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Preferred Path Routing (PPR) in IS-IS
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Abstract

This document specifies Preferred Path Routing (PPR), a routing protocol extension to simplify the path description on the packet for Segment Routing (SR) deployments and beyond. PPR aims to mitigate the MTU and data plane processing issues that may result from SR packet overhead; and also supports further extensions along the paths.

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 [RFC2119](#) [[RFC2119](#)], [RFC8174](#) [[RFC8174](#)] when, and only when they appear in all capitals, as shown here.

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1. Introduction

In a network implementing Segment Routing (SR), packets are steered through the network using Segment Identifiers (SIDs) carried in the packet header. Each SID uniquely identifies a segment as defined in [\[RFC8402\]](#). SR capabilities are defined for MPLS and IPv6 data planes called SR-MPLS and SRv6 respectively. [Appendix A.1](#) and [Appendix A.2](#) describe performance, hardware capabilities and various associated issues which may result in SR deployments.

The above motivate the proposed solution, Preferred Path Routing (PPR). In brief, PPR involves, associating path descriptions to IS-IS advertised prefixes, mapping those to a data-plane identifier and specifying a mechanism to route packets with the abstracted identifier (PPR-ID), as opposed to individual segments on the packet. This is specified in detail in [Section 2](#) and [Section 3](#).

1.1. Acronyms

EL	- Entropy Label
ELI	- Entropy Label Indicator
LSP	- IS-IS Link State PDU
MPLS	- Multi Protocol Label Switching
MSD	- Maximum SID Depth
MTU	- Maximum Transferrable Unit
NH	- Next-Hop
PPR	- Preferred Path Routing/Route
PPR-ID	- Preferred Path Route Identifier, a data plane identifier
SID	- Segment Identifier
SPF	- Shortest Path First
SR-MPLS	- Segment Routing with MPLS data plane
SRH	- Segment Routing Header - IPv6 routing Extension header

- SRv6 - Segment Routing with IPv6 data plane with SRH
- TE - Traffic Engineering

2. Preferred Path Routing (PPR)

PPR mitigates the issues described in [Appendix A.1](#), while continuing to allow the direction of traffic along an engineered path through the network by replacing the label stack with a PPR-ID. The PPR-ID can either be a single label or a native destination address. To facilitate the use of a single label to describe an entire path, a new TLV is added to IS-IS, as described below in [Section 3](#).

A PPR could be an SR path, a traffic engineered path computed based on some constraints, an explicitly provisioned Fast Re-Route (FRR) path or a service chained path. A PPR can be signaled by any node, computed by a central controller, or manually configured by an operator. PPR extends the source routing and path steering capabilities to native IP (IPv4 and IPv6) data planes without hardware upgrades; see [Section 5](#).

2.1. PPR-ID and Data Plane Extensibility

The PPR-ID describes a path through the network. A data plane type and corresponding data plane identifier as specified in [Section 3.2](#) is mapped to PPR-ID to allow data plane extensibility.

For SR-MPLS, PPR-ID is mapped to an MPLS Label/SID and for SRv6, this is mapped to an IPv6-SID. For native IP data planes, this is mapped to either IPv4 or IPv6 address/prefix.

2.2. PPR Path Description

The path identified by the PPR-ID is described as a set of Path Description Elements (PDEs), each of which represents a segment of the path. Each node determines its location in the path as described, and forwards to the next segment/hop or label of the path description (see the Forwarding Procedure Example later in this document).

These PPR-PDEs as defined in [Section 3.3](#), like SR SIDs, can represent topological elements like links/nodes, backup nodes, as well as non-topological elements such as a service, function, or context on a particular node.

A PPR path can be described as a Strict-PPR or a Loose-PPR. In a Strict-PPR all nodes/links on the path are described with SR SIDs for SR data planes or IPv4/IPv6 addresses for native IP data planes. In

a Loose-PPR only some of the nodes/links from source to destination are described. More specifics and restrictions around Strict/Loose PPRs are described in respective data planes in [Section 5](#). Each PDE is described as either an MPLS label towards the Next-Hop (NH) in MPLS enabled networks, or as an IP NH, in the case of either "plain"/"native" IP or SRv6 enabled networks. A PPR path is related to a set of PDEs using the TLVs as specified in [Section 3](#).

[2.3.](#) ECMP Considerations

PPR inherently supports Equal Cost Multi Path (ECMP) for both strict and loose paths. If a path is described using nodes, would have ECMP NHs established for PPR-ID along the path. However, one can avoid ECMP on any segment of the path by pinning the path using link identifier to the next segment.

[2.4.](#) Scalability and PPR Graphs

In a network of N nodes $O(N^2)$ total (unidirectional) paths are necessary to establish any-to-any connectivity, and multiple (k) such path sets may be desirable if multiple path policies are to be supported (lowest latency, highest throughput etc.).

In many solutions and topologies, N may be small enough and/or only a small set of paths need to be preferred paths, for example for high value traffic (DetNet, some of the defined 5G slices), and then the technology specified in this document can support these deployments.

However, to address the scale needed when a larger number of PPR paths are required, the PPR TREE structure can be used [I-D.[draft-ce-ppr-graph-00](#)]. Each PPR Tree uses one label/SID and defines paths from any set of nodes to one destination, thus reduces the number of entries needed in SRGB at each node (for SR-MPLS data plane [Section 5.1](#)). These paths form a tree rooted in the destination. In other word, PPR Tree identifiers are destination identifiers and PPR Treed are path engineered destination routes (like IP routes) and it scaling simplifies to linear in N i.e., $O(k*N)$.

