

The following figure shows how an ALTO Server can get network topology information from the underlying network using the mechanism described in this document.

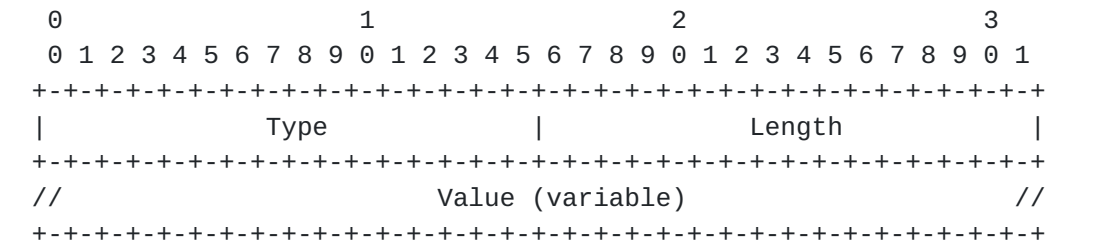



## 3. Carrying Link State Information in BGP

This specification contains two parts: definition of a new BGP NLRI that describes links, nodes and prefixes comprising IGP link state information, and definition of a new BGP path attribute (BGP-LS attribute) that carries link, node and prefix properties and attributes, such as the link and prefix metric or auxiliary Router-IDs of nodes, etc.

### 3.1. TLV Format

Information in the new Link-State NLRIs and attributes is encoded in Type/Length/Value triplets. The TLV format is shown in Figure 4.




The Length field defines the length of the value portion in octets (thus a TLV with no value portion would have a length of zero). The TLV is not padded to four-octet alignment. Unrecognized types are preserved and propagated. In order to compare NLRIs with unknown TLVs all TLVs MUST be ordered in ascending order. If there are more TLVs of the same type, then the TLVs MUST be ordered in ascending order of the TLV value within the set of TLVs with the same type. All TLVs that are not specified as mandatory are considered optional.

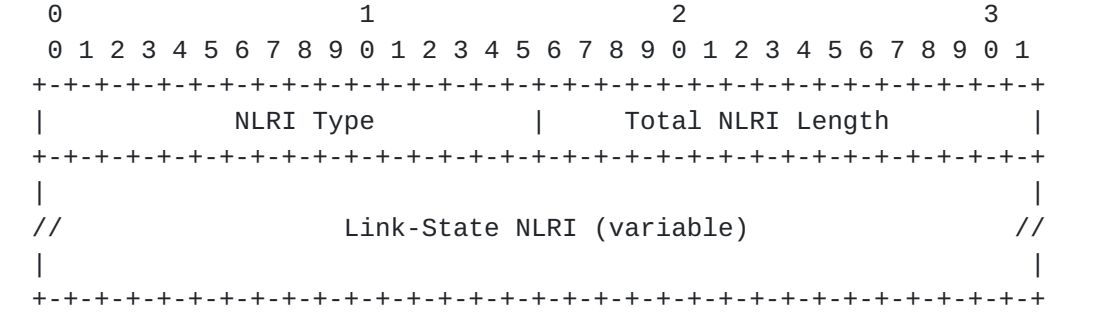
## 3.2. The Link-State NLRI

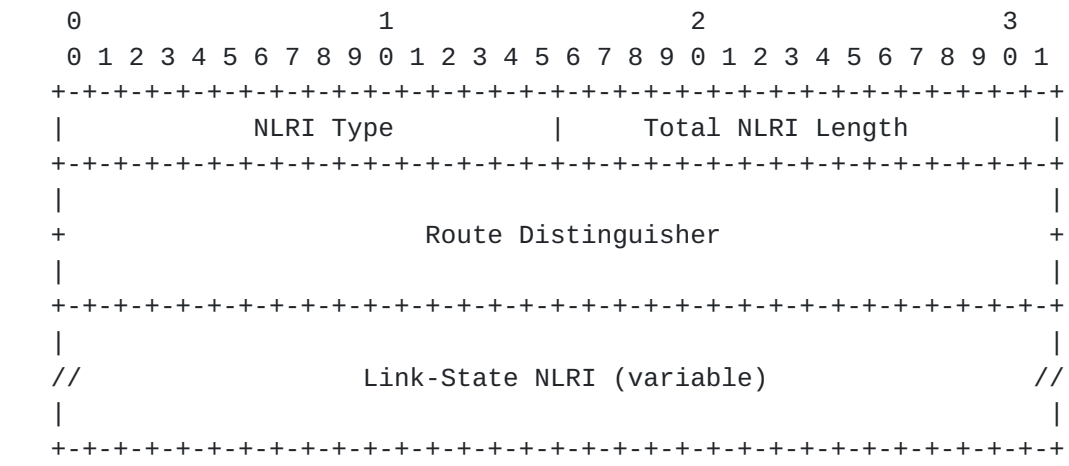
The MP_REACH and MP_UNREACH attributes are BGP's containers for carrying opaque information. Each Link-State NLRI describes either a node, a link or a prefix.

All non-VPN link, node and prefix information SHALL be encoded using AFI 16388 / SAFI 71. VPN link, node and prefix information SHALL be encoded using AFI 16388 / SAFI 128.

In order for two BGP speakers to exchange Link-State NLRI, they MUST use BGP Capabilities Advertisement to ensure that they both are capable of properly processing such NLRI. This is done as specified in [RFC4760], by using capability code 1 (multi-protocol BGP), with an AFI 16388 / SAFI 71 and AFI 16388 / SAFI 128 for the VPN flavor.

The format of the Link-State NLRI is shown in the following figure.






The 'Total NLRI Length' field contains the cumulative length, in octets, of rest of the NLRI not including the NLRI Type field or itself. For VPN applications it also includes the length of the Route Distinguisher.

The 'NLRI Type' field can contain one of the following values:

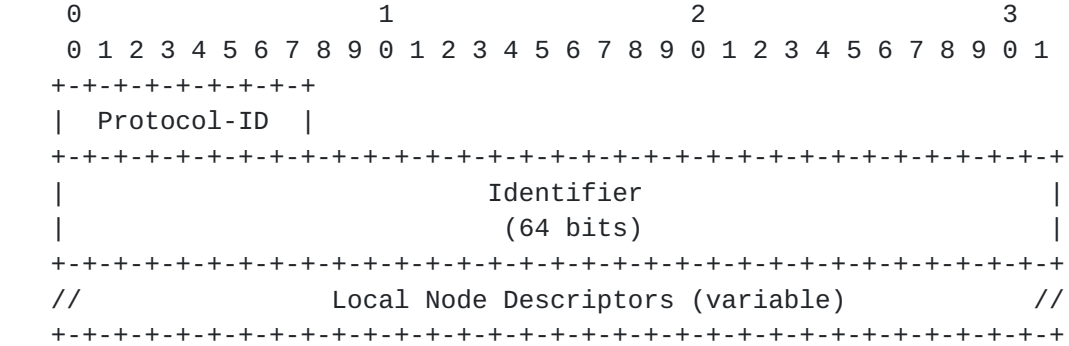
Type = 1: Node NLRI

Type = 2: Link NLRI

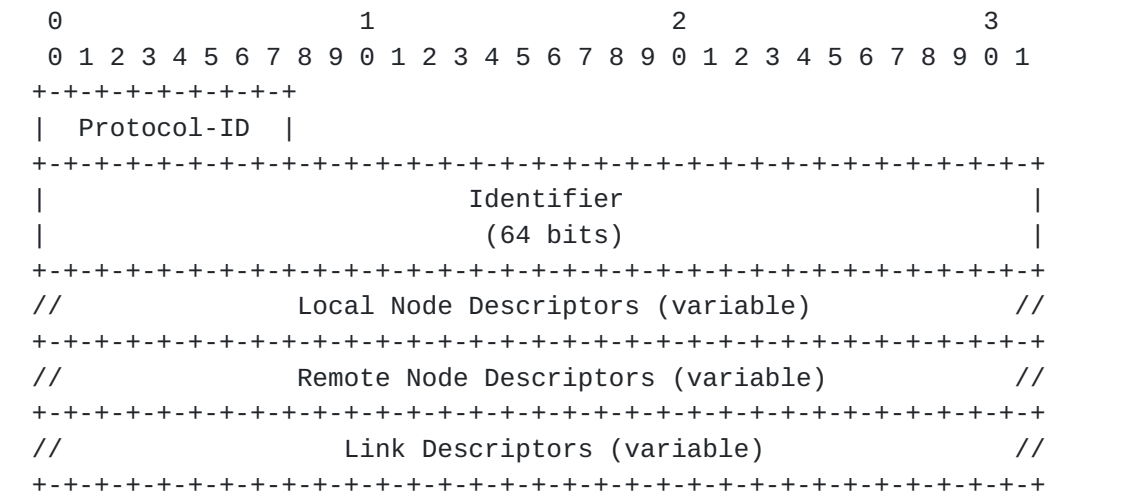
Type = 3: IPv4 Topology Prefix NLRI

Type = 4: IPv6 Topology Prefix NLRI

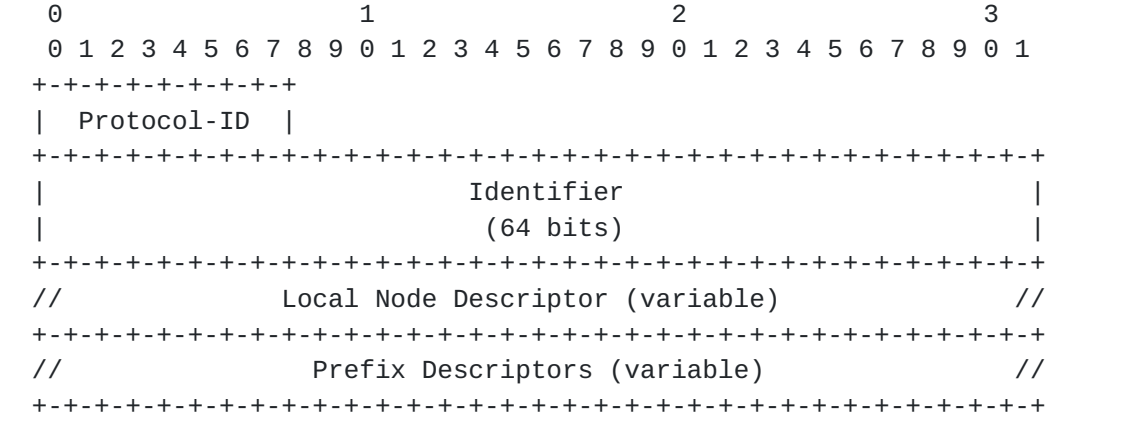
The Node NLRI (NLRI Type = 1) is shown in the following figure.




The Link NLRI (NLRI Type = 2) is shown in the following figure.




The IPv4 and IPv6 Prefix NLRIs (NLRI Type = 3 and Type = 4) use the same format as shown in the following figure.




The 'Protocol-ID' field can contain one of the following values:

Protocol-ID = 0: Unknown, The source of NLRI information could not be determined

Protocol-ID = 1: IS-IS Level 1, The NLRI information has been sourced by IS-IS Level 1

Protocol-ID = 2: IS-IS Level 2, The NLRI information has been sourced by IS-IS Level 2

Protocol-ID = 3: OSPF, The NLRI information has been sourced by OSPF

Protocol-ID = 4: Direct, The NLRI information has been sourced from local interface state

Protocol-ID = 5: Static, The NLRI information has been sourced by

static configuration

Both OSPF and IS-IS may run multiple routing protocol instances over the same link. See [RFC6822] and [RFC6549]. These instances define independent "routing universes". The 64-Bit 'Identifier' field is used to identify the "routing universe" where the NLRI belongs. The NLRIs representing IGP objects (nodes, links or prefixes) from the same routing universe MUST have the same 'Identifier' value; NLRIs with different 'Identifier' values MUST be considered to be from different routing universes. Table Table 1 lists the 'Identifier' values that are defined as well-known in this draft.

| Identifier | Routing Universe |
|---|---|
| 0 | L3 packet topology |
| 1 | L1 optical topology |

Each Node Descriptor and Link Descriptor consists of one or more TLVs described in the following sections.

### 3.2.1. Node Descriptors

Each link is anchored by a pair of Router-IDs that are used by the underlying IGP, namely, 48 Bit ISO System-ID for IS-IS and 32 bit Router-ID for OSPFv2 and OSPFv3. An IGP may use one or more additional auxiliary Router-IDs, mainly for traffic engineering purposes. For example, IS-IS may have one or more IPv4 and IPv6 TE Router-IDs [RFC5305], [RFC6119]. These auxiliary Router-IDs MUST be included in the link attribute described in Section Section 3.3.2.

It is desirable that the Router-ID assignments inside the Node Descriptor are globally unique. However there may be Router-ID spaces (e.g. ISO) where no global registry exists, or worse, Router-IDs have been allocated following private-IP RFC 1918 [RFC1918] allocation. We use Autonomous System (AS) Number and BGP-LS Identifier in order to disambiguate the Router-IDs, as described in Section 3.2.1.1.

#### 3.2.1.1. Globally Unique Node/Link/Prefix Identifiers

One problem that needs to be addressed is the ability to identify an IGP node globally (by "global", we mean within the BGP-LS database collected by all BGP-LS speakers that talk to each other). This can be expressed through the following two requirements:

(A) The same node must not be represented by two keys (otherwise one

node will look like two nodes).

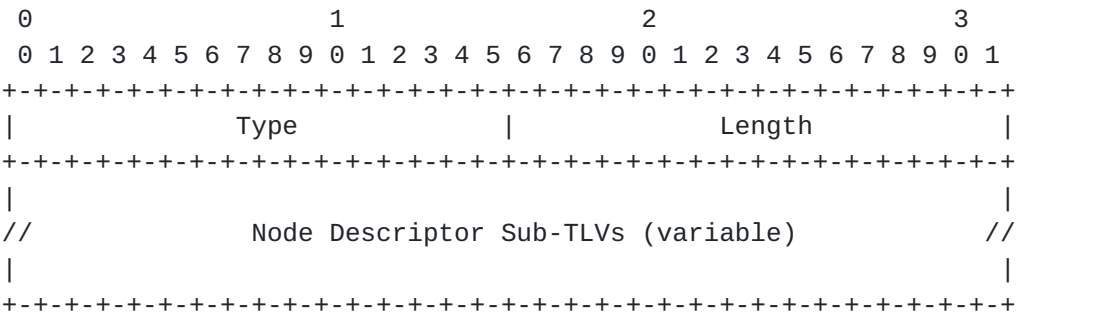
(B) Two different nodes must not be represented by the same key (otherwise, two nodes will look like one node).

We define an "IGP domain" to be the set of nodes (hence, by extension links and prefixes), within which, each node has a unique IGP representation by using the combination of Area-ID, Router-ID, Protocol, Topology-ID, and Instance ID. The problem is that BGP may receive node/link/prefix information from multiple independent "IGP domains" and we need to distinguish between them. Moreover, we can't assume there is always one and only one IGP domain per AS. During IGP transitions it may happen that two redundant IGPs are in place.

In section Section 3.2.1.4 a set of sub-TLVs is described, which allows to specify a flexible key for any given Node/Link information such that global uniqueness of the NLRI is ensured.

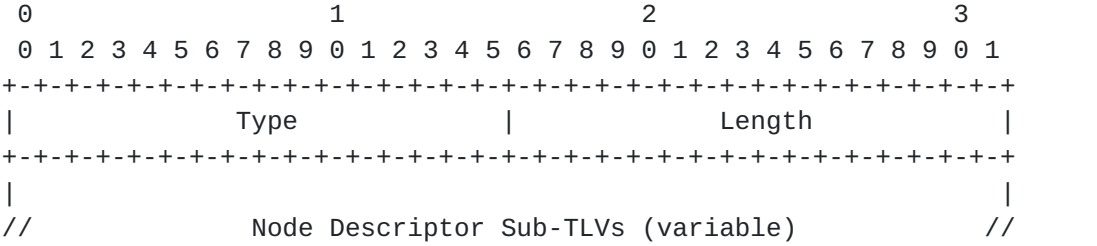
### 3.2.1.2. Local Node Descriptors

The Local Node Descriptors TLV contains Node Descriptors for the node anchoring the local end of the link. This is a mandatory TLV in all three types of NLRIs. The length of this TLV is variable. The value contains one or more Node Descriptor Sub-TLVs defined in Section 3.2.1.4.




### 3.2.1.3. Remote Node Descriptors

The Remote Node Descriptors contains Node Descriptors for the node anchoring the remote end of the link. This is a mandatory TLV for link NLRIs. The length of this TLV is variable. The value contains one or more Node Descriptor Sub-TLVs defined in Section 3.2.1.4.



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### 3.2.1.4. Node Descriptor Sub-TLVs

The Node Descriptor Sub-TLV type codepoints and lengths are listed in the following table:

| Sub-TLV Code Point | Description | Length |
|---|---|---|
| 512 | Autonomous System | 4 |
| 513 | BGP-LS Identifier | 4 |
| 514 | Area-ID | 4 |
| 515 | IGP Router-ID | Variable |

The sub-TLV values in Node Descriptor TLVs are defined as follows:

Autonomous System: opaque value (32 Bit AS Number)

BGP-LS Identifier: opaque value (32 Bit ID). In conjunction with ASN, uniquely identifies the BGP-LS domain. The combination of ASN and BGP-LS ID MUST be globally unique. All BGP-LS speakers within an IGP flooding-set (set of IGP nodes within which an LSP/LSA is flooded) MUST use the same ASN, BGP-LS ID tuple. If an IGP domain consists of multiple flooding-sets, then all BGP-LS speakers within the IGP domain SHOULD use the same ASN, BGP-LS ID tuple. The ASN, BGP Router-ID tuple (which is globally unique [RFC6286] ) of one of the BGP-LS speakers within the flooding-set (or IGP domain) may be used for all BGP-LS speakers in that flooding-set (or IGP domain).

