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IGP Extensions for Scalable Segment Routing based Enhanced VPN

Abstract

Enhanced VPN (VPN+) aims to provide enhanced VPN services to support some application's needs of enhanced isolation and stringent performance requirements. VPN+ requires integration between the overlay VPN connectivity and the characteristics provided by the underlay network. A Virtual Transport Network (VTN) is a virtual underlay network which has a customized network topology and a set of network resources allocated from the physical network. A VTN could be used to support one or a group of VPN+ services. In the context of network slicing, a VTN could be instantiated as a network resource partition (NRP).

This document specifies the IGP mechanisms with necessary extensions to advertise the associated topology and resource attributes for scalable Segment Routing (SR) based NRPs. Each NRP can have a customized topology and a set of network resources allocated from the physical network. Multiple NRPs may shared the same topology, and multiple NRPs may share the same set of network resources on some network segments. This allows flexible combination of the network topology and network resource attributes to build a relatively large number of NRPs with a relatively small number of logical topologies. A group of resource-aware SIDs and SRv6 Locators can be assigned to each NRP. The proposed mechanism is applicable to both Segment Routing with MPLS data plane (SR-MPLS) and Segment Routing with IPv6 data plane (SRv6). This document also describes the mechanism of using dedicated NRP ID in the data plane instead of the per-NRP resource-aware SIDs and SRv6 Locators to further reduce the control plane and data plane overhead of maintaining a large number of NRPs.

Status of This Memo

This Internet-Draft will expire on 12 January 2023.

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1. Introduction

Enhanced VPN (VPN+) is an enhancement to VPN services to support the needs of new applications, particularly the applications that are associated with 5G services. These applications require enhanced isolation and have more stringent performance requirements than that can be provided with traditional overlay VPNs. These properties require integration between the underlay and the overlay networks. [I-D.ietf-teas-enhanced-vpn] specifies the framework of enhanced VPN and describes the candidate component technologies in different network planes and layers. An enhanced VPN can be used for 5G network slicing, and will also be of use in more generic scenarios.

To meet the requirement of different enhanced VPN services, a number of virtual underlay networks need to be created, each with a customized network topology and a set of network resources allocated from the physical network to meet the requirement of one or a group of VPN+ services. Such a virtual underlay network is called Virtual Transport Network (VTN) in [I-D.ietf-teas-enhanced-vpn].

[I-D.ietf-teas-ietf-network-slices] introduces the concept Network Resource Partition (NRP) as a set of network resources that are available to carry traffic and meet the SLOs and SLEs. In order to allocate network resources to an NRP, the NRP is associated with a network topology to define the set of links and nodes. Thus VTN and NRP are similar concepts, and NRP can be seen as an instantiation of VTN in the context of network slicing. For clarity, the rest of this document uses NRP in the description of the proposed mechanisms and protocol extensions.

[I-D.ietf-spring-resource-aware-segments] introduces resource-aware segments by associating existing type of SIDs with network resource attributes (e.g. bandwidth, processing or storage resources). These resource-aware SIDs retain their original functionality, with the additional semantics of identifying the set of network resources available for the packet processing action.[I-D.ietf-spring-sr-for-enhanced-vpn] describes the use of resource-aware segments to build SR based NRPs. To allow the network controller and network nodes to perform NRP-specific explicit path computation and/or shortest path computation, the group of resource-aware SIDs allocated by network nodes to each NRP and the associated topology and resource attributes need to be distributed using the control plane.

[I-D.ietf-teas-nrp-scalability] analyzes the scalability requirements and the control plane and data plane scalability considerations of NRP. In order to support a relatively large number of NRPs in the network, one proposed approach is to separate the topology and resource attributes of the NRP in control plane, so that the advertisement and processing of each type of attribute could be decoupled. Multiple NRPs may shared the same topology, and multiple NRPs may share the same set of network resources on some network segments, while the difference in either the topology or resource attributes makes them different NRPs. This allows flexible combination of network topology and network resource attributes to build a large number of NRPs with a relatively small number of logical topologies.