[3.](#) PPR Related TLVs

This section describes the encoding of PPR TLV. This TLV can be seen as having 4 logical sections viz, encoding of the PPR-Prefix (IS-IS Prefix), encoding of PPR-ID, encoding of path description with an ordered PDE Sub-TLVs and a set of optional PPR attribute Sub-TLVs, which can be used to describe one or more parameters of the path. Multiple instances of this TLV MAY be advertised in IS-IS LSPs with different PPR-ID Type (data plane) and with corresponding PDE Sub-

TLVS. The PPR TLV has Type TBD (suggested value xxx), and has the following format:

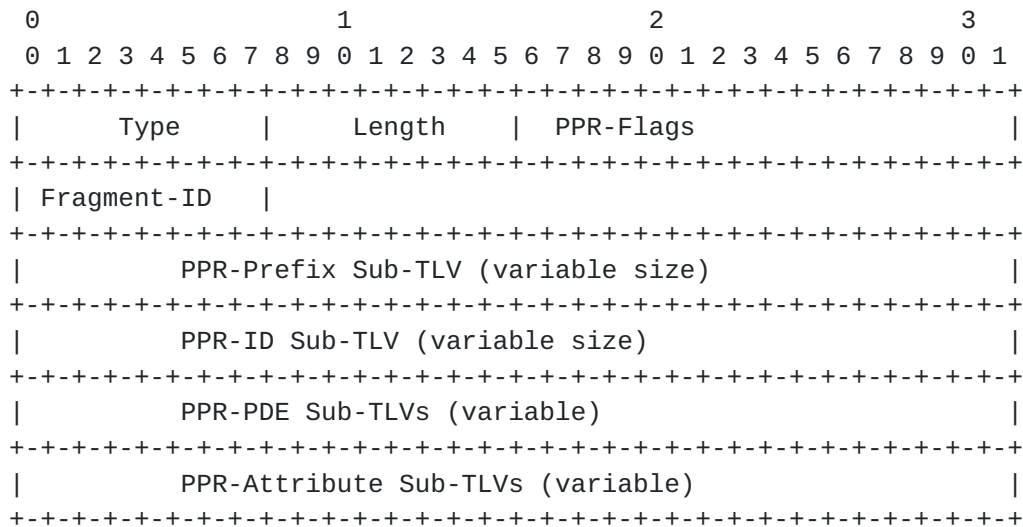


Figure 1: PPR TLV Format

- o Type: 1555555 (Suggested Value, TBD IANA) from IS-IS top level TLV registry.
- o Length: Total length of the value field in bytes.
- o PPR-Flags: 2 Octet bit-field of flags for this TLV; described below.
- o Fragment-ID: This is an 8-bit Identifier value (0-255) of the TLV fragment. If fragments are not needed to represent the complete path, L bit MUST be set and this value MUST be set to 0.
- o PPR-Prefix: A variable size Sub-TLV representing the destination of the path being described. This is defined in [Section 3.1](#).
- o PPR-ID: A variable size Sub-TLV representing the data plane or forwarding identifier of the PPR. Defined in [Section 3.2](#).
- o PPR-PDEs: Variable number of ordered PDE Sub-TLVs which represents the path. This is defined in [Section 3.3](#).
- o PPR-Attributes: Variable number of PPR-Attribute Sub-TLVs which represent the path attributes. These are defined in [Section 3.4](#).

The `Flags` field has the following flag bits defined:

PPR TLV Flags Format

```

    0 1 2 3 4 5 6 7                15
+-+--+--+--+--+--+--+--+--+--+--+
|S|D|A|L|Reserved                |
+-+--+--+--+--+--+--+--+--+--+--+

```

1. S: If set, the PPR TLV MUST be flooded across the entire routing domain. If the S flag is not set, the PPR TLV MUST NOT be leaked between IS-IS levels. This bit MUST NOT be altered during the TLV leaking
2. D: When the PPR TLV is leaked from IS-IS level-2 to level-1, the D bit MUST be set. Otherwise, this bit MUST be clear. PPR TLVs with the D bit set MUST NOT be leaked from level-1 to level-2. This is to prevent TLV looping across levels.
3. A: The originator of the PPR TLV MUST set the A bit in order to signal that the prefixes and PPR-IDs advertised in the PPR TLV are directly connected to the originators. If this bit is not set, this allows any other node in the network to advertise this TLV on behalf of the originating node of the PPR-Prefix. If PPR TLV is leaked to other areas/levels the A-flag MUST be cleared. In case if the originating node of the prefix must be disambiguated for any reason including, if it is a Multi Homed Prefix (MHP) or leaked to a different IS-IS level or because [\[RFC7794\]](#) X-Flag is set, then PPR-Attribute Sub-TLV Source Router ID SHOULD be included.
4. L: L bit MUST be set if a path has only one fragment or if it is the last Fragment of the path. PPR-ID value for all fragments of the same path MUST be same.
5. Reserved: For future use; MUST be set to 0 on transmit and ignored on receive.

PPR path description for each IS-IS level is computed and given to one of the nodes for L1 and L2 respectively. Similarly path information when crossing the level boundaries MUST be relevant to the destination level. If there is no path information available for the destination level PPR TLV MUST NOT be leaked regardless of S and D bits as defined above.

The following Sub-TLVs draw from a new registry for Sub-TLV numbers as specified in [Section 7.1](#) and [Section 7.2](#).

