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P. Psenak, Ed.
L. Ginsberg
Cisco Systems
W. Henderickx
Nokia
J. Tantsura
Apstra
J. Drake
Juniper Networks

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OSPF Link Traffic Engineering Attribute Reuse
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Abstract

Existing traffic engineering related link attribute advertisements have been defined and are used in RSVP-TE deployments. Since the original RSVP-TE use case was defined, additional applications (e.g., Segment Routing Traffic Engineering, Loop Free Alternate) have been defined which also make use of the link attribute advertisements. In cases where multiple applications wish to make use of these link attributes the current advertisements do not support application specific values for a given attribute nor do they support indication of which applications are using the advertised value for a given link. This document introduces new link attribute advertisements in OSPFv2 and OSPFv3 which address both of these shortcomings.

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1. Introduction

Advertisement of link attributes by the OSPFv2 [RFC2328] and OSPFv3 [RFC5340] protocols in support of traffic engineering (TE) was introduced by [RFC3630] and [RFC5329] respectively. It has been extended by [RFC4203], [RFC7308] and [RFC7471]. Use of these extensions has been associated with deployments supporting Traffic Engineering over Multiprotocol Label Switching (MPLS) in the presence of the Resource Reservation Protocol (RSVP) - more succinctly referred to as RSVP-TE [RFC3209].

For the purposes of this document an application is a technology which makes use of link attribute advertisements - examples of which are listed in Section 5.

In recent years new applications have been introduced which have use cases for many of the link attributes historically used by RSVP-TE. Such applications include Segment Routing Traffic Engineering (SRTE) [I-D.ietf-spring-segment-routing-policy] and Loop Free Alternates (LFA) [RFC5286]. This has introduced ambiguity in that if a deployment includes a mix of RSVP-TE support and SRTE support (for example) it is not possible to unambiguously indicate which advertisements are to be used by RSVP-TE and which advertisements are to be used by SRTE. If the topologies are fully congruent this may not be an issue, but any incongruence leads to ambiguity.

An additional issue arises in cases where both applications are supported on a link but the link attribute values associated with each application differ. Current advertisements do not support advertising application specific values for the same attribute on a specific link.

This document defines extensions which address these issues. Also, as evolution of use cases for link attributes can be expected to continue in the years to come, this document defines a solution which is easily extensible for the introduction of new applications and new use cases.

2. Requirements Language

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

3. Existing Advertisement of Link Attributes

There are existing advertisements used in support of RSVP-TE. These advertisements are carried in the OSPFv2 TE Opaque LSA [RFC3630] and OSPFv3 Intra-Area-TE-LSA [RFC5329]. Additional RSVP-TE link attributes have been defined by [RFC4203], [RFC7308] and [RFC7471].

Extended Link Opaque LSAs as defined in [RFC7684] for OSPFv2 and Extended Router-LSAs [RFC8362] for OSPFv3 are used to advertise link attributes that are used by applications other then RSVP-TE or GMPLS. These LSAs were defined as a generic containers for distribution of the extended link attributes.

4. Advertisement of Link Attributes

This section outlines the solution for advertising link attributes originally defined for RSVP-TE or GMPLS when they are used for other applications.

4.1. OSPFv2 Extended Link Opaque LSA and OSPFv3 E-Router-LSA

Advantages of Extended Link Opaque LSAs as defined in [RFC7684] for OSPFv2 and Extended Router-LSAs [RFC8362] for OSPFv3 when used for advertisement of link attributes originally defined for RSVP-TE or GMPLS:

1. Advertisement of the link attributes does not make the link part of the RSVP-TE topology. It avoids any conflicts and is fully compatible with [RFC3630] and [RFC5329].

2. The OSPFv2 TE Opaque LSA and OSPFv3 Intra-Area-TE-LSA remains truly opaque to OSPFv2 and OSPFv3 as originally defined in [RFC3630] and [RFC5329] respectively. Their contents are not inspected by OSPF, that acts as a pure transport.

3. There is clear distinction between link attributes used by RSVP-TE and link attributes used by other OSPFv2 or OSPFv3 applications.

4. All link attributes that are used by other applications are advertised in a single LSA, the Extended Link Opaque LSA in OSPFv2 or the OSPFv3 E-Router-LSA [RFC8362] in OSPFv3.