This document specifies the IGP control plane mechanisms with necessary extensions for scalable SR based NRPs. A group of resource-aware SIDs and SRv6 Locators can be assigned to each NRP. The proposed mechanism is applicable to both segment routing with MPLS data plane (SR-MPLS) and segment routing with IPv6 data plane (SRv6). This document also describes the mechanisms of using dedicated NRP ID in the data plane instead of the per-NRP resource-aware SIDs to further reduce the control plane and data plane overhead of maintaining a large number of NRPs.

In general this approach applies to both IS-IS and OSPF, while the specific protocol extensions and encodings are different. In the current version of this document, the required IS-IS extensions are described. The required OSPF extensions will be described in a future version or in a separate document.

1.1. 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.

2. Advertisement of NRP Definition

According to [I-D.ietf-teas-ietf-network-slices], an NRP is a collection of network resources allocated in the underlay network, and is associated with a network topology. Thus an NRP can be defined as the combination of a set of network attributes, which include the topology attribute, the resource attributes, and other possible attributes.

The IS-IS Network Resource Partition Definition (NRPD) sub-TLV is used to advertise the definition of a NRP. It is a sub-TLV of the IS-IS Router-Capability TLV 242 as defined in [RFC7981].

The format of IS-IS NRPD sub-TLV is as below:

```
 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     |            NRP ID             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       NRP ID (Continue)       |           MT-ID               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Algorithm   |     Flags     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
~                         Sub-sub-TLVs                          ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*Type: TBD

*Length: The length of the value field of the sub-TLV. It is variable dependent on the included sub-TLVs.

*NRP ID: A domain significant 32-bit identifier which is used to identify an NRP.

*MT-ID: 16-bit field which indicates the multi-topology identifier as defined in [RFC5120]. The first 4-bit are set to zero.

*Algorithm: 8-bit identifier which indicates the algorithm which applies to this NRP. It can be either a normal algorithm [RFC8402] or a Flexible Algorithm [I-D.ietf-lsr-flex-algo].

*Flags: 8-bit flags. Currently all the flags are reserved for future use. They SHOULD be set to zero on transmission and MUST be ignored on receipt.

*Sub-sub-TLVs: optional sub-sub-TLVs to specify the additional attributes of an NRP. Currently no sub-sub-TLV is defined in this document.

The NRPD Sub-TLV MAY be advertised in an LSP of any number. A node MUST NOT advertise more than one NRPD Sub-TLV for a given NRP ID.

3. Advertisement of NRP Topology Attribute

This section describes the mechanisms used to advertise the topology attribute associated with SR based NRPs. Basically the topology of an NRP can be determined by the MT-ID and/or the algorithm ID included in the NRP definition. In practice, it could be described using two optional approaches.

The first approach is to use Multi-Topology Routing (MTR) [RFC4915] [RFC5120] with the segment routing extensions to advertise the topology associated with the SR based NRPs. Different algorithms MAY be used to further specify the computation algorithm or the metric type used for path computation within the topology. Multiple NRPs can be associated with the same <topology, algorithm>, and the IGP computation with the <topology, algorithm> tuple can be shared by these NRPs.

The second approach is to use Flex-Algo [I-D.ietf-lsr-flex-algo] to describe the topological constraints of SR based NRPs on a shared network topology (e.g. the default topology). Multiple NRPs can be associated with the same Flex-Algo, and the IGP computation with this Flex-Algo can be shared by these NRPs.

3.1. MTR based Topology Advertisement

Multi-Topology Routing (MTR) has been defined in [RFC4915] and [RFC5120] to create different network topologies in one network. It also has the capability of specifying customized attributes for each topology. The traditional use cases of multi-topology are to maintain separate topologies for unicast and multicast services, or to create different topologies for IPv4 and IPv6 in a network. There are some limitations when MTR is used with native IP forwarding, the considerations about MT based IP forwarding are described in [RFC5120].

MTR can be used with SR-MPLS data plane. [RFC8667] specifies the IS-IS extensions to support SR-MPLS data plane, in which the Prefix-SID sub-TLVs can be carried in IS-IS TLV 235 (MT IP Reachability) and TLV 237 (MT IPv6 IP Reachability), and the Adj-SID sub-TLVs can be carried in IS-IS TLV 222 (MT-ISN) and TLV 223 (MT IS Neighbor Attribute).