3.1. PPR-Prefix Sub-TLV

The structure of PPR-Prefix is:

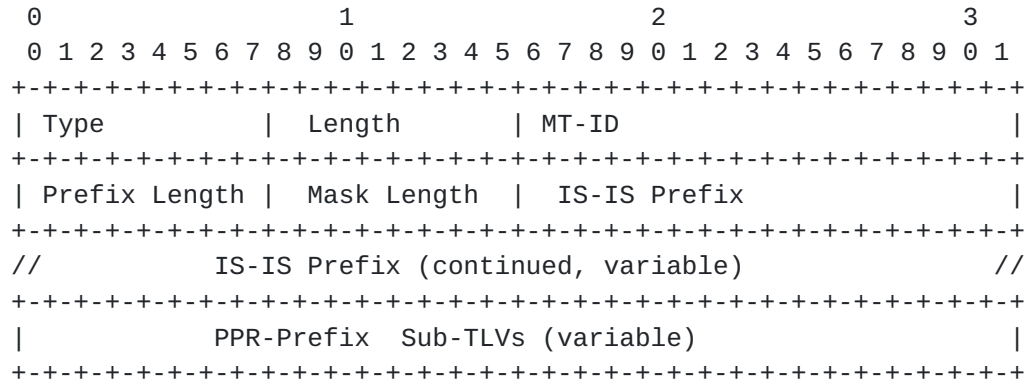


Figure 2: PPR-Prefix Sub-TLV Format

- o Type: 1 (IANA to assign from Sub-TLV registry described above).
- o Length: Total length of the value field in bytes.
- o MT-ID: The multi-topology identifier defined in [\[RFC5120\]](#); the 4 most significant bits MUST be set to 0 on transmit and ignored on receive. The remaining 12-bit field contains the MT-ID.
- o Prefix Length: The length of the IS-IS Prefix being encoded in bytes. For IPv4 it MUST be 4 and IPv6 it MUST be 16 bytes.
- o Mask Length: The length of the prefix in bits. Only the most significant octets of the Prefix are encoded.
- o IS-IS Prefix: The IS-IS prefix at the tail-end of the advertised PPR. This corresponds to a routable prefix of the originating node and it MAY have one of the [\[RFC7794\]](#) flags set (X-Flag/R-Flag/N-Flag) in the IS-IS reachability TLVs. Length of this field MUST be as per "Prefix Length". Encoding is same as TLV 135 [\[RFC5305\]](#) and TLV 236 [\[RFC5308\]](#) or MT-Capable [\[RFC5120\]](#) IPv4 (TLV 235) and IPv6 Prefixes (TLV 237) respectively.
- o PPR-Prefix Sub-TLVs have 1 octet type, 1 octet length and value field is defined per the type field.

3.2. PPR-ID Sub-TLV

This is the actual data plane identifier in the packet header and could be of any data plane as defined in PPR-ID Type field. Both PPR-Prefix and PPR-ID belongs to a same node in the network.

significant octets of the Prefix are encoded. This is needed, if PPR-ID followed is an IPv4/IPv6 Prefix instead of 4/16 octet Address respectively.

- o **Algo:** 1 octet value represents the SPF algorithm. Algorithm registry is as defined in [\[I-D.ietf-isis-segment-routing-extensions\]](#).
- o **PPR-ID:** This is the Preferred Path forwarding identifier that would be on the data packet. The value of this field is variable and it depends on the PPR-ID Type - for Type 1, this is encoded as SR-MPLS SID/Label. For Type 2 this is a 4 byte IPv4 address. For Type 3 this is a 16 byte IPv6 address. For Type 2 and Type 3 encoding is similar to "IS-IS Prefix" as specified in [Section 3.1](#). For Type 4, this is encoded as 16 byte SRv6 SID.

For PPR-ID Type 2, 3 or 4, if the PPR-ID Len is set to non-zero value, then the PPR-ID MUST NOT be advertised as a routable prefix in TLV 135, TLV 235, TLV 236 and TLV 237. Also PPR-ID MUST belong to the node where Prefix is advertised from. PPR-ID Len = 0 case is a special case and is discussed in [Section 4.1](#).

3.3. PPR-PDE Sub-TLV

This Sub-TLV represents the PPR Path Description Element (PDE). PPR-PDEs are used to describe the path in the form of set of contiguous and ordered Sub-TLVs, where first Sub-TLV represents (the top of the stack in MPLS data plane or) first node/segment of the path. These set of ordered Sub-TLVs can have both topological elements and non-topological elements (e.g., service segments).

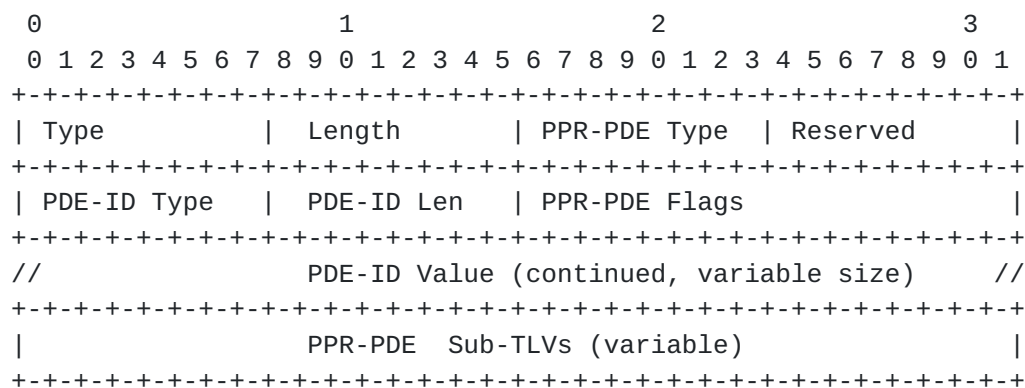


Figure 4: PPR-PDE Sub-TLV Format

- o Type: 3 (See IANA for suggested value) from IS-IS PPR TLV [Section 3](#) Sub-TLV registry.

- o Length: Total length of the value field in bytes.
- o PPR-PDE Type: A new registry (TBD IANA) for this Sub-TLV and the defined types are as follows:

Type: 1 Topological

Type: 2 Non-Topological

- o PDE-ID Type: 1 Octet PDE-forwarding IDentifier Type. A new registry (Suggested Values as listed, IANA TBD) for this Sub-TLV and the defined types and corresponding PDE-ID Len, PDE-ID Value are as follows:

Type 0: This value MUST be set only when PPR-PDE Type is Non-Topological. PDE-ID Len specified in bytes and encoded in NBO in PDE-ID Value field which can represent a service/function. This information is provisioned on the immediate topological PDE preceding to this PDE based on the 'E' bit.