The disadvantage of this approach is that in rare cases, the same link attribute is advertised in both the TE Opaque and Extended Link Attribute LSAs in OSPFv2 or the Intra-Area-TE-LSA and E-Router-LSA in OSPFv3.

Extended Link Opaque LSA [RFC7684] and E-Router-LSA [RFC8362] are used to advertise any link attributes used for non-RSVP-TE applications in OSPFv2 or OSPFv3 respectively, including those that have been originally defined for RSVP-TE applications (See Section 6).

TE link attributes used for RSVP-TE/GMPLS continue use OSPFv2 TE Opaque LSA [RFC3630] and OSPFv3 Intra-Area-TE-LSA [RFC5329].

The format of the link attribute TLVs that have been defined for RSVP-TE applications will be kept unchanged even when they are used for non-RSVP-TE applications. Unique code points are allocated for these link attribute TLVs from the OSPFv2 Extended Link TLV Sub-TLV Registry [RFC7684] and from the OSPFv3 Extended LSA Sub-TLV Registry [RFC8362], as specified in Section 14.

5. Advertisement of Application Specific Values

To allow advertisement of the application specific values of the link attribute, a new Application Specific Link Attributes (ASLA) sub-TLV is defined. The ASLA sub-TLV is a sub-TLV of the OSPFv2 Extended Link TLV [RFC7684] and OSPFv3 Router-Link TLV [RFC8362].