Area ID: It is used to identify the 32 Bit area to which the NLRI belongs. Area Identifier allows the different NLRIs of the same router to be discriminated.

IGP Router ID: opaque value. This is a mandatory TLV. For an IS-IS non-Pseudonode, this contains 6 octet ISO node-ID (ISO system-ID). For an IS-IS Pseudonode corresponding to a LAN, this contains 6 octet ISO node-ID of the "Designated Intermediate System" (DIS) followed by one octet nonzero PSN identifier (7 octet in total). For an OSPFv2 or OSPFv3 non-"Pseudonode", this contains 4 octet Router-ID. For an OSPFv2 "Pseudonode" representing a LAN, this contains 4 octet Router-ID of the designated router (DR) followed by 4 octet IPv4 address of the DR's interface to the LAN (8 octet in total). Similarly, for an OSPFv3 "Pseudonode", this contains 4 octet Router-ID of the DR followed by 4 octet interface identifier of the DR's interface to the LAN (8 octet in total). The TLV size in combination with protocol identifier enables the decoder to

determine the type of the node.

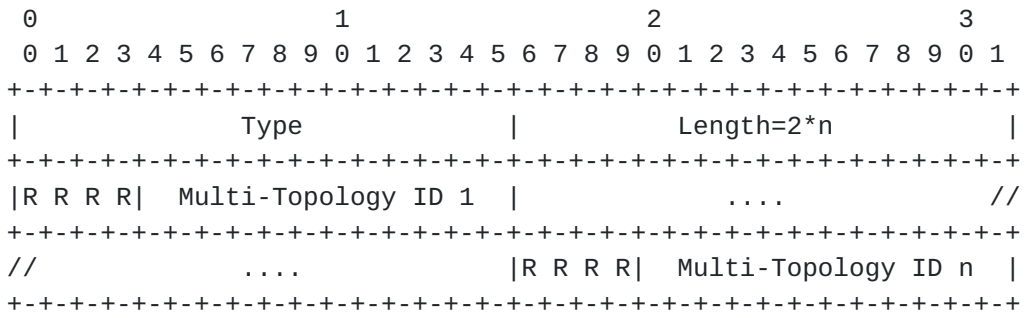
There can be at most one instance of each sub-TLV type present in any Node Descriptor. The TLV ordering within a Node descriptor MUST be kept in order of increasing numeric value of type. This needs to be done in order to compare NLRIs, even when an implementation encounters an unknown sub-TLV. Using stable sorting an implementation can do binary comparison of NLRIs and hence allow incremental deployment of new key sub-TLVs.

#### 3.2.1.5. Multi-Topology ID

The Multi-Topology ID (MT-ID) TLV carries one or more IS-IS or OSPF Multi-Topology IDs for a link, node or prefix.

Semantics of the IS-IS MT-ID are defined in RFC5120, Section 7.2 [RFC5120]. Semantics of the OSPF MT-ID are defined in RFC4915, Section 3.7 [RFC4915]. If the value in the MT-ID TLV is derived from OSPF, then the upper 9 bits MUST be set to 0. Bits R are reserved, SHOULD be set to 0 when originated and ignored on receipt.

The format of the MT-ID TLV is shown in the following figure.




where Type is 263, Length is 2*n and n is the number of MT-IDs carried in the TLV.

The MT-ID TLV MAY be present in a Link Descriptor, a Prefix Descriptor, or in the BGP-LS attribute of a node NLRI. In Link or Prefix Descriptor, only one MT-ID TLV containing only the MT-ID of the topology where the link or the prefix belongs is allowed. In the

BGP-LS attribute of a node NLRI, one MT-ID TLV containing the array of MT-IDs of all topologies where the node belongs can be present.

### 3.2.2. Link Descriptors

The 'Link Descriptor' field is a set of Type/Length/Value (TLV) triplets. The format of each TLV is shown in Section 3.1. The 'Link descriptor' TLVs uniquely identify a link among multiple parallel links between a pair of anchor routers. A link described by the Link descriptor TLVs actually is a "half-link", a unidirectional representation of a logical link. In order to fully describe a single logical link two originating routers advertise a half-link each, i.e. two link NLRIs are advertised for a given point-to-point link.

The format and semantics of the 'value' fields in most 'Link Descriptor' TLVs correspond to the format and semantics of value fields in IS-IS Extended IS Reachability sub-TLVs, defined in [RFC5305], [RFC5307] and [RFC6119]. Although the encodings for 'Link Descriptor' TLVs were originally defined for IS-IS, the TLVs can carry data sourced either by IS-IS or OSPF.

The following TLVs are valid as Link Descriptors in the Link NLRI:

| TLV Code Point | Description | IS-IS TLV /Sub-TLV | Value defined in: |
|---|---|---|---|
| 258 | Link Local/Remote Identifiers | 22/4 | [RFC5307]/1.1 |
| 259 | IPv4 interface address | 22/6 | [RFC5305]/3.2 |
| 260 | IPv4 neighbor address | 22/8 | [RFC5305]/3.3 |
| 261 | IPv6 interface address | 22/12 | [RFC6119]/4.2 |
| 262 | IPv6 neighbor address | 22/13 | [RFC6119]/4.3 |
| 263 | Multi-Topology Identifier | --- | Section 3.2.1.5 |

The information about a link present in the LSA/LSP originated by the local node of the link determines the set of TLVs in the Link Descriptor of the link.

If interface and neighbor addresses, either IPv4 or IPv6, are present, then the IP address TLVs are included in the link descriptor, but not the link local/remote Identifier TLV. The link

local/remote identifiers MAY be included in the link attribute.

If interface and neighbor addresses are not present and the link local/remote identifiers are present, then the link local/remote Identifier TLV is included in link descriptor.

The Multi-Topology Identifier TLV is included in link descriptor if that information is present.

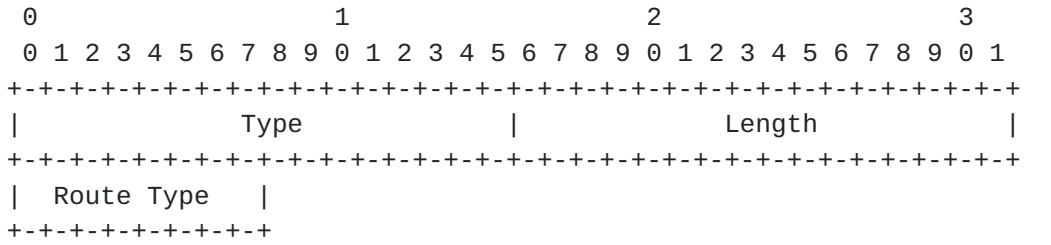
### 3.2.3. Prefix Descriptors

The 'Prefix Descriptor' field is a set of Type/Length/Value (TLV) triplets. 'Prefix Descriptor' TLVs uniquely identify an IPv4 or IPv6 Prefix originated by a Node. The following TLVs are valid as Prefix Descriptors in the IPv4/IPv6 Prefix NLRI:

| TLV Code Point | Description | Length | Value defined in: |
|---|---|---|---|
| 263 | Multi-Topology Identifier | variable | Section 3.2.1.5 |
| 264 | OSPF Route Type | 1 | Section 3.2.3.1 |
| 265 | IP Reachability Information | variable | Section 3.2.3.2 |

#### 3.2.3.1. OSPF Route Type

OSPF Route Type is an optional TLV that MAY be present in Prefix NLRIs. It is used to identify the OSPF route-type of the prefix. It is used when an OSPF prefix is advertised in the OSPF domain with multiple different route-types. The Route Type TLV allows to discriminate these advertisements. The format of the OSPF Route Type TLV is shown in the following figure.




where the Type and Length fields of the TLV are defined in Table 4. The OSPF Route Type field values are defined in the OSPF protocol, and can be one of the following:

Intra-Area (0x1)

Inter-Area (0x2)

External 1 (0x3)