Type 1: SID/Label type as defined in [\[I-D.ietf-isis-segment-routing-extensions\]](#). PDE-ID Len and PDE-ID Value fields are per [Section 2.3](#) of the referenced document.

Type 2: SR-MPLS Prefix SID. PDE-ID Len and PDE-ID Value are same as Type 1.

Type 3: SR-MPLS Adjacency SID. PDE-ID Len and PDE-ID Value are same as Type 1.

Type 4: IPv4 Node Address. PDE-ID Len is 4 bytes and PDE-ID Value is 4 bytes IPv4 address encoded similar to IPv4 Prefix described in [Section 3.1](#).

Type 5: IPv4 P2P interface Address. PDE-ID Len is 4 bytes and PDE-ID Value is 4 bytes IPv4 address encoded similar to IPv4 Prefix described in [Section 3.1](#).

Type 6: IPv4 LAN interface Address. PDE-ID Len is 4 bytes and PDE-ID Value is 4 bytes IPv4 address encoded similar to IPv4 Prefix described in [Section 3.1](#). This type MUST have IS-IS System-ID Sub-TLV in the PDE.

Type 7: IPv6 Node Address. PDE-ID Len is 16 bytes and PDE-ID Value is 16 bytes IPv6 address encoded similar to IPv6 Prefix described in [Section 3.1](#).

Type 8: IPv6 P2P interface Address. PDE-ID Len is 16 bytes and PDE-ID Value is 16 bytes IPv6 address encoded similar to IPv6 Prefix described in [Section 3.1](#).

Type 9: IPv6 LAN interface Address. PDE-ID Len is 16 bytes and PDE-ID Value is 16 bytes IPv6 address encoded similar to IPv6 Prefix described in [Section 3.1](#). This type MUST have IS-IS System-ID Sub-TLV in the PDE.

Type 10: SRv6 Node SID as defined in [\[I-D.bashandy-isis-srv6-extensions\]](#). PDE-ID Len and PDE-ID Value are as defined in SRv6 SID from the referenced draft.

Type 11: SRv6 Adjacency-SID. PDE-ID Len and PDE-ID Values are similar to SRv6 Node SID above.

- o PPR-PDE Flags: 2 Octet bit-field of flags; described below:

PPR-PDE Flags Format

```

  0 1 2 3 4 5 6 7 ..          15
+-+--+--+--+--+--+--+--+--+
|L|D|E|Reserved              |
+-+--+--+--+--+--+--+--+--+

```

L: Loose Bit. Indicates the type of next "Topological PDE-ID" in the path description. If set, the next Topological PDE is Loose. If this flag is unset, the next Topological PDE is Strict Type.

D: Destination Bit. By default this bit MUST be unset. This bit MUST be set only for PPR-PDE Type is 1 i.e., Topological and this PDE represents the node PPR-Prefix [Section 3.1](#) belongs to, if there is no further PDE specific Sub-TLVs to override PPR-Prefix and PPR-ID values.

E: Egress Bit. By default this bit MUST be unset. This bit MUST be set only for PPR-PDE Type is 2 i.e., Non-Topological and the service needs to be applied on the egress side of the topological PDE preceding this PDE.

Reserved: Reserved bits for future use. Reserved bits MUST be reset on transmission and ignored on receive.

- o PPR-PDE Sub-TLVs: These have 1 octet type, 1 octet length and value field is defined per the type field. Types are as defined

in [Section 7](#) and the length field represents the length of the value field in bytes.

PPR-PDE Sub-TLV: Type 4 (IANA TBD), Length Total length of value field in bytes, Value: IS-IS System-ID of length "ID Length" as defined in [[ISO.10589.1992](#)]. This Sub-TLV MUST NOT be present, if the PPR-PDE Type is not equal to 1 i.e, Topological PDE.

3.4. PPR-Attributes Sub-TLV

PPR-Attribute Sub-TLVs describe the attributes of the path. The following Sub-TLVs draw from a new registry for Sub-TLV numbers; this registry is to be created by IANA, and administered using the first come first serve process:

- o Type 1 (Suggested Value - IANA TBD): PPR-Prefix originating node's IPv4 Router ID Sub-TLV. Length and Value field are as specified in [[RFC7794](#)].
- o Type 2 (Suggested Value - IANA TBD): PPR-Prefix originating node's IPv6 Router ID Sub-TLV. Length and Value field are as specified in [[RFC7794](#)].
- o Type 3 (Suggested Value - IANA TBD): PPR-Metric Sub-TLV. Length 4 bytes, and Value is metric of this path represented through the PPR-ID. Different nodes can advertise the same PPR-ID for the same Prefix with a different set of PPR-PDE Sub-TLVs and the receiving node MUST consider the lowest metric value.

4. PPR Processing Procedure Example

As specified in [Section 2](#), a PPR can be a TE path, locally provisioned by the operator or by a controller. Consider the following IS-IS network to describe the operation of PPR TLV as defined in [Section 3](#):