The ASLA sub-TLV is an optional sub-TLV and can appear multiple times in the OSPFv2 Extended Link TLV and OSPFv3 Router-Link TLV. The ASLA sub-TLV MUST be used for advertisement of the link attributes listed at the end on this section if these are advertised inside OSPFv2 Extended Link TLV and OSPFv3 Router-Link TLV. It 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            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  SABM Length  |  UDABM Length |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Standard Application Identifier Bit-Mask             |
+-                                                             -+
|                              ...                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           User Defined Application Identifier Bit-Mask        |
+-                                                             -+
|                              ...                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Link Attribute sub-sub-TLVs              |
+-                                                             -+
|                              ...                              |
```

where:

Type: 10 (OSPFv2), 11 (OSPFv3)

Length: variable

SABM Length: Standard Application Identifier Bit-Mask Length in octets. The legal values are 0, 4 or 8. If the Standard Application Bit-Mask is not present, the Standard Application Bit-Mask Length MUST be set to 0.

UDABM Length: User Defined Application Identifier Bit-Mask Length in octets. The legal values are 0, 4 or 8. If the User Defined Application Bit-Mask is not present, the User Defined Application Bit-Mask Length MUST be set to 0.

Standard Application Identifier Bit-Mask: Optional set of bits, where each bit represents a single standard application. Bits are defined in [I-D.ietf-isis-te-app]. The bits are repeated here for informational purpose:

Bit-0 (R-bit): RSVP-TE

Bit-1 (S-bit): Segment Routing TE

Bit-2 (F-bit): Loop Free Alternate (LFA). Includes all LFA types

User Defined Application Identifier Bit-Mask: Optional set of bits, where each bit represents a single user defined application.

If the SABM or UDABM length is other than 0, 4, or 8, the ASLA sub-TLV MUST be ignored by the receiver.

Standard Application Identifier Bits are defined/sent starting with Bit 0. Undefined bits MUST be transmitted as 0 and MUST be ignored on receipt. Bits that are NOT transmitted MUST be treated as if they are set to 0 on receipt. Bits that are not supported by an implementation MUST be ignored on receipt.

User Defined Application Identifier Bits have no relationship to Standard Application Identifier Bits and are NOT managed by IANA or any other standards body. It is recommended that bits are used starting with Bit 0 so as to minimize the number of octets required to advertise all UDAs.

If the link attribute advertisement is limited to be used by a specific set of applications, corresponding Bit-Masks MUST be present and application specific bit(s) MUST be set for all applications that use the link attributes advertised in the ASLA sub-TLV.

Application Bit-Masks apply to all link attributes that support application specific values and are advertised in the ASLA sub-TLV.

The advantage of not making the Application Bit-Masks part of the attribute advertisement itself is that the format of any previously defined link attributes can be kept and reused when advertising them in the ASLA sub-TLV.

If the same attribute is advertised in more than single ASLA sub-TLVs with the application listed in the Application Bit-Masks, the application SHOULD use the first instance of advertisement and ignore any subsequent advertisements of that attribute.

This document defines the initial set of link attributes that MUST use the ASLA sub-TLV if advertised in the OSPFv2 Extended Link TLV or in the OSPFv3 Router-Link TLV. Documents which define new link attributes MUST state whether the new attributes support application specific values and as such MUST be advertised in an ASLA sub-TLV. The link attributes that MUST be advertised in ASLA sub-TLVs are:

- Shared Risk Link Group [RFC4203]

- Unidirectional Link Dela [RFC7471]

- Min/Max Unidirectional Link Delay [RFC7471]

- Unidirectional Delay Variation [RFC7471]

- Unidirectional Link Loss [RFC7471]

- Unidirectional Residual Bandwidth [RFC7471]

- Unidirectional Available Bandwidth [RFC7471]

- Unidirectional Utilized Bandwidth [RFC7471]

- Administrative Group [RFC3630]

- Extended Administrative Group [RFC7308]

- TE Metric [RFC3630]

6. Reused TE link attributes

This section defines the use case and indicates the code points (Section 14) from the OSPFv2 Extended Link TLV Sub-TLV Registry and OSPFv3 Extended LSA Sub-TLV Registry for some of the link attributes that have been originally defined for RSVP-TE or GMPLS.

6.1. Shared Risk Link Group (SRLG)

The SRLG of a link can be used in OSPF calculated IPFRR [RFC5714] to compute a backup path that does not share any SRLG group with the protected link.

To advertise the SRLG of the link in the OSPFv2 Extended Link TLV, the same format for the sub-TLV defined in section 1.3 of [RFC4203] is used and TLV type 11 is used. Similarly, for OSPFv3 to advertise the SRLG in the OSPFv3 Router-Link TLV, TLV type 12 is used.

6.2. Extended Metrics

[RFC3630] defines several link bandwidth types. [RFC7471] defines extended link metrics that are based on link bandwidth, delay and loss characteristics. All these can be used to compute primary and backup paths within an OSPF area to satisfy requirements for bandwidth, delay (nominal or worst case) or loss.