MTR can also be used with SRv6 data plane. [I-D.ietf-lsr-isis-srv6-extensions] specifies the IS-IS extensions to support SRv6 data plane, in which the MT-ID is carried in the SRv6 Locator TLV. The SRv6 End SIDs are carried as sub-TLVs in the SRv6 Locator TLV, and inherit the topology/algorithm from the parent locator. The SRv6 End.X SIDs are carried as sub-TLVs in the IS-IS TLV 222 (MT-ISN) and

TLV 223 (MT IS Neighbor Attribute), and inherit the topology/algorithm from the parent locator.

These IGP extensions for SR-MPLS and SRv6 can be used to advertise and build the topology for a group of SR based NRPs.

An algorithm ID MAY be used to further specify the computation algorithm or the metric type used for path computation within the topology.

3.2. Flex-Algo based Topology Advertisement

[I-D.ietf-lsr-flex-algo] specifies the mechanisms to provide distributed computation of constraint-based paths, and how the SR-MPLS prefix-SIDs and SRv6 locators can be used to steer packets along the constraint-based paths.

The Flex-Algo Definition (FAD) can be used to describe the topological constraints for path computation on a network topology. According to the network nodes' participation of a Flex-Algo, and the rules of including or excluding specific Administrative Groups (colors) and the Shared Risk Link Groups (SRLGs), the topology of an NRP can be determined using the associated Flex-Algo on a particular topology (e.g. the default topology).

With the mechanisms defined in[RFC8667] [I-D.ietf-lsr-flex-algo], prefix-SID advertisement can be associated with a <topology, algorithm> tuple, in which the algorithm can be a Flex-Algo. This allows network nodes to use the prefix-SID to steer traffic along distributed computed paths according to the identified Flex-Algo in the topology.

[I-D.ietf-lsr-isis-srv6-extensions] specifies the IS-IS extensions to support SRv6 data plane, in which the SRv6 locators advertisement can be associated with a specific topology and a specific algorithm, which can be a Flex-Algo. With the mechanism defined in [I-D.ietf-lsr-flex-algo], The SRv6 locator can be used to steer traffic along distributed computed paths according to the identified Flex-Algo in the topology. In addition, topology/algorithm specific SRv6 End SID and End.X SID can be used to enforce traffic over the LFA computed backup path.

Multiple Flex-Algos MAY be defined to describe the topological constraints on a shared network topology (e.g. the default topology).

4. Advertisement of NRP Resource Attribute

This section specifies the mechanisms to advertise the network resource attributes associated with the NRPs. The mechanism of advertising the link resources and attributes associated with NRPs is described. The mechanism of advertising node resources and attributes associated with NRPs are for further study. Two optional approaches are described in the following sub-sections: the first option is the L2 Bundle [RFC8668] based approach, the second option is to extend IGP to advertise per-NRP link TE attributes.

4.1. Option 1: L2 Bundle based Approach

On a Layer-3 interface, each NRP can be allocated with a subset of link resources (e.g. bandwidth). A subset of link resources may be dedicated to an NRP, or may be shared by a group of NRPs. Each subset of link resource can be represented as a virtual layer-2 member link under the Layer-3 interface, and the Layer-3 interface is considered as a virtual Layer-2 bundle. The Layer-3 interface may also be a physical Layer 2 link bundle, in this case a subset of link resources allocated to an NRP may be provided by one of the physical Layer-2 member links.

[RFC8668] describes the IS-IS extensions to advertise the link attributes of the Layer 2 member links which comprise a Layer 3 interface. Such mechanism can be extended to advertise the attributes of each physical or virtual member links, and its associated NRPs.

A new flag "E" (Exclusive) is defined in the flag field of the Parent L3 Neighbor Descriptor in the L2 Bundle Member Attributes TLV (25).

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

E flag: When the E flag is set, it indicates each member link under the Parent L3 link are used exclusively for one or a specific group of NRPs, and load sharing among the member links is not allowed. When the E flag is clear, it indicates load balancing and sharing among the member links are allowed.

A new NRP IDs sub-TLV is carried under the L2 Bundle Attribute Descriptors to describe the mapping relationship between the NRPs and the virtual or physical member links. As one or more NRPs may use the same set of link resource on a specific network segment, these NRP IDs will be advertised under the same virtual or physical member link.

The format of the NRP IDs Sub-TLV is as below:

```
 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            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           NRP ID #1                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                              ...                              ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           NRP ID #n                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

* Type: TBD

* Length: The length of the value field of the sub-TLV. It is variable dependent on the number of NRP IDs included.

* Flags: 16 bit flags. All the bits are reserved for future use, which SHOULD be set to 0 on transmission and MUST be ignored on receipt.

* NRP IDs: One or more 32-bit identifiers to identify the NRPs this member link belongs to.

Each physical or virtual member link MAY be associated with a different group of NRPs. Thus each L2 Bundle Attribute Descriptor may carry the link local identifier and attributes of only one Layer 2 member link. Multiple L2 Bundle Attribute Descriptors will be used to carry the attributes and the associated NRP IDs of all the Layer 2 member links.

The TE attributes of each virtual or physical member link, such as the bandwidth attributes and the SR SIDs, can be advertised using the mechanism as defined in [RFC8668].

4.2. Option 2: Per-NRP Link TE Attributes

A Layer-3 interface can participate in multiple NRPs, each of which is allocated with a subset of the forwarding resources of the interface. For each NRP, the associated resources can be described using per-NRP TE attributes. A new NRP-specific TE attribute sub-TLV is defined to advertise the link attributes associated with an NRP. This sub-TLV MAY be advertised as a sub-TLV of the following TLVs:

TLV-22 (Extended IS reachability) [RFC5305]

TLV-23 (IS Neighbor Attribute) [RFC5311]

TLV-141 (Inter-AS Reachability Information) [RFC5316]

TLV-222 (MT ISN) [RFC5120]

TLV-223 (MT IS Neighbor Attribute) [RFC5311]

The format of the sub-TLV is shown as below:

```
 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   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     NRP ID Sub-sub-TLV                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                     Other Sub-sub-TLVs                        ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

* Type: TBD

* Length: The length of the value field of the sub-TLV. It is variable dependent on the length of the Sub-sub-TLVs field.

* Flags: 8-bit flags. All the 8 bits are reserved for future use, which SHOULD be set to 0 on transmission and MUST be ignored on receipt.

* Reserved: 8-bit field reserved for future use, SHOULD be set to 0 on transmission and MUST be ignored on receipt.

* NRP ID Sub-sub-TLV: contains one or more NRP IDs which is associated with the same group of TE attributes.

* Other Sub-sub-TLVs: the TLVs which carry the TE attributes associated with the NRPs.

The format of the NRP ID sub-sub-TLV is shown as below:

```
 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     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            NRP ID #1                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                               ...                             ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

* *Type: TBD

* *Length: The length of the value field of the sub-sub-TLV. It is the number of the NRP IDs in the TLV multiplied by 4.

* *NRP ID: A 32-bit identifier which is used to identify an NRP.