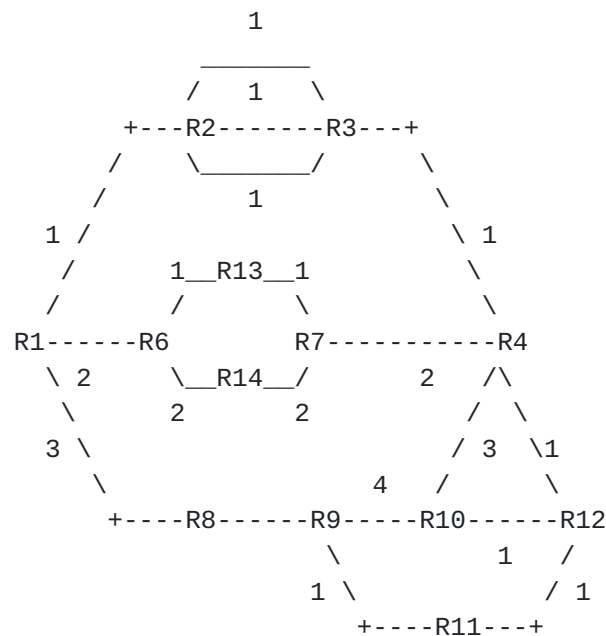


Figure 5: IS-IS Network

In the (Figure 5), consider node R1 as an ingress node, or a head-end node, and the node R4 may be an egress node or another head-end node. The numbers shown on links between nodes indicate the bi-directional IS-IS metric as provisioned. R1 may be configured to receive TE source routed path information from a central entity (PCE [RFC5440], Netconf [RFC6241] or a Controller) that comprises of PPR information which relates to sources that are attached to R1. It is also possible to have a PPR provisioned locally by the operator for non-TE needs (e.g. FRR or for chaining certain services).

The PPR TLV (as specified in [Section 3](#)) is encoded as an ordered list of PPR-PDEs from source to a destination node in the network and is represented with a PPR-ID ([Section 3.2](#)). The PPR TLV includes PPR-PDE Sub-TLVs [Section 3.3](#), which represent both topological and non-topological elements and specifies the actual path towards a PPR-Prefix at R4.

- o The shortest path towards R4 from R1 are through the following sequence of nodes: R1-R2-R3-R4 based on the provisioned metrics.
- o The central entity can define a few PPRs from R1 to R4 that deviate from the shortest path based on other network characteristic requirements as requested by an application or service. For example, the network characteristics or performance requirements may include bandwidth, jitter, latency, throughput, error rate, etc.

- o A first PPR may be identified by PPR-ID = 1 (value) and may include the path of R1-R6-R7-R4 for a Prefix advertised by R4. This is an example for a Loose-PPR and 'L' bit MUST be set appropriately at [Section 3.3](#).
- o A second PPR may be identified by PPR-ID = 2 (value) and may include the path of R1-R8-R9-R10-R4. This is an example for a Strict-PPR and 'L' bit MUST be unset appropriately at [Section 3.3](#). Though this example shows PPR with all nodal SIDs, it is possible to have a PPR with combination of node and adjacency SIDs (local or global) or with PPR-PDE Type set to Non-Topological as defined in [Section 3.3](#) elements along with these.

[4.1](#). PPR TLV Processing

The first topological sub-object or PDE ([Section 3.3](#)) relative to the beginning of PPR Path contains the information about the first node (e.g. in SR-MPLS it's the topmost label). The last topological sub-object or PDE contains information about the last node (e.g. in SR-MPLS it's the bottommost label).

Each receiving node, determines whether an advertised PPR includes information regarding the receiving node. Before processing any further, validation MUST be done to see if any PPR topological PDE is seen more than once (possible loop), if yes, this PPR TLV MUST be ignored. Processing of PPR TLVs may be done, during the end of the SPF computation (for MTID that is advertised in this TLV) and for each prefix described through PPR TLV. For example, node R9 receives the PPR information, and ignores the PPR-ID=1 ([Section 4](#)) because this PPR TLV does not include node R9 in the path description/ordered PPR-PDE list.

However, node R9 may determine that the second PPR identified by PPR-ID = 2 does include the node R9 in its PDE list. Therefore, node R9 updates the local forwarding database to include an entry for the destination address that R4 indicates, so that when a data packet comprising a PPR-ID of 2 is received, forward the data packet to node R10 instead of R11. This is done, even though from R9 the shortest path to reach R4 via R11 (Cost 3: R9-R11-R12-R4) it chooses the NH to R10 to reach R4 as specified in the PPR path description. Same process happens to all nodes or all topological PDEs as described in the PPR TLV.

In summary, the receiving node checks first, if this node is on the path by checking the node's topological elements (with PPR-PDE Type set to Topological) in the path list. If yes, it adds/adjusts the PPR-ID's shortest path NH towards the next topological PDE in the PPR's Path.

For PPR-ID ([Section 3.2](#)) Type 2, 3 or 4, if the PPR-ID Len is set to 0, then Prefix would also become the PPR-ID (a special case). This can be used for some situations, where certain optimizations are required in the network. For this, path described in the PPR TLV SHOULD be completely disjoint from the shortest path route to the prefix. If the disjoint-ness property is not maintained then the traffic may not be using the PPR path, as and when it encounters any node which is not in the path description.

4.2. Path Fragments

A complete PPR path may not fit into maximum allowable size of the IS-IS TLV. To overcome this a 7 bit Fragment-ID field is defined in [Section 3](#). With this, a single PPR path is represented via one or more fragmented PPR path TLVs, with all having the same PPR-ID. Each fragment carries the PPR-ID as well as a numeric Fragment-ID from 0 to (N-1), when N fragments are needed to describe the PPR Graph (where N>1). In this case Fragment (N-1) MUST set the L bit (PPR-Flags) to indicate it is the last fragment. If Fragment-ID is non zero in the TLV, then it MUST not carry PPR-Prefix Sub-TLV. The optional PPR Attribute Sub-TLVs which describe the path overall MUST be included in the last fragment only (i.e., when the L bit is set).

5. PPR Data Plane aspects

Data plane for PPR-ID is selected by the entity (e.g., a controller, locally provisioned by operator), which selects a particular PPR in the network. [Section 3.2](#) defines various data plane identifier types and a corresponding data plane identifier is selected by the entity which selects the PPR.