To advertise extended link metrics in the OSPFv2 Extended Link TLV, the same format for the sub-TLVs defined in [RFC7471] is used with the following TLV types:

12 - Unidirectional Link Delay

13 - Min/Max Unidirectional Link Delay

14 - Unidirectional Delay Variation

15 - Unidirectional Link Loss

16 - Unidirectional Residual Bandwidth

17 - Unidirectional Available Bandwidth

18 - Unidirectional Utilized Bandwidth

To advertise extended link metrics in the OSPFv3 Extended LSA Router-Link TLV, the same format for the sub-TLVs defined in [RFC7471] is used with the following TLV types:

13 - Unidirectional Link Delay

14 - Min/Max Unidirectional Link Delay

15 - Unidirectional Delay Variation

16 - Unidirectional Link Loss

17 - Unidirectional Residual Bandwidth

18 - Unidirectional Available Bandwidth

19 - Unidirectional Utilized Bandwidth

6.3. Administrative Group

[RFC3630] and [RFC7308] define the Administrative Group and Extended Administrative Group sub-TLVs respectively.

To advertise the Administrative Group and Extended Administrative Group in the OSPFv2 Extended Link TLV, the same format for the sub-TLVs defined in [RFC3630] and [RFC7308] is used with the following TLV types:

19 - Administrative Group

20 - Extended Administrative Group

To advertise Administrative Group and Extended Administrative Group in the OSPFv3 Router-Link TLV, the same format for the sub-TLVs defined in [RFC3630] and [RFC7308] is used with the following TLV types:

20 - Administrative Group

21 - Extended Administrative Group

6.4. Traffic Engineering Metric

[RFC3630] defines Traffic Engineering Metric.

To advertise the Traffic Engineering Metric in the OSPFv2 Extended Link TLV, the same format for the sub-TLV defined in section 2.5.5 of [RFC3630] is used and TLV type 22 is used. Similarly, for OSPFv3 to advertise the Traffic Engineering Metric in the OSPFv3 Router-Link TLV, TLV type 22 is used.

7. Maximum Link Bandwidth

Maximum link bandwidth is an application independent attribute of the link that is defined in [RFC3630]. Because it is an application independent attribute, it MUST NOT be advertised in ASLA sub-TLV. Instead, it MAY be advertised as a sub-TLV of the Extended Link Opaque LSA Extended Link TLV in OSPFv2 [RFC7684] or sub-TLV of OSPFv3 E-Router-LSA Router-Link TLV in OSPFv3 [RFC8362].

To advertise the Maximum link bandwidth in the OSPFv2 Extended Link TLV, the same format for sub-TLV defined in [RFC3630] is used with TLV type 23.

To advertise the Maximum link bandwidth in the OSPFv3 Router-Link TLV, the same format for sub-TLV defined in [RFC3630] is used with TLV type 23.

8. Considerations for Extended TE Metrics

[RFC7471] defines a number of dynamic performance metrics associated with a link. It is conceivable that such metrics could be measured specific to traffic associated with a specific application. Therefore this document includes support for advertising these link attributes specific to a given application. However, in practice it may well be more practical to have these metrics reflect the performance of all traffic on the link regardless of application. In such cases, advertisements for these attributes can be associated with all of the applications utilizing that link, for example, by listing all applications in the Application Bit-Mask.

9. Local Interface IPv6 Address Sub-TLV

The Local Interface IPv6 Address Sub-TLV is an application independent attribute of the link that is defined in [RFC5329]. Because it is an application independent attribute, it MUST NOT be advertised in the ASLA sub-TLV. Instead, it MAY be advertised as a sub-TLV of the OSPFv3 E-Router-LSA Router-Link TLV [RFC8362].

To advertise the Local Interface IPv6 Address Sub-TLV in the OSPFv3 Router-Link TLV, the same format for sub-TLV defined in [RFC5329] is used with TLV type 24.

10. Remote Interface IPv6 Address Sub-TLV

The Remote Interface IPv6 Address Sub-TLV is an application independent attribute of the link that is defined in [RFC5329]. Because it is an application independent attribute, it MUST NOT be advertised in the ASLA sub-TLV. Instead, it MAY be advertised as a sub-TLV of the OSPFv3 E-Router-LSA Router-Link TLV [RFC8362].

To advertise the Remote Interface IPv6 Address Sub-TLV in the OSPFv3 Router-Link TLV, the same format for sub-TLV defined in [RFC5329] is used with TLV type 25.

11. Attribute Advertisements and Enablement

This document defines extensions to support the advertisement of application specific link attributes.

Whether the presence of link attribute advertisements for a given application indicates that the application is enabled on that link depends upon the application. Similarly, whether the absence of link attribute advertisements indicates that the application is not enabled depends upon the application.

In the case of RSVP-TE, the advertisement of application specific link attributes has no implication of RSVP-TE being enabled on that link. The RSVP-TE enablement is solely derived from the information carried in the OSPFv2 TE Opaque LSA [RFC3630] and OSPFv3 Intra-Area-TE-LSA [RFC5329].

In the case of SRTE, advertisement of application specific link attributes does NOT indicate enablement of SRTE. The advertisements are only used to support constraints which may be applied when specifying an explicit path. SRTE is implicitly enabled on all links which are part of the Segment Routing enabled topology independent of the existence of link attribute advertisements

In the case of LFA, advertisement of application specific link attributes does NOT indicate enablement of LFA on that link. Enablement is controlled by local configuration.

