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Preferred Path Route Graph Structure
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Abstract

This document defines a graph structure for the Preferred Path Route (PPR) for IS-IS, OSPFv2 and OSPFv3 protocols. This structure helps further scale of the PPR and reduce domain level global entries needed in some data planes.

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

Preferred Path Routing (PPR) is a routing protocol mechanism concerned with the creation of a routing path as specified in the PPR-Path objects. These can be signaled via appropriate IGPs (IS-IS, OSPFv2, OSPFv3) and indicate the path for a data plane identifier (PPR-ID). With this, all PPR capable nodes along that path establish forwarding state for the PPR-ID and any packet destined to the PPR-ID would use that path instead of the IGP computed shortest path to the destination.

PPR-Paths and relevant IGP extensions are defined in [I-D.chunduri-lsr-isis-preferred-path-routing] and [I-D.chunduri-lsr-ospf-preferred-path-routing]. In these IGP

extensions, PPR-Paths are described as a path structure, which is an ordered linear list of Path Description Elements (PDEs) starting with a sender PDE followed by zero or more transit PDE and finishing with the destination PED. PDEs can indicate the node, a link to the node and services on a node.

A separate PPR-ID is required for every possible PPR-Path, even if one is just a subset of another path with the same destination. To provide PPR-Paths from N possible source nodes to one destination node, N PPR-IDs are therefore necessary. To create full-mesh connectivity via PPR-Paths between N nodes, N^2 PPR-Paths and N^2 PPR-IDs would be needed. Even if PPR-Paths would only be used for a subset of connections, such as for high-value traffic in larger networks, this scale behavior is less than ideal.

To allow scalability, in-terms of number of PPR-IDs needed on the destination nodes, number of forwarding entries needed on the nodes in the paths (for overlapping paths), and to minimize the amount of PPR information needed in the control plane, this document introduces a PPR-Tree structure in Section 2.

The terminology in this document uses the more generic term of PPR Graphs instead of PPR Trees because it is extensible.

1.1. Acronyms

MPLS	- Multi Protocol Label Switching
MSD	- Maximum SID Depth
PDE	- Path Description Element
PPG	- Preferred Path Graph
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. PPR Graph TLVs

2.1. IS-IS TLVs

This section describes the encoding of IS-IS PPR Tree TLV. This TLV can be seen as having 4 logical section viz., encoding of the PPR-Prefix (IS-IS Prefix), encoding of PPG-ID, encoding of path description with an ordered PDE (Path Description Element) Sub-TLVs, belonging to one or more Branch-IDs and a set of optional PPR attribute Sub-TLVs, which can be used to describe PPR Graph common parameters. Multiple instances of this TLV MAY be advertised in IS-IS LSPs with different PPG-ID Type and with corresponding Branch-ID/PDE Sub-TLVs. The PPR Graph TLV has Type TBD (suggested value xxx), and has the following format:

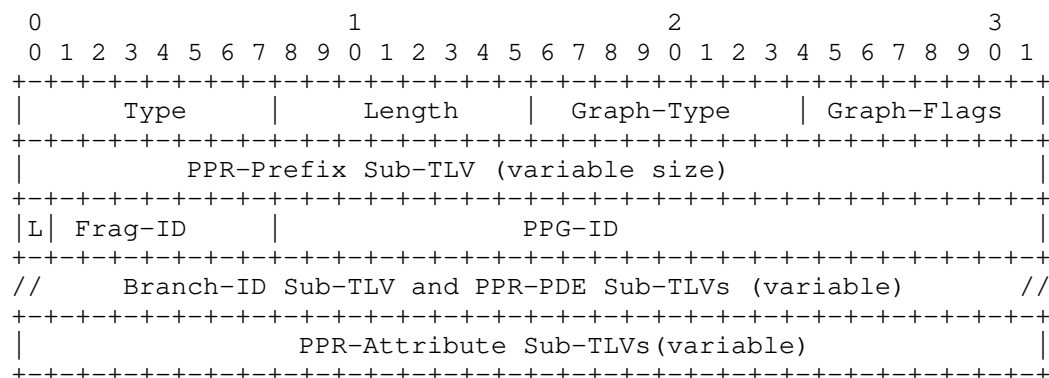


Figure 1: PPR Tree TLV Format

- o Type - TBD (IANA) from IS-IS top level TLV registry.
- o Length - Total length of the value field in bytes (variable).
- o Graph-Type - 1 Octet value (0-255, IANA Registry TBD). Value 0 defines a PPR Tree structure (this document). PPR-Paths can also be encoded as PPR-Trees with a single branch.
- o Graph-Flags - 1 Octet flags for this TLV are described below.
- o Frag-ID - 1 Octet TLV Fragment-ID, with 7-bit Identifier value (0-127). L bit MUST be set if a graph has only one fragment or if it is the last Fragment of the graph. PPG-ID value for all fragments MUST be the same.