5.1. SR-MPLS with PPR

If PPR-ID Type is 1, then the PPR belongs to SR-MPLS data plane and the complete PPR stack is represented with a unique SR SID/Label and this gets programmed on the data plane of each node, with the appropriate NH computed as specified in [Section 4](#). PPR-ID here is a label/index from the SRGB (like another node SID or global ADJ-SID). PPR path description here is a set of ordered SIDs represented with PPR-PDE ([Section 3.2](#)) Sub-TLVs. Non-Topological segments also programmed in the forwarding to enable specific function/service, when the data packet hits with corresponding PPR-ID.

Based on 'L' flag in PPR-ID Flags ([Section 3.2](#)), for SR-MPLS data plane either 1 label or 2 labels need to be provisioned on individual nodes on the path description. For the example network in [Section 4](#), for PPR-ID=1, which is a loose path, node R6 programs the bottom label as PPR-ID and the top label as the next topological PPR-PDE in

the path, which is a node SID of R7. The NH computed at R6 would be the shortest path towards R7 i.e., the interface towards R13. If 'L' flag is unset only PPR-ID is programmed on the data plane with NH set to the shortest path towards next topological PPR-PDE.

5.2. PPR Native IP Data Planes

If PPR-ID Type is 2 then source routing and packet steering can be done in IPv4 data plane (PPR-IPv4), along the path as described in PPR Path description. This is achieved by setting the destination IP address as PPR-ID, which is an IPv4 address in the data packet (tunneled/encapsulated). There is no data plane change or upgrade needed to support this.

Similarly for PPR-ID Type is 3, then source routing and packet steering can be done in IPv6 data plane (PPR-IPv6), along the path as described in PPR Path description. Whatever specified above for IPv4 applies here too, except that destination IP address of the data packet is an IPv6 Address (PPR-ID). This doesn't require any IPv6 extension headers (EH), if there is no metadata/TLVs need to be carried in the data packet.

Based on 'L' flag in PPR-ID Flags ([Section 3.2](#)), for PPR-ID Type 2 or 3 (Native IPv4 or IPv6 data planes respectively) the packet has to be encapsulated using the capabilities (either dynamically signaled through [[I-D.ietf-isis-encapsulation-cap](#)] or statically provisioned on the nodes) of the next loose PDE in the path description.

For the example network in [Section 4](#), for PPR-ID=1, which is a loose path, node R6 programs to encapsulate the data packet towards the next loose topological PPR-PDE in the path, which is R7. The NH computed at R6 would be the shortest path towards R7 i.e., the interface towards R13. If 'L' flag is unset only PPR-ID is programmed on the data plane with NH set to the shortest path towards next topological PPR-PDE, with no further encapsulation of the data packet.

5.3. SRv6 with PPR

If PPR-ID Type is 4, the PPR belongs to SRv6 with SRH data plane and the complete PPR stack is represented with IPV6 SIDs and this gets programmed on the data plane with the appropriate NH computed as specified in [Section 4](#). PPR-ID here is a SRv6 SID. PPR path description here is a set of ordered SID TLVs similar to as specified in [Section 5.1](#). One way PPR-ID would be used in this case is by setting it as the destination IPv6 address and SL field in SRH would be set to 0; however SRH [[I-D.ietf-6man-segment-routing-header](#)] can contain any other TLVs and non-topological SIDs as needed.

6. Acknowledgements

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Earlier versions of [draft-ietf-isis-segment-routing-extensions](#) have a mechanism to advertise EROs through Binding SID.

7. IANA Considerations

This document requests the following new TLV in IANA IS-IS TLV code-point registry.

TLV #	Name
-----	-----
155	PPR TLV (Suggested Value, IANA TBD)

7.1. PPR Sub-TLVs

This document requests IANA to create a new Sub-TLV registry for PPR TLV [Section 3](#) with the following initial entries (suggested values):

Sub-TLV #	Sub-TLV Name
-----	-----
1	PPR-Prefix (Section 3.1)
2	PPR-ID (Section 3.2)
3	PPR-PDE (Section 3.3)
4	IS-IS System-ID (Section 3.3)

7.2. IGP Parameters

This document requests additional IANA registries in an IANA managed registry "Interior Gateway Protocol (IGP) Parameters" for various PPR TLV parameters. The registration procedure is based on the "Expert Review" as defined in [[RFC8126](#)]. The suggested registry names are:

- o "PPR-Type" - Types are an unsigned 8 bit numbers. Values are as defined in [Section 3](#) of this document.

- o "PPR-Flags" - 1 Octet. Bits as described in [Section 3](#) of this document.
- o "PPR-ID Type" - Types are an unsigned 8 bit numbers. Values are as defined in [Section 3.2](#) of this document.
- o "PPR-ID Flags" - 1 Octet. Bits as described in [Section 3.2](#) of this document.
- o "PPR-PDE Type" - Types are an unsigned 8 bit numbers. Values are as defined in [Section 3.3](#) of this document.
- o "PPR-PDE Flags" - 1 Octet. Bits as described in [Section 3.3](#) of this document.
- o "PDE-ID Type" - Types are an unsigned 8 bit numbers. Values are as defined in [Section 3.3](#) of this document.

This document also requests IANA to create a new Sub-TLV registry in "Interior Gateway Protocol (IGP) Parameters" for PPR Path attributes with the following initial entries (suggested values):

Sub-TLV #	Sub-TLV Name
-----	-----
1	PPR-Prefix Source IPv4 Router ID (Section 3.4)
2	PPR-Prefix Source IPv6 Router ID (Section 3.4)
3	PPR-Metric (Section 3.4)

[8.](#) Security Considerations

Security concerns for IS-IS are addressed in [[RFC5304](#)] and [[RFC5310](#)]. Further security analysis for IS-IS protocol is done in [[RFC7645](#)] with detailed analysis of various security threats and why [[RFC5304](#)] should not be used in the deployments. Advertisement of the additional information defined in this document introduces no new security concerns in IS-IS protocol. However, for extensions related to SR-MPLS and SRH data planes, those particular data plane security considerations does apply here.