One sub-sub-TLV "NRP bandwidth sub-sub-TLV" is defined in this document. Its format is shown as below:

```
 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   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Bandwidth                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

* *Type: TBD

* *Length: The length of the value field of the sub-sub-TLV. It is set to 6.

* *Flags: 8-bit flags. All the 8 bits are reserved for future use, which SHOULD be set to 0 on transmission and MUST be ignored on receipt.

* *Reserved: 8-bit field reserved for future use, SHOULD be set to 0 on transmission and MUST be ignored on receipt.

* *Bandwidth: The bandwidth allocated to the NRP, encoded in 32 bits in IEEE floating point format.

The NRP Bandwidth sub-sub-TLV is optional. This sub-sub-TLV SHOULD appear once at most in each NRP-specific TE attribute sub-TLV.

5. Advertisement of NRP specific Data Plane Identifiers

In order to steer packets to the NRP-specific paths which are computed taking the topology and network resources of the NRP as the constraints, some fields in the data packet needs to be used to infer or identify the NRP the packet belongs to. As multiple NRPs may share the same topology or Flex-Algo, the topology/Flex-Algo specific SR SIDs or Locators cannot be used to distinguish the packets which belong to different NRPs. Some additional data plane identifiers would be needed to identify the NRP a packet belongs to.

This section describes the mechanisms to advertise the NRP identifiers in different data plane encapsulations.

5.1. Advertisement of NRP-specific SR-MPLS SIDs

With SR-MPLS data plane, the NRP identification information can be implicitly carried in the NRP-specific SIDs. Each node SHOULD allocate a unique Prefix-SID for each NRP it participates in. On a Layer-3 interface, if each Layer 2 member link is associated with only one NRP, the adj-SIDs of the L2 member links could also identify the NRPs. If a member link is associated with multiple NRPs, NRP-specific adj-SIDs MAY need to be allocated to help the NRP-specific local protection.

A new NRP-specific prefix-SID sub-TLV is defined to advertise the prefix-SID and its associated NRP. This sub-TLV MAY be advertised as a sub-TLV of the following TLVs:

TLV-135 (Extended IPv4 Reachability) defined in [RFC5305].

TLV-235 (MT IP Reachability) defined in [RFC5120].

TLV-236 (IPv6 IP Reachability) defined in [RFC5308].

TLV-237 (MT IPv6 IP Reachability) defined in [RFC5120].

The format of the sub-TLV is shown as below:

```
  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             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                             NRP ID                            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                  SID/Index/Label(Variable)                    |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*Type: TBD

*Length: The length of the value field of the sub-TLV. It is variable dependent on the length of the SID/Index/Label field.

*Flags: 16-bit flags. The high-order 8 bits are the same as in the Prefix-SID sub-TLV defined in [RFC8667]. The lower-order 8 bits are reserved for future use, which SHOULD be set to 0 on transmission and MUST be ignored on receipt.

*NRP ID: A 32-bit identifier to identify the NRP this prefix-SID associates with.

*SID/Index/Label: The same as defined in [RFC8667].

One or more of NRP-specific Prefix-SID sub-TLVs MAY be carried in the Multi-topology IP Reachability TLVs (TLV 235 or TLV 237), the MT-ID of the TLV SHOULD be the same as the MT-ID in the definition of these NRPs.

A new NRP-specific Adj-SID sub-TLV is defined to advertise the adj-SID and its associated NRP. This sub-TLV may be advertised as a sub-TLV of the following TLVs:

TLV-22 (Extended IS reachability) [RFC5305]

TLV-23 (IS Neighbor Attribute) [RFC5311]

TLV-25 (L2 Bundle Member Attributes) [RFC8668]

TLV-141 (Inter-AS Reachability Information) [RFC5316]

TLV-222 (MT ISN) [RFC5120]

TLV-223 (MT IS Neighbor Attribute) [RFC5311]

The format of the sub-TLV is shown as below:

```
 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              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            NRP ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  SID/Index/Label(Variable)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*Type: TBD

*Length: The length of the value field of the sub-TLV. It is variable dependent on the length of the SID/Index/Label field.

*Flags: 16-bit flags. The high-order 8 bits are the same as in the Adj-SID sub-TLV defined in [RFC8667]. The lower-order 8 bits are reserved for future use, which SHOULD be set to 0 on transmission and MUST be ignored on receipt.

*NRP ID: A 32-bit global identifier to identify the NRP this Adj-SID associates with.

*SID/Index/Label: The same as defined in [RFC8667].

One or more NRP-specific Adj-SID sub-TLV MAY be carried in the Multi-topology ISN or Multi-topology IS Attribute TLVs (TLV 222 or TLV 223), the MT-ID of the TLV SHOULD be the same as the MT-ID in the definition of these NRPs.

A new NRP-specific LAN Adj-SID sub-TLV is defined to advertise the adj-SID and its associated NRP for each neighbor on a LAN interface. This sub-TLV may be advertised as a sub-TLV of the following TLVs:

TLV-22 (Extended IS reachability) [RFC5305]

TLV-23 (IS Neighbor Attribute) [RFC5311]

TLV-222 (MT ISN) [RFC5120]

TLV-223 (MT IS Neighbor Attribute) [RFC5311]

The format of the sub-TLV is shown as below:

```
 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             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            NRP ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                 Neighbor System-ID  (ID length octets)        ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      SID/Index/Label(Variable)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*Type: TBD

*Length: The length of the value field of the sub-TLV. It is variable dependent on the length of the SID/Index/Label field.

*Flags: 16-bit flags. The high-order 8 bits are the same as in the Adj-SID sub-TLV defined in [RFC8667]. The lower-order 8 bits are reserved for future use, which SHOULD be set to 0 on transmission and MUST be ignored on receipt.

*NRP ID: A 32-bit global identifier to identify the NRP this Adj-SID associates with.

*Neighbor System-ID: IS-IS System-ID of length "ID Length" as defined in [ISO10589].

*SID/Index/Label: The same as defined in [RFC8667].

One or more NRP-specific LAN Adj-SID sub-TLV MAY be carried in the Multi-topology ISN or Multi-topology IS Attribute TLVs (TLV 222 or TLV 223), the MT-ID of the TLV SHOULD be the same as the MT-ID in the definition of these NRPs.

5.2. Advertisement of NRP-specific SRv6 Locators and SIDs

5.2.1. NRP-specific SRv6 Locators and End SIDs

With SRv6 data plane, the NRP identification information can be implicitly or explicitly carried in the SRv6 Locator of the corresponding NRP, this is to ensure that all network nodes (including both the end nodes and the transit nodes) can identify the NRP to which a packet belongs to. Network nodes SHOULD allocate NRP-specific Locators for each NRP it participates in. The NRP-specific Locators are used as the covering prefix of NRP-specific SRv6 End SIDs, End.X SIDs and other types of SIDs.

In one possible approach, each NRP-specific Locator is advertised in a separate TLV called "NRP specific SRv6 Locator TLV". Its format is shown as below:

```
 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    |R|R|R|R|    MT ID              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Locator Entries . . .                       |
```

Where:

*Type: TBD

*The semantics of the Length field, the R bits and the MT ID field are the same as those defined in [I-D.ietf-lsr-isis-srv6-extensions].

Followed by one or more locator entries of the form:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Metric                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Flags      |  Algorithm    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            NRP ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Loc Size   |
+-+-+-+-+-+-+-+-+

+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
//              Locator (continued, variable)                   //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Sub-TLV-len  |         Sub-TLVs (variable) . . .             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*NRP ID: A 32-bit identifier to identify the NRP this Locator is associated with.

*All the other fields are the same as those defined in [I-D.ietf-lsr-isis-srv6-extensions].

The NRP-specific SRv6 End SIDs are carried in the NRP-specific SRv6 Locator TLV, and inherits the topology, algorithm and NRP from the parent NRP-specific Locator.

In another possible approach, when a group of NRPs share the same topology/algorithm, the topology/algorithm specific Locator is the covering prefix of a group of NRP-specific Locators. Then the advertisement of NRP-specific locators can be optimized to reduce the amount of Locator TLVs advertised in the control plane.