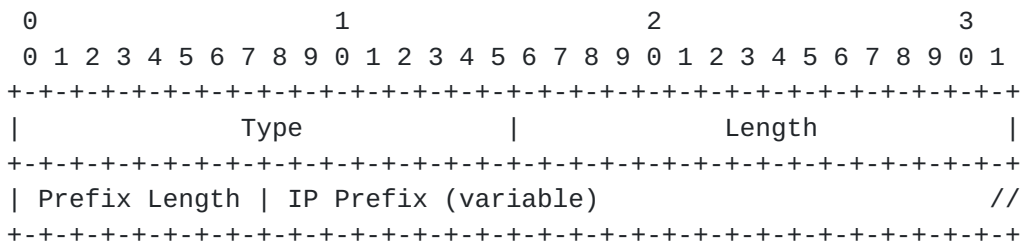
External 2 (0x4)

NSSA 1 (0x5)

NSSA 2 (0x6)

#### 3.2.3.2. IP Reachability Information

The IP Reachability Information is a mandatory TLV that contains one IP address prefix (IPv4 or IPv6) originally advertised in the IGP topology. Its purpose is to glue a particular BGP service NLRI vi virtue of its BGP next-hop to a given Node in the LSDB. A router SHOULD advertise an IP Prefix NLRI for each of its BGP Next-hops. The format of the IP Reachability Information TLV is shown in the following figure:




The Type and Length fields of the TLV are defined in Table 4. The following two fields determine the address-family reachability information. The 'Prefix Length' field contains the length of the prefix in bits. The 'IP Prefix' field contains the most significant octets of the prefix; i.e., 1 octet for prefix length 1 up to 8, 2 octets for prefix length 9 to 16, 3 octets for prefix length 17 up to 24 and 4 octets for prefix length 25 up to 32, etc.

## 3.3. The BGP-LS Attribute

This is an optional, non-transitive BGP attribute that is used to carry link, node and prefix parameters and attributes. It is defined as a set of Type/Length/Value (TLV) triplets, described in the following section. This attribute SHOULD only be included with Link-State NLRIs. This attribute MUST be ignored for all other address-families.

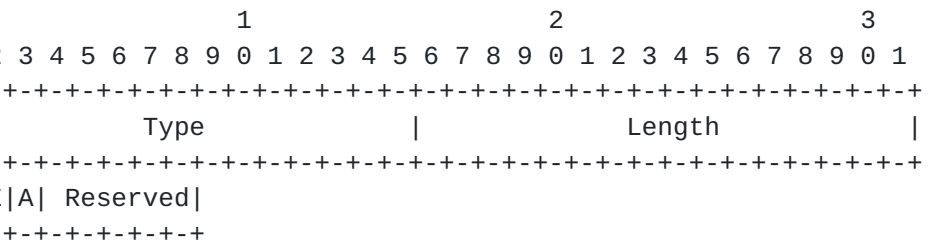
### 3.3.1. Node Attribute TLVs

Node attribute TLVs are the TLVs that may be encoded in the BGP-LS attribute with a node NLRI. The following node attribute TLVs are defined:

| TLV Code Point | Description | Length | Value defined in: |
|---|---|---|---|
| 263 | Multi-Topology Identifier | variable | Section 3.2.1.5 |
| 1024 | Node Flag Bits | 1 | Section 3.3.1.1 |
| 1025 | Opaque Node Properties | variable | Section 3.3.1.5 |
| 1026 | Node Name | variable | Section 3.3.1.3 |
| 1027 | IS-IS Area Identifier | variable | Section 3.3.1.2 |
| 1028 | IPv4 Router-ID of Local Node | 4 | [RFC5305]/4.3 |
| 1029 | IPv6 Router-ID of Local Node | 16 | [RFC6119]/4.1 |

### 3.3.1.1. Node Flag Bits TLV

The Node Flag Bits TLV carries a bit mask describing node attributes. The value is a variable length bit array of flags, where each bit represents a node capability.



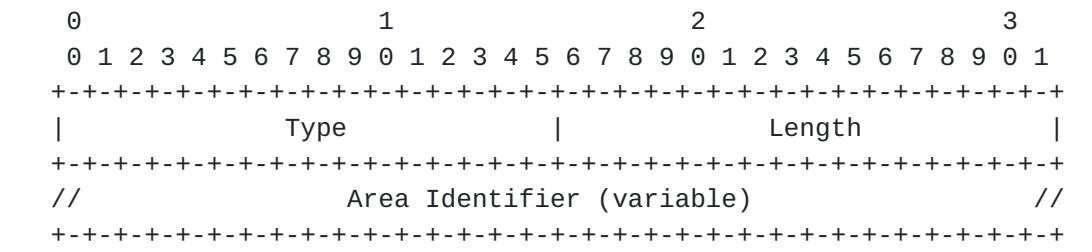

The bits are defined as follows:

| Bit | Description | Reference |
|---|---|---|
| 'O' | Overload Bit | [RFC1195] |
| 'T' | Attached Bit | [RFC1195] |
| 'E' | External Bit | [RFC2328] |
| 'A' | ABR Bit | [RFC2328] |
| Reserved | Reserved for future use | |

### 3.3.1.2. IS-IS Area Identifier TLV

An IS-IS node can be part of one or more IS-IS areas. Each of these area addresses is carried in the IS-IS Area Identifier TLV. If more

than one Area Addresses are present, multiple TLVs are used to encode them. The IS-IS Area Identifier TLV may be present in the BGP-LS attribute only with the Link-State Node NLRI.

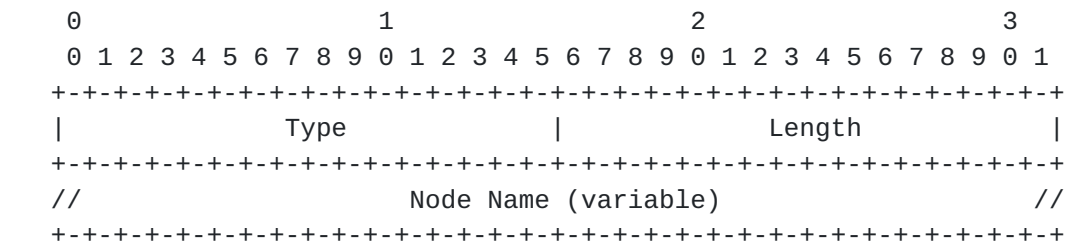



#### 3.3.1.3. Node Name TLV

The Node Name TLV is optional. Its structure and encoding has been borrowed from [RFC5301]. The value field identifies the symbolic name of the router node. This symbolic name can be the FQDN for the router, it can be a subset of the FQDN, or it can be any string operators want to use for the router. The use of FQDN or a subset of it is strongly recommended.

The Value field is encoded in 7-bit ASCII. If a user-interface for configuring or displaying this field permits Unicode characters, that user-interface is responsible for applying the ToASCII and/or ToUnicode algorithm as described in [RFC5890] to achieve the correct format for transmission or display.

Altough [RFC5301] is a IS-IS specific extension, usage of the Node Name TLV is possible for all protocols. How a router derives and injects node names for e.g. OSPF nodes, is outside of the scope of this document.

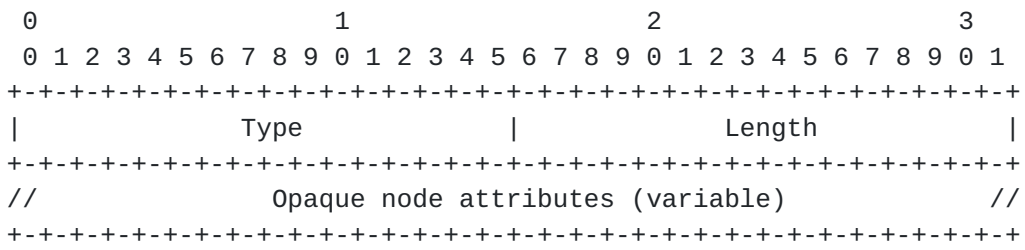



#### 3.3.1.4. Local IPv4/IPv6 Router-ID

The local IPv4/IPv6 Router-ID TLVs are used to describe auxiliary Router-IDs that the IGP might be using, e.g., for TE and migration purposes like correlating a Node-ID between different protocols. If there is more than one auxiliary Router-ID of a given type, then each one is encoded in its own TLV.

#### 3.3.1.5. Opaque Node Attribute TLV

The Opaque Node attribute TLV is an envelope that transparently carries optional node attribute TLVs advertised by a router. An originating router shall use this TLV for encoding information specific to the protocol advertised in the NLRI header Protocol-ID field or new protocol extensions to the protocol as advertised in the NLRI header Protocol-ID field for which there is no protocol neutral representation in the BGP link-state NLRI. A router for example could use this extension in order to advertise the native protocols node attribute TLVs, such as the OSPF Router Informational Capabilities TLV defined in [RFC4970], or the IGP TE Node Capability Descriptor TLV described in [RFC5073].