- o PPG-ID - 3 byte Preferred Path Graph Identifier. Originator of the graph MUST ensure uniqueness across the domain.
- o Branch-ID Sub-TLV is defined in Section 2.1.1. This represents the branch-id of the structure followed by PDE Sub-TLVs in that branch. Different branches of the graph can be in different fragments of this TLV. However, a complete set of PDE Sub-TLVs MUST be specified in one TLV fragment.
- o PPR-PDE Sub-TLV defined in [I-D.chunduri-lsr-isis-preferred-path-routing]. Additional information in the PPR-PDE Sub-TLV is described in Section 2.1.2.
- o PPR-Attribute Sub-TLVs defined in [I-D.chunduri-lsr-isis-preferred-path-routing] are applicable here.

PPR-Flags field of PPR TLV has the following flag bits defined. These flags, at this point mostly related to applicability of this TLV in an L1 area or entire IS-IS domain or from where the PPR-Prefix is being originated:

PPR Graph-Flags Format

```

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

```

1. S - If set, the PPR Graph TLV MUST be flooded across the entire routing domain. If the S flag is not set, the PPR Graph TLV MUST NOT be leaked between IS-IS levels. This bit MUST NOT be altered during the TLV leaking
2. D - when the PPR Graph 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. Reserved - reserved bits for future use. Reserved bits MUST be reset on transmission and ignored on receive.

2.1.1. Branch-ID Sub-TLV

Branch-ID Sub-TLVs represent the branch of the graph described. This is a new Sub-TLV type (IANA TBD) in PPR TLV [I-D.chunduri-lsr-isis-preferred-path-routing]. Type TBD (Suggested

Value - IANA TBD), with a length of 1 byte, and Value is the branch identification number in the range of 0 to 255.

2.1.2. PPR PDE Sub-TLV

PPR PDE Sub-TLV is defined in [I-D.chunduri-lsr-isis-preferred-path-routing]. This document extends the same with the following:

1. PPR-PDE Flags (Bit position 2), S: Source Bit. Indicates the PPR head-end and MUST be set if this PDE corresponds to the same.
2. PPR-ID Sub-Sub-TLV: Type, length and value fields would be same as PPR-ID Sub-TLV defined in [I-D.chunduri-lsr-isis-preferred-path-routing]. This Sub-Sub-TLV MUST be present only when 'D' flag is set in the PPR-PDE Flags field.

PPR-PDE Flags field is defined in PPR-PDE Sub-TLV [I-D.chunduri-lsr-isis-preferred-path-routing].

2.2. OSPF TLVs

2.2.1. OSPFv2 TLVs

TBD.

2.2.2. OSPFv3 TLVs

TBD.

3. Encoding and Processing details

[I-D.chunduri-lsr-isis-preferred-path-routing] describes how a PPR path can be established. This document builds on the same base concept but expands the same with a graph structure as defined in Section 2. The key new encoding element here over prior PPR Paths is the existence of multiple Branches in the PPR Graph description.

Each Branch-ID sub-TLV is followed by ordered sequence of PDEs. A PPR Graph can be constructed from one or more PPR Branches. Branches are stitched together by using the same PDE in two branches. To simplify parsing of branches, only the last PDE of a branch can be stitched to another branch. In result, any PDE can only be a non-last PDE in one Branch but last PDE in more than one branch. A PPG-ID field is defined in this document. This MUST be unique in the domain and represents the graph structure as whole.

A complete Graph may not fit into maximum allowable size of the IS-IS TLV. To overcome this a 7 bit Frag-ID field is defined (Section 2). With this, a single PPR Graph is represented via one or more fragmented PPR Graph TLVs all having the same PPG-ID. Each Fragment carries the PPG-ID as well as a numeric Frag-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 to indicate it is the last fragment. The optional PPR Attribute Sub-TLVs which describe the Graph overall MUST be included in the last fragment only.

3.1. S And D bits in PDEs

In PPR Paths as defined in [I-D.chunduri-lsr-isis-preferred-path-routing], currently only a simple linear path structure for a destination node is possible. However, with a bit on path element source and a bit for destination (refer section) - same path ID/PPR-ID can be used to represent multiple paths if some of the nodes are also sources and terminating on the same destination node.