If, in the future, additional standard applications are defined to use this mechanism, the specification defining this use MUST define the relationship between application specific link attribute advertisements and enablement for that application.

This document allows the advertisement of application specific link attributes with no application identifiers i.e., both the Standard Application Identifier Bit Mask and the User Defined Application Identifier Bit Mask are not present (See Section 5). This supports the use of the link attribute by any application. In the presence of an application where the advertisement of link attribute advertisements is used to infer the enablement of an application on that link (e.g., RSVP-TE), the absence of the application identifier leaves ambiguous whether that application is enabled on such a link. This needs to be considered when making use of the "any application" encoding.

12. Deployment Considerations

12.1. Use of Legacy RSVP-TE LSA Advertisements

Bit Identifiers for Standard Applications are defined in Section 5. All of the identifiers defined in this document are associated with applications which were already deployed in some networks prior to the writing of this document. Therefore, such applications have been deployed using the RSVP-TE LSA advertisements. The Standard Applications defined in this document MAY continue to use RSVP-TE LSA advertisements for a given link so long as at least one of the following conditions is true:

The application is RSVP-TE

The application is SRTE or LFA and RSVP-TE is not deployed anywhere in the network

The application is SRTE or LFA, RSVP-TE is deployed in the network, and both the set of links on which SRTE and/or LFA advertisements are required and the attribute values used by SRTE and/or LFA on all such links is fully congruent with the links and attribute values used by RSVP-TE

Under the conditions defined above, implementations which support the extensions defined in this document have the choice of using RSVP-TE LSA advertisements or application specific advertisements in support

of SRTE and/or LFA. This will require implementations to provide controls specifying which type of advertisements are to be sent/ processed on receive for these applications. Further discussion of the associated issues can be found in Section 12.3.

New applications which future documents define to make use of the advertisements defined in this document MUST NOT make use of RSVP-TE LSA advertisements. This simplifies deployment of new applications by eliminating the need to support multiple ways to advertise attributes for the new applications.

12.2. Use of Zero Length Application Identifier Bit Masks

If link attributes are advertised associated with zero length Application Identifier Bit Masks for both standard applications and user defined applications, then any Standard Application and/or any User Defined Application is permitted to use that set of link attributes so long as there is not another set of attributes advertised on that same link which is associated with a non-zero length Application Identifier Bit Mask with a matching Application Identifier Bit set. If support for a new application is introduced on any node in a network in the presence of such advertisements, these advertisements are permitted to be used by the new application. If this is not what is intended, then existing advertisements MUST be readvertised with an explicit set of applications specified before a new application is introduced.

12.3. Interoperability, Backwards Compatibility and Migration Concerns

Existing deployments of RSVP-TE, SRTE, and/or LFA utilize the legacy advertisements listed in Section 3. Routers which do not support the extensions defined in this document will only process legacy advertisements and are likely to infer that RSVP-TE is enabled on the links for which legacy advertisements exist. It is expected that deployments using the legacy advertisements will persist for a significant period of time. Therefore deployments using the extensions defined in this document must be able to co-exist with use of the legacy advertisements by routers which do not support the extensions defined in this document. The following sub-sections discuss interoperability and backwards compatibility concerns for a number of deployment scenarios.

12.3.1. Multiple Applications: Common Attributes with RSVP-TE

In cases where multiple applications are utilizing a given link, one of the applications is RSVP-TE, and all link attributes for a given link are common to the set of applications utilizing that link, interoperability is achieved by using legacy advertisements for RSVP-

TE. Attributes for applications other than RSVP-TE MUST be advertised using application specific advertisements. This results in duplicate advertisements for those attributes.

12.3.2. Multiple Applications: Some Attributes Not Shared with RSVP-TE

In cases where one or more applications other than RSVP-TE are utilizing a given link and one or more link attribute values are NOT shared with RSVP-TE, interoperability is achieved by using legacy advertisements for RSVP-TE. Attributes for applications other than RSVP-TE MUST be advertised using application specific advertisements. In cases where some link attributes are shared with RSVP-TE, this requires duplicate advertisements for those attributes

12.3.3. Interoperability with Legacy Routers