[9.](#) References

9.1. Normative References

- [ISO.10589.1992]
International Organization for Standardization,
"Intermediate system to intermediate system intra-domain-
routing routine information exchange protocol for use in
conjunction with the protocol for providing the
connectionless-mode Network Service (ISO 8473)",
ISO Standard 10589, 1992.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
Requirement Levels", [BCP 14](#), [RFC 2119](#),
DOI 10.17487/RFC2119, March 1997,
<<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in [RFC 2119](#) Key Words", [BCP 14](#), [RFC 8174](#), DOI 10.17487/RFC8174,
May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.

9.2. Informative References

- [I-D.bashandy-isis-srv6-extensions]
Psenak, P., Filsfils, C., Bashandy, A., Decraene, B., and
Z. Hu, "IS-IS Extensions to Support Routing over IPv6
Dataplane", [draft-bashandy-isis-srv6-extensions-05](#) (work
in progress), March 2019.
- [I-D.ietf-6man-segment-routing-header]
Filsfils, C., Previdi, S., Leddy, J., Matsushima, S., and
d. daniel.voyer@bell.ca, "IPv6 Segment Routing Header
(SRH)", [draft-ietf-6man-segment-routing-header-18](#) (work in
progress), April 2019.
- [I-D.ietf-isis-encapsulation-cap]
Xu, X., Decraene, B., Raszuk, R., Chunduri, U., Contreras,
L., and L. Jalil, "Advertising Tunnelling Capability in
IS-IS", [draft-ietf-isis-encapsulation-cap-01](#) (work in
progress), April 2017.
- [I-D.ietf-isis-mpls-elc]
Xu, X., Kini, S., Psenak, P., Filsfils, C., and S.
Litkowski, "Signaling Entropy Label Capability and Entropy
Readable Label Depth Using IS-IS", [draft-ietf-isis-mpls-
elc-07](#) (work in progress), May 2019.

[I-D.ietf-isis-segment-routing-extensions]

Previdi, S., Ginsberg, L., Filsfils, C., Bashandy, A., Gredler, H., and B. Decraene, "IS-IS Extensions for Segment Routing", [draft-ietf-isis-segment-routing-extensions-24](#) (work in progress), April 2019.

[I-D.ietf-mppls-sfc]

Farrel, A., Bryant, S., and J. Drake, "An MPLS-Based Forwarding Plane for Service Function Chaining", [draft-ietf-mppls-sfc-07](#) (work in progress), March 2019.

[I-D.xuclad-spring-sr-service-chaining]

Clad, F., Xu, X., Filsfils, C., daniel.bernier@bell.ca, d., Li, C., Decraene, B., Ma, S., Yadlapalli, C., Henderickx, W., and S. Salsano, "Segment Routing for Service Chaining", [draft-xuclad-spring-sr-service-chaining-01](#) (work in progress), March 2018.

[RFC5120] Przygienda, T., Shen, N., and N. Sheth, "M-ISIS: Multi Topology (MT) Routing in Intermediate System to Intermediate Systems (IS-ISs)", [RFC 5120](#), DOI 10.17487/RFC5120, February 2008, <<https://www.rfc-editor.org/info/rfc5120>>.

[RFC5304] Li, T. and R. Atkinson, "IS-IS Cryptographic Authentication", [RFC 5304](#), DOI 10.17487/RFC5304, October 2008, <<https://www.rfc-editor.org/info/rfc5304>>.

[RFC5305] Li, T. and H. Smit, "IS-IS Extensions for Traffic Engineering", [RFC 5305](#), DOI 10.17487/RFC5305, October 2008, <<https://www.rfc-editor.org/info/rfc5305>>.

[RFC5308] Hopps, C., "Routing IPv6 with IS-IS", [RFC 5308](#), DOI 10.17487/RFC5308, October 2008, <<https://www.rfc-editor.org/info/rfc5308>>.

[RFC5310] Bhatia, M., Manral, V., Li, T., Atkinson, R., White, R., and M. Fanto, "IS-IS Generic Cryptographic Authentication", [RFC 5310](#), DOI 10.17487/RFC5310, February 2009, <<https://www.rfc-editor.org/info/rfc5310>>.

[RFC5440] Vasseur, JP., Ed. and JL. Le Roux, Ed., "Path Computation Element (PCE) Communication Protocol (PCEP)", [RFC 5440](#), DOI 10.17487/RFC5440, March 2009, <<https://www.rfc-editor.org/info/rfc5440>>.

- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", [RFC 6241](#), DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6790] Kompella, K., Drake, J., Amante, S., Henderickx, W., and L. Yong, "The Use of Entropy Labels in MPLS Forwarding", [RFC 6790](#), DOI 10.17487/RFC6790, November 2012, <<https://www.rfc-editor.org/info/rfc6790>>.
- [RFC7645] Chunduri, U., Tian, A., and W. Lu, "The Keying and Authentication for Routing Protocol (KARP) IS-IS Security Analysis", [RFC 7645](#), DOI 10.17487/RFC7645, September 2015, <<https://www.rfc-editor.org/info/rfc7645>>.
- [RFC7794] Ginsberg, L., Ed., Decraene, B., Previdi, S., Xu, X., and U. Chunduri, "IS-IS Prefix Attributes for Extended IPv4 and IPv6 Reachability", [RFC 7794](#), DOI 10.17487/RFC7794, March 2016, <<https://www.rfc-editor.org/info/rfc7794>>.
- [RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", [BCP 26](#), [RFC 8126](#), DOI 10.17487/RFC8126, June 2017, <<https://www.rfc-editor.org/info/rfc8126>>.
- [RFC8402] Filsfils, C., Ed., Previdi, S., Ed., Ginsberg, L., Decraene, B., Litkowski, S., and R. Shakir, "Segment Routing Architecture", [RFC 8402](#), DOI 10.17487/RFC8402, July 2018, <<https://www.rfc-editor.org/info/rfc8402>>.
- [RFC8491] Tantsura, J., Chunduri, U., Aldrin, S., and L. Ginsberg, "Signaling Maximum SID Depth (MSD) Using IS-IS", [RFC 8491](#), DOI 10.17487/RFC8491, November 2018, <<https://www.rfc-editor.org/info/rfc8491>>.