1. A Linear Path structure:

```
PDE1 --> PDE2 --> PDE3 --> PDE4 --> PDE5
[First PDE always Source and last PDE is always Destination]
```

2. A PPR Graph with S and D bits:

```
PDE1(with-S-bit-set)-->PDE2-->PDE3(with-S-bit-set)..
...-->PDE4(with-D-bit-set)-->PDE5(with-D-bit-Set)
```

```
==> PDE1 --> PDE2 --> PDE3 --> PDE4
==> PDE1 --> PDE2 --> PDE3 --> PDE4 --> PDE5
==> PDE3 --> PDE4
==> PDE3 --> PDE4 --> PDE5
```

Figure 2: PPR Graph with S and D bits

In the above Figure 2 example, in (1) a linear path list of 5 nodes are described where PDE1 is the source/ingress-point and PDE5 is the destination/egress point of the path. In (2), the path can be defined in this document, where some PDEs can have S(ource) and/or D(estination) bit or both can be set. Here, PDE1 and PDE3 have the Source bit set, PDE4 and PDE5 the Destination bit set. This Branch structure is equivalent to the set of 4 PPR-PDE lists as shown: PDE1->PDE5, PDE1->PDE45, PDE3->PDE4, PDE3->PDE5. This reduces the amount of information that needs to be sent across the IGP and that needs to be processed by each node.

If the bits and branch structure were not used, the 4 PPR PDE lists would have required each a unique PPR-ID (and the resulting forwarding entries created), but the Branch requires only 2 PPR-IDs: one for both paths terminating in PDE4, and one for both paths terminating in PDE5.

3.2. Graph processing procedure example

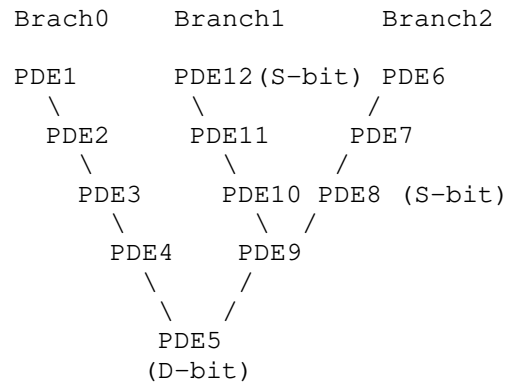


Figure 3: PPR Graph (Tree) Example

With a PPR Tree structure both flooding optimization and reduction in the number of SIDs needed at the destination can be achieved. To do this encoding as specified in Section 2 (a) Every PDE-ID can be non-last-PDE in at most one Branch. It can be last-PDE in one or more Branches (ex: PDE9). (b) Branches form a tree by joining nodes with same PDE-ID (PDE9 and PDE5 in the above example). Leafs of the tree must be S(ources), e.g.: PDE1, PDE12, PDE6. Root of the tree must be the only D(estination) of the tree (e.g.: PDE5).

How to build forwarding entry (referring to the Figure 3 above):

1. If PPR-ID in PDE of PPR Graph is indicating this node (example: PDE5): This node is D(estination) of this tree. Forwarding state is built for this PPR-Tree like for PPR-Path, no changes.
2. If PPR-ID is NOT indicating this node, then this node MAY be source (PDE12, PDE8) or midpoint (PDE9, neither source nor destination):
 - a. Node sequentially examines all branches until it finds a PDE with its own PDE-ID. It then establishes a forwarding entry for the PPR-ID indicated in the PPR header with the next-hop being the next PDE in the current branch.

- b. This nodes PDE may be the last PDE in a Branch, for example PDE9 in Branch1. In this case, the node ignores this branch because it cannot build a complete forwarding entry from it. Instead, it will build the forwarding entry from another branch, e.g.: Node with PDE9 will build forwarding entry for destination PDE5 when it examines Branch2 because there it will have a next hop PDE5. After forwarding entry is built, node can stop examining rest of Branch or further Branches.
- c. If node does not find its own PDE in any branch it is not on the graph and ignores this PPR-Graph.

4. Acknowledgements

Thanks to Yingzhen Qu and Richard Li for multiple discussions on this topic.

5. IANA Considerations

5.1. IS-IS IANA

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

TLV #	Name
-----	-----
TBD	PPR Graph TLV

This document requests IANA to create a new Sub-TLV registry for PPR TLV Section 2 with the following initial entries (suggested values):

Sub-TLV #	Sub-TLV Name
-----	-----
TBD	Branch-ID (Section 2)

5.2. OSPFv2 IANA

5.3. OSPFv3 IANA

5.4. IGP Parameter IANA

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 "Graph-Type" - Types are an unsigned 8 bit numbers. Values are as defined in Section 2 of this document.
- o "Graph-Flags" - 1 Octet. Bits as described in Section 2 of this document.

6. 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.

OSPF security extensions are described in [RFC2328] and [RFC7684] and these apply to the extensions specified 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 [RFC7474] SHOULD be used.

Advertisement of the additional information defined in this document introduces no new security concerns in IS-IS or OSPF protocols.

7. References

7.1. Normative References

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