For the applications defined in this document, routers which do not support the extensions defined in this document will send and receive only legacy link attribute advertisements. So long as there is any legacy router in the network which has any of the applications enabled, all routers MUST continue to advertise link attributes using legacy advertisements. In addition, the link attribute values associated with the set of applications supported by legacy routers (RSVP-TE, SRTE, and/or LFA) are always shared since legacy routers have no way of advertising or processing application specific values. Once all legacy routers have been upgraded, migration from legacy advertisements to application specific advertisements can be achieved via the following steps:

1)Send application specific advertisements while continuing to advertise using legacy (all advertisements are then duplicated). Receiving routers continue to use legacy advertisements.

2)Enable the use of the application specific advertisements on all routers

3)Keep legacy advertisements if needed for RSVP-TE purposes.

When the migration is complete, it then becomes possible to advertise incongruent values per application on a given link.

Documents defining new applications which make use of the application specific advertisements defined in this document MUST discuss interoperability and backwards compatibility issues that could occur in the presence of routers which do not support the new application.

12.3.4. Use of Application Specific Advertisements for RSVP-TE

The extensions defined in this document support RSVP-TE as one of the supported applications. It is however RECOMMENDED to advertise all link-attributes for RSVP-TE in the existing OSPFv2 TE Opaque LSA [RFC3630] and OSPFv3 Intra-Area-TE-LSA [RFC5329] to maintain backward compatibility. RSVP-TE can eventually utilize the application specific advertisements for newly defined link attributes, which are defined as application specific.

Link attributes that are NOT allowed to be advertised in the ASLA Sub-TLV, such as Maximum Reservable Link Bandwidth and Unreserved Bandwidth MUST use the OSPFv2 TE Opaque LSA [RFC3630] and OSPFv3 Intra-Area-TE-LSA [RFC5329] and MUST NOT be advertised in ASLA Sub-TLV.

13. Security Considerations

Existing security extensions as described in [RFC2328], [RFC5340] and [RFC8362] apply to extensions defined in this document. While OSPF is under a single administrative domain, there can be deployments where potential attackers have access to one or more networks in the OSPF routing domain. In these deployments, stronger authentication mechanisms such as those specified in [RFC5709], [RFC7474], [RFC4552] or [RFC7166] SHOULD be used.

Implementations must assure that malformed TLV and Sub-TLV defined in this document are detected and do not provide a vulnerability for attackers to crash the OSPF router or routing process. Reception of a malformed TLV or Sub-TLV SHOULD be counted and/or logged for further analysis. Logging of malformed TLVs and Sub-TLVs SHOULD be rate-limited to prevent a Denial of Service (DoS) attack (distributed or otherwise) from overloading the OSPF control plane.

This document defines a new way to advertise link attributes. Tampering with the information defined in this document may have an effect on applications using it, including impacting Traffic Engineering. This is similar in nature to the impacts associated with (for example) [RFC3630]. As the advertisements defined in this document limit the scope to specific applications, the impact of tampering is similarly limited in scope.

14. IANA Considerations

14.1. OSPFv2

The OSPFv2 Extended Link TLV Sub-TLVs registry [RFC7684] defines sub-TLVs at any level of nesting for OSPFv2 Extended Link TLVs. IANA has assigned the following Sub-TLV types from the OSPFv2 Extended Link TLV Sub-TLVs Registry:

10 - Application Specific Link Attributes

11 - Shared Risk Link Group

12 - Unidirectional Link Delay

13 - Min/Max Unidirectional Link Delay

14 - Unidirectional Delay Variation

15 - Unidirectional Link Loss

16 - Unidirectional Residual Bandwidth

17 - Unidirectional Available Bandwidth

18 - Unidirectional Utilized Bandwidth

19 - Administrative Group

20 - Extended Administrative Group

22 - TE Metric

23 - Maximum Link Bandwidth

14.2. OSPFv3

The OSPFv3 Extended LSA Sub-TLV Registry [RFC8362] defines sub-TLVs at any level of nesting for OSPFv3 Extended LSAs. IANA has assigned the following Sub-TLV types from the OSPFv3 Extended LSA Sub-TLV Registry:

11 - Application Specific Link Attributes

12 - Shared Risk Link Group

13 - Unidirectional Link Delay

14 - Min/Max Unidirectional Link Delay

15 - Unidirectional Delay Variation

16 - Unidirectional Link Loss

16 - Unidirectional Residual Bandwidth

18 - Unidirectional Available Bandwidth

19 - Unidirectional Utilized Bandwidth

20 - Administrative Group

21 - Extended Administrative Group

22 - TE Metric

23 - Maximum Link Bandwidth

24 - Local Interface IPv6 Address Sub-TLV

25 - Remote Interface IPv6 Address Sub-TLV

15. Contributors

The following people contributed to the content of this document and should be considered as co-authors:

Acee Lindem
Cisco Systems
301 Midenhall Way
Cary, NC 27513
USA

Email: acee@cisco.com

Ketan Talaulikar
Cisco Systems, Inc.
India

Email: ketant@cisco.com

Hannes Gredler
RtBrick Inc.
Austria

Email: hannes@rtbrick.com

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17.1. Normative References

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Authors' Addresses

Peter Psenak (editor)
Cisco Systems
Eurovea Centre, Central 3
Pribinova Street 10
Bratislava 81109
Slovakia

Email: ppsenak@cisco.com

Les Ginsberg
Cisco Systems
821 Alder Drive
MILPITAS, CA 95035
USA

Email: ginsberg@cisco.com

Wim Henderickx
Nokia
Copernicuslaan 50
Antwerp, 2018 94089
Belgium

Email: wim.henderickx@nokia.com

Jeff Tantsura
Apstra
US

Email: jefftant.ietf@gmail.com

John Drake
Juniper Networks
1194 N. Mathilda Ave
Sunnyvale, California 94089
USA

Email: jdrake@juniper.net