### 3.3.2. Link Attribute TLVs

Link attribute TLVs are TLVs that may be encoded in the BGP-LS attribute with a link NLRI. Each 'Link Attribute' is a Type/Length/Value (TLV) triplet formatted as defined in Section 3.1. The format and semantics of the 'value' fields in some 'Link Attribute' TLVs correspond to the format and semantics of value fields in IS-IS Extended IS Reachability sub-TLVs, defined in [RFC5305] and [RFC5307]. Other 'Link Attribute' TLVs are defined in this document. Although the encodings for 'Link Attribute' TLVs were originally defined for IS-IS, the TLVs can carry data sourced either by IS-IS or OSPF.

The following 'Link Attribute' TLVs are are valid in the LINK_STATE attribute:

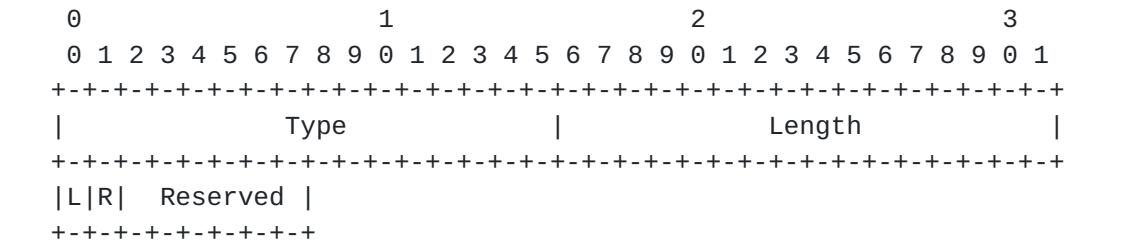
| TLV Code Point | Description | IS-IS TLV /Sub-TLV | Defined in: |
|---|---|---|---|
| 1028 | IPv4 Router-ID of Local Node | 134/--- | [RFC5305]/4.3 |
| 1029 | IPv6 Router-ID of Local Node | 140/--- | [RFC6119]/4.1 |
| 1030 | IPv4 Router-ID of Remote Node | 134/--- | [RFC5305]/4.3 |
| 1031 | IPv6 Router-ID of Remote Node | 140/--- | [RFC6119]/4.1 |
| 1032 | Link Local/Remote Identifiers | 22/4 | [RFC5307]/1.1 |
| 1088 | Administrative group (color) | 22/3 | [RFC5305]/3.1 |
| 1089 | Maximum link bandwidth | 22/9 | [RFC5305]/3.3 |
| 1090 | Max. reservable link bandwidth | 22/10 | [RFC5305]/3.5 |
| 1091 | Unreserved bandwidth | 22/11 | [RFC5305]/3.6 |
| 1092 | TE Default Metric | 22/18 | Section 3.3.2.3/ |
| 1093 | Link Protection Type | 22/20 | [RFC5307]/1.2 |
| 1094 | MPLS Protocol Mask | --- | Section 3.3.2.2 |
| 1095 | IGP Metric | --- | Section 3.3.2.4 |
| 1096 | Shared Risk Link Group | --- | Section 3.3.2.5 |
| 1097 | Opaque link attribute | --- | Section 3.3.2.6 |
| 1098 | Link Name attribute | --- | Section 3.3.2.7 |

#### 3.3.2.1. IPv4/IPv6 Router-ID

The local/remote IPv4/IPv6 Router-ID TLVs are used to describe auxiliary Router-IDs that the IGP might be using, e.g., for TE purposes. All auxiliary Router-IDs of both the local and the remote node MUST be included in the link attribute of each link NLRI. If there are more than one auxiliary Router-ID of a given type, then multiple TLVs are used to encode them.

#### 3.3.2.2. MPLS Protocol Mask TLV

The MPLS Protocol TLV carries a bit mask describing which MPLS signaling protocols are enabled. The length of this TLV is 1. The value is a bit array of 8 flags, where each bit represents an MPLS Protocol capability.

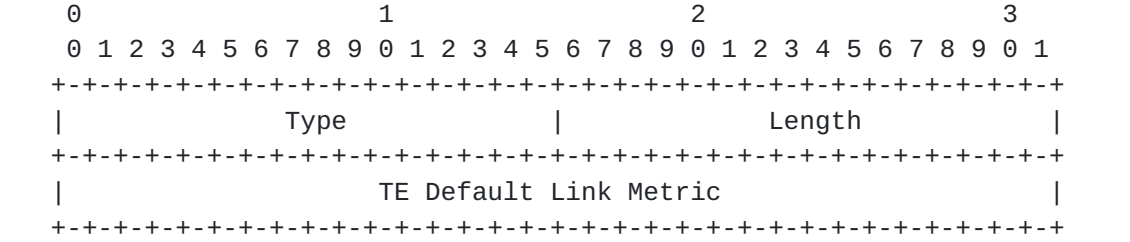



The following bits are defined:

| Bit | Description | Reference |
|---|---|---|
| 'L' | Label Distribution Protocol (LDP) | [RFC5036] |
| 'R' | Extension to RSVP for LSP Tunnels (RSVP-TE) | [RFC3209] |
| 'Reserved' | Reserved for future use | |

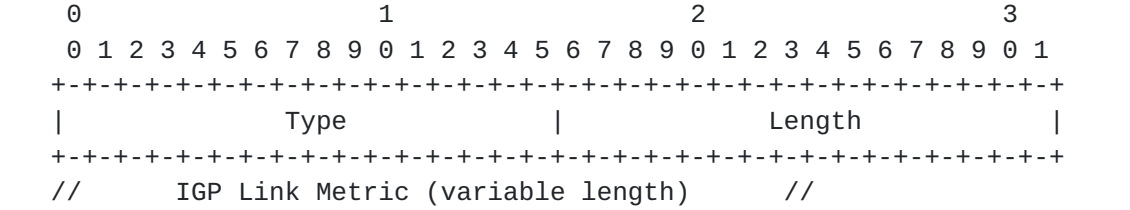
### 3.3.2.3. TE Default Metric TLV

The TE Default Metric TLV carries the TE-metric for this link. The length of this TLV is fixed at 4 octets. If a source protocol (e.g. IS-IS) does not support a Metric width of 32 bits then the high order octet MUST be set to zero.



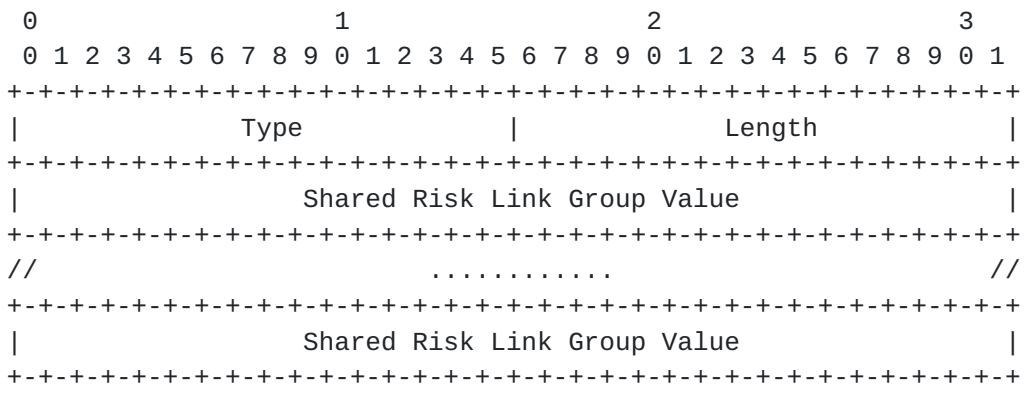

### 3.3.2.4. IGP Metric TLV

The IGP Metric TLV carries the metric for this link. The length of this TLV is variable, depending on the metric width of the underlying protocol. IS-IS small metrics have a length of 1 octet (the two most significant bits are ignored). OSPF metrics have a length of two octects. IS-IS wide-metrics have a length of three octets.



### 3.3.2.5. Shared Risk Link Group TLV

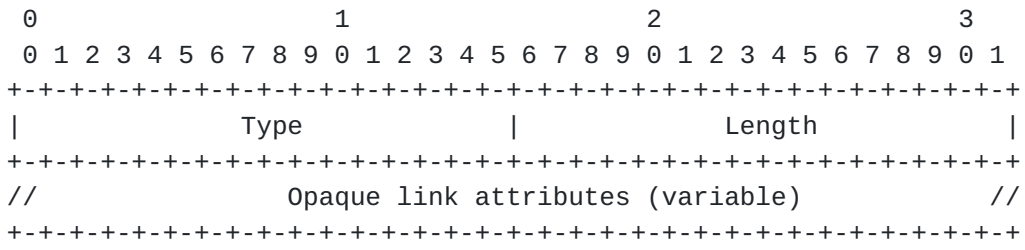
The Shared Risk Link Group (SRLG) TLV carries the Shared Risk Link Group information (see Section 2.3, "Shared Risk Link Group Information", of [RFC4202]). It contains a data structure consisting of a (variable) list of SRLG values, where each element in the list has 4 octets, as shown in Figure 22. The length of this TLV is 4 * (number of SRLG values).