A new NRP locator-block sub-TLV under the SRv6 Locator TLV is defined to advertise a set of sub-blocks which follows the topology/algorithm specific Locator. Each NRP locator-block value is assigned to one of the NRPs which share the same topology/algorithm.

```
 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     | Number of NRPs|  Block Length |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            NRP ID #1                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                       Locator Block Value                     ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                               ...                             ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            NRP ID #n                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                       Locator Block Value                     ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*Type: TBD

*Length: The length of the value field of the sub-TLV. It is variable dependent on the number of NRPs and the Block Length.

*Number of NRPs: The number of NRPs which share the same topology/algorithm specific Locator as the covering prefix.

*Block Length: The length of the NRP locator-block which follows the length of the topology/algorithm specific Locator.

*NRP ID: A 32-bit identifier to identify the NRP the locator-block is associates with.

*Block Value: The value of the NRP locator-block for each NRP.

With the NRP locator-block sub-TLV, the NRP-specific Locator can be obtained by concatenating the topology/algorithm specific locator and the locator-block value advertised for the NRP.

The NRP-specific SRv6 End SIDs inherit the topology, algorithm and the NRP from the parent NRP-specific Locator.

5.2.2. NRP-specific SRv6 End.X SIDs

The SRv6 End.X SIDs are advertised as sub-TLVs of TLV 22, 23, 25, 141, 222, and 223. In order to distinguish the End.X SIDs which belong to different NRPs, a new "NRP ID sub-sub-TLV" is introduced under the SRv6 End.X SID sub-TLV and SRv6 LAN End.X SID sub-TLV defined in [I-D.ietf-lsr-isis-srv6-extensions]. Its format is shown as below:

```
    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    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            NRP ID                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

*Type: TBD.

*Length: the length of the Value field of the TLV. It is set to 4.

*NRP ID: A 32-bit identifier to identify the NRP this End.X SID associates with.

5.3. Advertisement of Dedicated Data Plane NRP ID

As the number of NRPs increases, with the mechanism described in [I-D.ietf-spring-sr-for-enhanced-vpn], the number of SR SIDs and SRv6 Locators allocated for different NRPs would also increase. In network scenarios where the number of SIDs or Locators becomes a concern, some data plane optimization may be needed to reduce the amount of SR SIDs and Locators allocated. As described in [I-D.ietf-teas-nrp-scalability], one approach is to decouple the data plane identifiers used for topology based forwarding and the identifiers used for the NRP-specific processing. Thus a dedicated data plane NRP ID could be encapsulated in the packet. One possible encapsulation of NRP ID in IPv6 data plane is proposed in [I-D.ietf-6man-enhanced-vpn-vtn-id]. One possible encapsulation of NRP ID in MPLS data plane is proposed in [I-D.li-mpls-enhanced-vpn-vtn-id].

In that case, the NRP ID encapsulated in data plane can have the same value as the NRP ID in control plane, so that the overhead of advertising the mapping between the control plane NRP IDs and the corresponding data plane identifiers could be saved.

6. Security Considerations

This document introduces no additional security vulnerabilities to IS-IS.

The mechanism proposed in this document is subject to the same vulnerabilities as any other protocol that relies on IGPs.

7. IANA Considerations

IANA is requested to assign a new code point in the "sub-TLVs for TLV 242 registry".

Type: TBD1
Description: Network Resource Partition Definition

IANA is requested to assign four new code points in the "sub-TLVs for TLVs 22, 23, 25, 141, 222, and 223 registry".

Type: TBD2
Description: Network Resource Partition Identifiers sub-TLV

Type: TBD3
Description: NRP-specific TE attribute sub-TLV

Type: TBD4
Description: NRP-specific Adj-SID

Type: TBD5
Description: NRP-specific LAN Adj-SID

IANA is requested to assign two new code points in the "Sub-TLVs for TLVs 27, 135, 235, 236 and 237 registry".

Type: TBD6
Description: NRP-specific Prefix-SID

Type: TBD7
Description: NRP locator-block

IANA is requested to assign a new code point in the "IS-IS TLV Codepoints registry".

Type: TBD8
Description: NRP-specific SRv6 Locator TLV

IANA is requested to assign a new code point in the "sub-sub-TLVs for SRv6 End SID and SRv6 End.X SID registry".

Type: TBD9
Description: NRP ID Sub-sub-TLV

8. Contributors

TBD

9. Acknowledgments

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