[Appendix A](#). Appendix

[A.1](#). Challenges with Increased SID Depth

SR label stacks carried in the packet header create challenges in the design and deployment of networks and networking equipment. Following examples illustrates the need for increased SID depth in various use cases:

(a). Consider the following network where SR-MPLS data plane is in use and with same SRGB (5000-6000) on all nodes i.e., A1 to A11 and B1 to B7 for illustration:

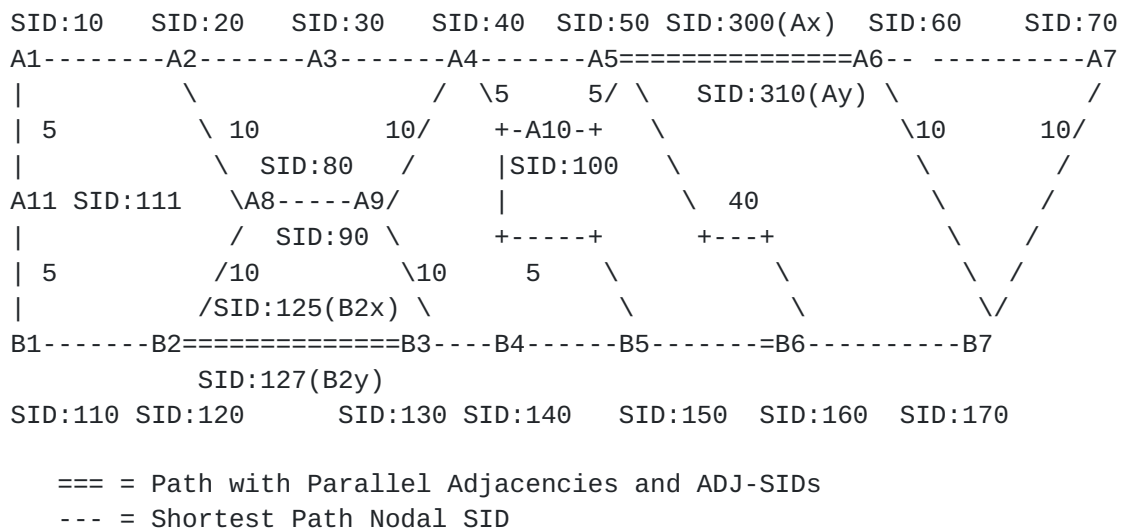


Figure 6: SR-MPLS Network

Global ADJ-SIDs are provisioned between A5-A6 and B2-B3 (with parallel adjecencies). All other SIDs shown are nodal SID indices.

All metrics of the links are set to 1, unless marked otherwise.

Shortest Path from A1 to A7: A2-A3-A4-A5-A6-A7

Path-x: From A1 to A7 - A2-A8-B2-B2x-A9-A10-Ax-A7; Pushed Label Stack @A1: 5020:5080:5120:5125:5090:5100:5300:5070 (where B2x is a local ADJ-SID and Ax is a global ADJ-SID).

In this example, the traffic engineered path is represented with a combination of Adjacency and Node SIDs with a stack of 8 labels. However, this value can be larger, if the use of entropy label [RFC6790] is desired and based on the Readable Label Depth (Appendix A.2) capabilities of each node and additional labels required to insert ELI/EL at appropriate places.

Though above network is shown with SR-MPLS data plane, if the network were to use SRv6 data plane, path size would be increased even more because of the size of the IPv6 SID (16 bytes) in SRH.

(b). Apart from the TE case above, when deploying [I-D.ietf-mpls-sfc] or [I-D.xuclad-spring-sr-service-chaining], with the inclusion of services, or non-topological segments on the label stack, can also make the size of the stack much larger.

Overall the additional path overhead in various SR deployments may cause the following issues:

- a. HW Capabilities: Not all nodes in the path can support the ability to push or read label stack (with additional non-topological and special labels) needed to satisfy user/operator requirements. Alternate paths, which meet these user/operator requirements may not be available.
- b. Line Rate: Potential performance issues in deployments, which use data plane with extension header as both size of the SIDs in the extension header and the fixed extension header size itself needs to be factored by the hardware.
- c. MTU: Larger SID stacks on the data packet can cause potential MTU/fragmentation issues (SRH).
- d. Header Tax: Some deployments, such as 5G, require minimal packet overhead in order to conserve network resources. Carrying 40 or 50 octets of data in a packet with hundreds of octet of header would be an unacceptable use of available bandwidth.

With the solution proposed in this document ([Section 2](#)), for Path-x in Figure 6 above, SID stack would be reduced from 8 SIDs to a single SID without any additional overhead.

A.2. Mitigation with MSD

The number of SIDs in the stack a node can impose is referred as Maximum SID Depth (MSD) capability [[RFC8491](#)], which must be taken into consideration when computing a path to transport a data packet in a network implementing segment routing. [[I-D.ietf-isis-mpls-elc](#)] defines another MSD type, Readable Label Depth (RLD) that is used by a head-end to insert Entropy Label pair (ELI/EL) at appropriate depth, so it could be read by transit nodes. There are situations where the source routed path can be excessive as path represented by SR SIDs need to describe all the nodes and ELI/EL based on the readability of the nodes in that path. Registries set forth in [[RFC8491](#)] applicable for MPLS data plane and for IPv6 data plane with SRH.

MSDs (and RLD type) capabilities advertisement help mitigate the problem for a central entity to create the right source routed path per application/operator requirements. However the availability of actual paths meeting these requirements are still limited by the underlying hardware and their MSD capabilities in the data path.

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