Note that there is no SRLG TLV in OSPF-TE. In IS-IS the SRLG information is carried in two different TLVs: the IPv4 (SRLG) TLV (Type 138) defined in [RFC5307], and the IPv6 SRLG TLV (Type 139) defined in [RFC6119]. In Link-State NLRI both IPv4 and IPv6 SRLG information are carried in a single TLV.

### 3.3.2.6. Opaque Link Attribute TLV

The Opaque link attribute TLV is an envelope that transparently carries optional link atrribute TLVs advertised by a router. An originating router shall use this TLV for encoding information specific to the protocol advertised in the NLRI header Protocol-ID field or new protocol extensions to the protocol as advertised in the NLRI header Protocol-ID field for which there is no protocol neutral representation in the BGP link-state NLRI.



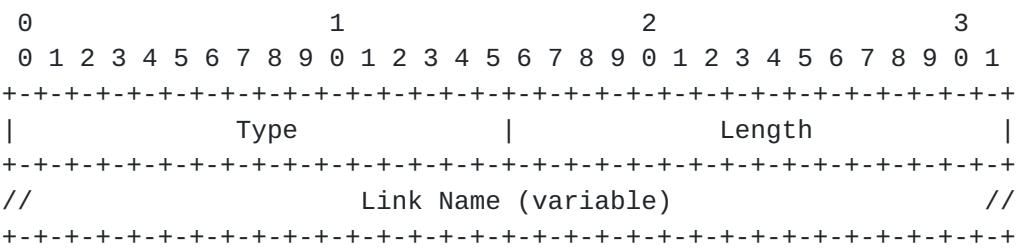

### 3.3.2.7. Link Name TLV

The Link Name TLV is optional. The value field identifies the symbolic name of the router link. This symbolic name can be the FQDN for the link, it can be a subset of the FQDN, or it can be any string

operators want to use for the link. The use of FQDN or a subset of it is strongly recommended.

The Value field is encoded in 7-bit ASCII. If a user-interface for configuring or displaying this field permits Unicode characters, that user-interface is responsible for applying the ToASCII and/or ToUnicode algorithm as described in [RFC5890] to achieve the correct format for transmission or display.

How a router derives and injects link names is outside of the scope of this document.



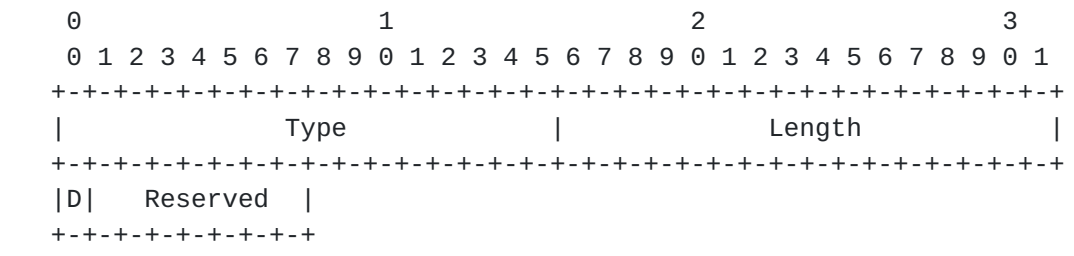

### 3.3.3. Prefix Attribute TLVs

Prefixes are learned from the IGP topology (IS-IS or OSPF) with a set of IGP attributes (such as metric, route tags, etc.) that MUST be reflected into the LINK_STATE attribute. This section describes the different attributes related to the IPv4/IPv6 prefixes. Prefix Attributes TLVs SHOULD be used when advertising NLRI types 3 and 4 only. The following attributes TLVs are defined:

| TLV Code Point | Description | Length | Reference |
|---|---|---|---|
| 1152 | IGP Flags | 1 | Section 3.3.3.1 |
| 1153 | Route Tag | 4*n | Section 3.3.3.2 |
| 1154 | Extended Tag | 8*n | Section 3.3.3.3 |
| 1155 | Prefix Metric | 4 | Section 3.3.3.4 |
| 1156 | OSPF Forwarding Address | 4 | Section 3.3.3.5 |
| 1157 | Opaque Prefix Attribute | variable | Section 3.3.3.6 |

#### 3.3.3.1. IGP Flags TLV

IGP Flags TLV contains IS-IS and OSPF flags and bits originally assigned tothe prefix. The IGP Flags TLV is encoded as follows:

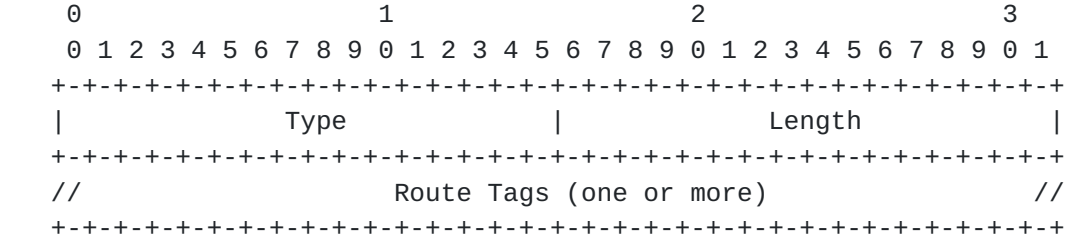



The value field contains bits defined according to the table below:

| Bit | Description | Reference |
|---|---|---|
| 'D' | IS-IS Up/Down Bit | [RFC5305] |
| Reserved | Reserved for future use. | |

#### 3.3.3.2. Route Tag

Route Tag TLV carries original IGP TAGs (IS-IS [RFC5130] or OSPF) of the prefix and is encoded as follows:

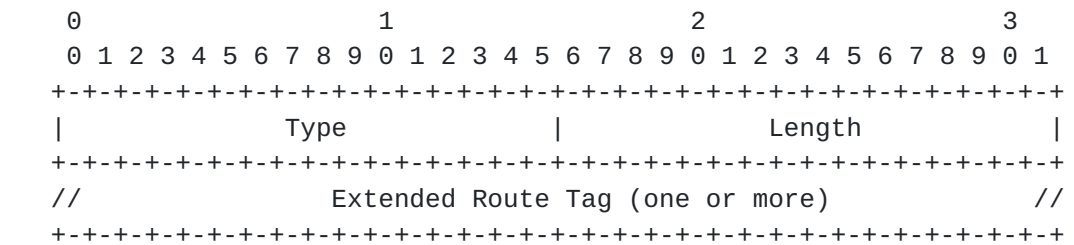



Length is a multiple of 4.

The value field contains one or more Route Tags as learned in the IGP topology.

#### 3.3.3.3. Extended Route Tag

Extended Route Tag TLV carries IS-IS Extended Route TAGs of the prefix [RFC5130] and is encoded as follows:

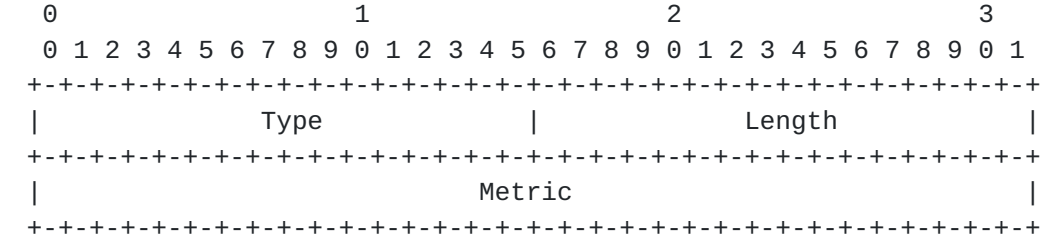



Length is a multiple of 8.

The 'Extended Route Tag' field contains one or more Extended Route Tags as learned in the IGP topology.

#### 3.3.3.4. Prefix Metric TLV

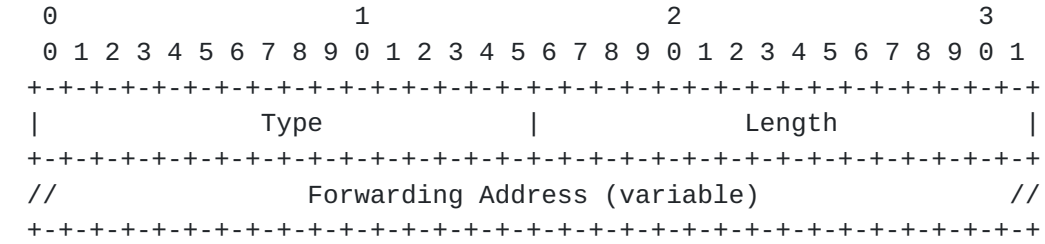
Prefix Metric TLV carries the metric of the prefix as known in the IGP topology [RFC5305]. The attribute is mandatory and can only appear once.




Length is 4.

#### 3.3.3.5. OSPF Forwarding Address TLV

OSPF Forwarding Address TLV [RFC2328] carries the OSPF forwarding address as known in the original OSPF advertisement. Forwarding address can be either IPv4 or IPv6.

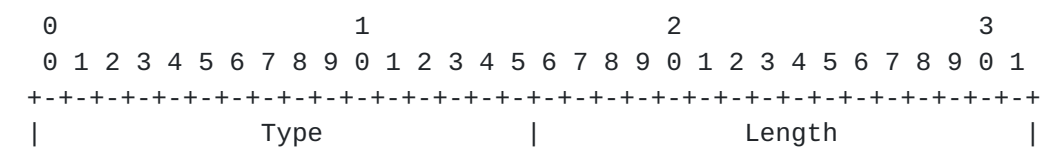


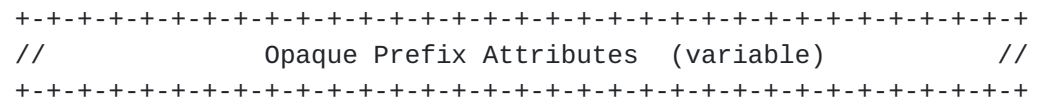

Length is 4 for an IPv4 forwarding address an 16 for an IPv6 forwarding address.

#### 3.3.3.6. Opaque Prefix Attribute TLV

The Opaque Prefix attribute TLV is an envelope that transparently carries optional prefix attribute TLVs advertised by a router. An originating router shall use this TLV for encoding information specific to the protocol advertised in the NLRI header Protocol-ID field or new protocol extensions to the protocol as advertised in the NLRI header Protocol-ID field for which there is no protocol neutral representation in the BGP link-state NLRI.

The format of the TLV is as follows:




Opaque Prefix Attributes (variable)

Type is as specified in Table 9 and Length is variable.

## 3.4. BGP Next Hop Information

BGP link-state information for both IPv4 and IPv6 networks can be carried over either an IPv4 BGP session, or an IPv6 BGP session. If IPv4 BGP session is used, then the next hop in the MP_REACH_NLRI SHOULD be an IPv4 address. Similarly, if IPv6 BGP session is used, then the next hop in the MP_REACH_NLRI SHOULD be an IPv6 address. Usually the next hop will be set to the local end-point address of the BGP session. The next hop address MUST be encoded as described in [RFC4760]. The length field of the next hop address will specify the next hop address-family. If the next hop length is 4, then the next hop is an IPv4 address; if the next hop length is 16, then it is a global IPv6 address and if the next hop length is 32, then there is one global IPv6 address followed by a link-local IPv6 address. The link-local IPv6 address should be used as described in [RFC2545]. For VPN SAFI, as per custom, an 8 byte route-distinguisher set to all zero is prepended to the next hop.

The BGP Next Hop attribute is used by each BGP-LS speaker to validate the NLRI it receives. However, this specification doesn't mandate any rule regarding the re-write of the BGP Next Hop attribute.

## 3.5. Inter-AS Links

The main source of TE information is the IGP, which is not active on inter-AS links. In some cases, the IGP may have information of inter-AS links ([RFC5392], [RFC5316]). In other cases, an implementation SHOULD provide a means to inject inter-AS links into BGP-LS. The exact mechanism used to provision the inter-AS links is outside the scope of this document

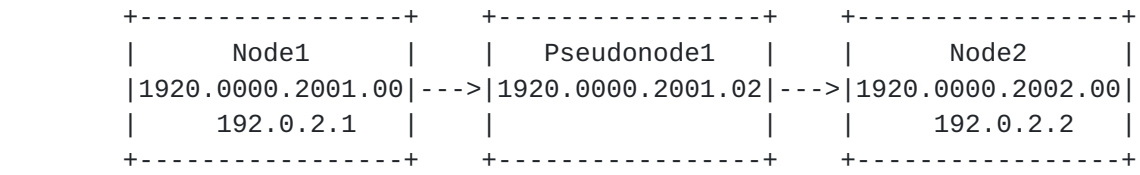
## 3.6. Router-ID Anchoring Example: ISO Pseudonode

Encoding of a broadcast LAN in IS-IS provides a good example of how Router-IDs are encoded. Consider Figure 31. This represents a Broadcast LAN between a pair of routers. The "real" (=non pseudonode) routers have both an IPv4 Router-ID and IS-IS Node-ID. The pseudonode does not have an IPv4 Router-ID. Node1 is the DIS for the LAN. Two unidirectional links (Node1, Pseudonode 1) and (Pseudonode1, Node2) are being generated.

The link NRLI of (Node1, Pseudonode1) is encoded as follows: the IGP Router-ID TLV of the local node descriptor is 6 octets long containing ISO-ID of Node1, 1920.0000.2001; the IGP Router-ID TLV of the remote node descriptor is 7 octets long containing the ISO-ID of Pseudonode1, 1920.0000.2001.02. The BGP-LS attribute of this link contains one local IPv4 Router-ID TLV (TLV type 1028) containing

192.0.2.1, the IPv4 Router-ID of Node1.

The link NRLI of (Pseudonode1. Node2) is encoded as follows: the IGP Router-ID TLV of the local node descriptor is 7 octets long containing the ISO-ID of Pseudonode1, 1920.0000.2001.02; the IGP Router-ID TLV of the remote node descriptor is 6 octets long containing ISO-ID of Node2, 1920.0000.2002. The BGP-LS attribute of this link contains one remote IPv4 Router-ID TLV (TLV type 1030) containing 192.0.2.2, the IPv4 Router-ID of Node2.




## 3.7. Router-ID Anchoring Example: OSPFv2 to IS-IS Migration

Graceful migration from one IGP to another requires coordinated operation of both protocols during the migration period. Such a coordination requires identifying a given physical link in both IGPs. The IPv4 Router-ID provides that "glue" which is present in the node descriptors of the OSPF link NLRI and in the link attribute of the IS-IS link NLRI.

Consider a point-to-point link between two routers, A and B, that initially were OSPFv2-only routers and then IS-IS is enabled on them. Node A has IPv4 Router-ID and ISO-ID; node B has IPv4 Router-ID, IPv6 Router-ID and ISO-ID. Each protocol generates one link NLRI for the link (A, B), both of which are carried by BGP-LS. The OSPFv2 link NLRI for the link is encoded with the IPv4 Router-ID of nodes A and B in the local and remote node descriptors, respectively. The IS-IS link NLRI for the link is encoded with the ISO-ID of nodes A and B in the local and remote node descriptors, respectively. In addition, the BGP-LS attribute of the IS-IS link NLRI contains the the TLV type 1028 containing the IPv4 Router-ID of node A; TLV type 1030 containing the IPv4 Router-ID of node B and TLV type 1031 containing the IPv6 Router-ID of node B. In this case, by using IPv4 Router-ID, the link (A, B) can be identified in both IS-IS and OSPF protocol.

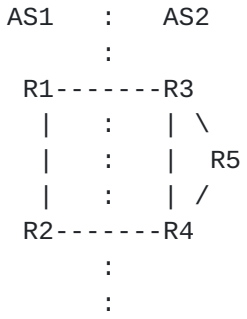
# 4. Link to Path Aggregation

Distribution of all links available in the global Internet is certainly possible, however not desirable from a scaling and privacy point of view. Therefore an implementation may support link to path aggregation. Rather than advertising all specific links of a domain, an ASBR may advertise an "aggregate link" between a non-adjacent pair of nodes. The "aggregate link" represents the aggregated set of link properties between a pair of non-adjacent nodes. The actual methods to compute the path properties (of bandwidth, metric) are outside the

scope of this document. The decision whether to advertise all specific links or aggregated links is an operator's policy choice. To highlight the varying levels of exposure, the following deployment examples are discussed.

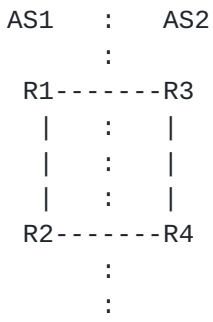
### 4.1. Example: No Link Aggregation

Consider Figure 32. Both AS1 and AS2 operators want to protect their inter-AS {R1,R3}, {R2, R4} links using RSVP-FRR LSPs. If R1 wants to compute its link-protection LSP to R3 it needs to "see" an alternate path to R3. Therefore the AS2 operator exposes its topology. All BGP TE enabled routers in AS1 "see" the full topology of AS and therefore can compute a backup path. Note that the decision if the direct link between {R3, R4} or the {R4, R5, R3) path is used is made by the computing router.




### 4.2. Example: ASBR to ASBR Path Aggregation

The brief difference between the "no-link aggregation" example and this example is that no specific link gets exposed. Consider Figure 33. The only link which gets advertised by AS2 is an "aggregate" link between R3 and R4. This is enough to tell AS1 that there is a backup path. However the actual links being used are hidden from the topology.




### 4.3. Example: Multi-AS Path Aggregation

Service providers in control of multiple ASes may even decide to not expose their internal inter-AS links. Consider Figure 34. AS3 is modeled as a single node which connects to the border routers of the aggregated domain.


## 5. IANA Considerations

This document requests a code point from the registry of Address Family Numbers. As per early allocation procedure this is AFI 16388.

This document requests a code point from the registry of Subsequent Address Family Numbers. As per early allocation procedure this is SAFI 71.

This document requests a code point from the BGP Path Attributes registry.

This document requests creation of a new registry for node anchor, link descriptor and link attribute TLVs. Values 0-255 are reserved. Values 256-65535 will be used for Codepoints. The registry will be initialized as shown in Table 11. Allocations within the registry will require documentation of the proposed use of the allocated value and approval by the Designated Expert assigned by the IESG (see [RFC5226]).

Note to RFC Editor: this section may be removed on publication as an RFC.

## 6. Manageability Considerations

This section is structured as recommended in [RFC5706].

### 6.1. Operational Considerations

#### 6.1.1. Operations

Existing BGP operational procedures apply. No new operation procedures are defined in this document. It is noted that the NLRI information present in this document purely carries application level data that has no immediate corresponding forwarding state impact. As such, any churn in reachability information has different impact than regular BGP updates which need to change forwarding state for an entire router. Furthermore it is anticipated that distribution of this NLRI will be handled by dedicated route-reflectors providing a

level of isolation and fault-containment between different NLRI types.

### 6.1.2. Installation and Initial Setup

Configuration parameters defined in Section 6.2.3 SHOULD be initialized to the following default values:

- The Link-State NLRI capability is turned off for all neighbors.
- The maximum rate at which Link-State NLRIs will be advertised/withdrawn from neighbors is set to 200 updates per second.

### 6.1.3. Migration Path

The proposed extension is only activated between BGP peers after capability negotiation. Moreover, the extensions can be turned on/off an individual peer basis (see Section 6.2.3), so the extension can be gradually rolled out in the network.

### 6.1.4. Requirements on Other Protocols and Functional Components

The protocol extension defined in this document does not put new requirements on other protocols or functional components.

### 6.1.5. Impact on Network Operation

Frequency of Link-State NLRI updates could interfere with regular BGP prefix distribution. A network operator MAY use a dedicated Route-Reflector infrastructure to distribute Link-State NLRIs.

Distribution of Link-State NLRIs SHOULD be limited to a single admin domain, which can consist of multiple areas within an AS or multiple ASes.

### 6.1.6. Verifying Correct Operation

Existing BGP procedures apply. In addition, an implementation SHOULD allow an operator to:

- List neighbors with whom the Speaker is exchanging Link-State NLRIs

## 6.2. Management Considerations

### 6.2.1. Management Information

### 6.2.2. Fault Management

TBD.

### 6.2.3. Configuration Management

An implementation SHOULD allow the operator to specify neighbors to which Link-State NLRIs will be advertised and from which Link-State

NLRIs will be accepted.

An implementation SHOULD allow the operator to specify the maximum rate at which Link-State NLRIs will be advertised/withdrawn from neighbors

An implementation SHOULD allow the operator to specify the maximum number of Link-State NLRIs stored in router's RIB.

An implementation SHOULD allow the operator to create abstracted topologies that are advertised to neighbors; Create different abstractions for different neighbors.

An implementation SHOULD allow the operator to configure a 64-bit instance ID.

An implementation SHOULD allow the operator to configure a pair of ASN and BGP-LS identifier per flooding set the node participates in.

#### 6.2.4. Accounting Management

Not Applicable.

#### 6.2.5. Performance Management

An implementation SHOULD provide the following statistics:

- Total number of Link-State NLRI updates sent/received
- Number of Link-State NLRI updates sent/received, per neighbor
- Number of errored received Link-State NLRI updates, per neighbor
- Total number of locally originated Link-State NLRIs

#### 6.2.6. Security Management

An operator SHOULD define ACLs to limit inbound updates as follows:

- Drop all updates from Consumer peers

## 7. TLV/Sub-TLV Code Points Summary

This section contains the global table of all TLVs/Sub-TLVs defined in this document.

| TLV Code Point | Description | IS-IS TLV/ Sub-TLV | Value defined in: |
|---|---|---|---|
| 256 | Local Node Descriptors | --- | Section 3.2.1.2 |
| 257 | Remote Node Descriptors | --- | Section 3.2.1.3 |
| 258 | Link Local/Remote Identifiers | 22/4 | [RFC5307]/1.1 |
| 259 | IPv4 interface address | 22/6 | [RFC5305]/3.2 |
| 260 | IPv4 neighbor address | 22/8 | [RFC5305]/3.3 |
| 261 | IPv6 interface address | 22/12 | [RFC6119]/4.2 |
| 262 | IPv6 neighbor address | 22/13 | [RFC6119]/4.3 |
| 263 | Multi-Topology ID | --- | Section 3.2.1.5 |
| 264 | OSPF Route Type | --- | Section 3.2.3 |
| 265 | IP Reachability Information | --- | Section 3.2.3 |
| 512 | Autonomous System | --- | Section 3.2.1.4 |
| 513 | BGP-LS Identifier | --- | Section 3.2.1.4 |
| 514 | Area ID | --- | Section 3.2.1.4 |
| 515 | IGP Router-ID | --- | Section 3.2.1.4 |
| 1024 | Node Flag Bits | --- | Section 3.3.1.1 |
| 1025 | Opaque Node Properties | --- | Section 3.3.1.5 |
| 1026 | Node Name | variable | Section 3.3.1.3 |
| 1027 | IS-IS Area Identifier | variable | Section 3.3.1.2 |
| 1028 | IPv4 Router-ID of Local Node | 134/--- | [RFC5305]/4.3 |
| 1029 | IPv6 Router-ID of Local Node | 140/--- | [RFC6119]/4.1 |
| 1030 | IPv4 Router-ID of Remote Node | 134/--- | [RFC5305]/4.3 |
| 1031 | IPv6 Router-ID of Remote Node | 140/--- | [RFC6119]/4.1 |
| 1032 | Link Local/Remote Identifiers | 22/4 | [RFC5307]/1.1 |
| 1088 | Administrative group (color) | 22/3 | [RFC5305]/3.1 |
| 1089 | Maximum link bandwidth | 22/9 | [RFC5305]/3.3 |
| 1090 | Max. reservable link | 22/10 | [RFC5305]/3.5 |

| | bandwidth | | |
|---|---|---|---|
| 1091 | Unreserved bandwidth | 22/11 | [RFC5305]/3.6 |
| 1092 | TE Default Metric | 22/18 | Section 3.3.2.3 |
| 1093 | Link Protection Type | 22/20 | [RFC5307]/1.2 |
| 1094 | MPLS Protocol Mask | --- | Section 3.3.2.2 |

| | | | | |
|---|---|---|---|---|
| | 1095 | IGP Metric | --- | Section 3.3.2.4 |
| | 1096 | Shared Risk Link Group | --- | Section 3.3.2.5 |
| | 1097 | Opaque link attribute | --- | Section 3.3.2.6 |
| | 1098 | Link Name attribute | --- | Section 3.3.2.7 |
| | 1152 | IGP Flags | --- | Section 3.3.3.1 |
| | 1153 | Route Tag | --- | [RFC5130] |
| | 1154 | Extended Tag | --- | [RFC5130] |
| | 1155 | Prefix Metric | --- | [RFC5305] |
| | 1156 | OSPF Forwarding Address | --- | [RFC2328] |
| | 1157 | Opaque Prefix Attribute | --- | Section 3.3.3.6 |

## 8. Security Considerations

Procedures and protocol extensions defined in this document do not affect the BGP security model. See the 'Security Considerations' section of [RFC4271] for a discussion of BGP security. Also refer to [RFC4272] and [RFC6952] for analysis of security issues for BGP.

In the context of the BGP peerings associated with this document, a BGP Speaker SHOULD NOT accept updates from a Consumer peer. That is, a participating BGP Speaker, should be aware of the nature of its relationships for link state relationships and should protect itself from peers sending updates that either represent erroneous information feedback loops, or are false input. Such protection can be achieved by manual configuration of Consumer peers at the BGP Speaker.

An operator SHOULD employ a mechanism to protect a BGP Speaker against DDOS attacks from Consumers. The principal attack a consumer may apply is to attempt to start multiple sessions either sequentially or simultaneously. Protection can be applied by imposing rate limits.

Additionally, it may be considered that the export of link state and TE information as described in this document constitutes a risk to confidentiality of mission-critical or commercially-sensitive information about the network. BGP peerings are not automatic and require configuration, thus it is the responsibility of the network operator to ensure that only trusted Consumers are configured to receive such information.

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