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**Segment Routing Centralized Egress Peer Engineering
draft-filsfils-spring-segment-routing-central-epe-02**

Abstract

Segment Routing (SR) leverages source routing. A node steers a packet through a controlled set of instructions, called segments, by prepending the packet with an SR header. A segment can represent any instruction topological or service-based. SR allows to enforce a flow through any topological path and service chain while maintaining per-flow state only at the ingress node of the SR domain.

The Segment Routing architecture can be directly applied to the MPLS dataplane with no change on the forwarding plane. It requires minor extension to the existing link-state routing protocols.

This document illustrates the application of Segment Routing to solve the Egress Peer Engineering (EPE) requirement. The SR-based EPE solution allows a centralized (SDN) controller to program any egress peer policy at ingress border routers or at hosts within the domain. This document is on the informational track.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

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[1.](#) Introduction

The document is structured as follows:

- o [Section 1](#) reminds the EPE problem statement and provides the key references.
- o [Section 2](#) defines the different BGP Peering Segments and the semantic associated to them.
- o [Section 3](#) describes the automated allocation of BGP Peering SID's by the EPE-enabled egress border router and the automated signaling of the external peering topology and the related BGP Peering SID's to the collector [[\[I-D.previdi-idr-bgppls-segment-routing-epe\]](#)].
- o [Section 4](#) overviews the components of a centralized EPE controller. The definition of the EPE controller is outside the scope of this document.
- o [Section 5](#) overviews the methods that could be used by the centralized EPE controller to implement an EPE policy at an ingress border router or at a source host within the domain. The exhaustive definition of all the means to program an EPE input policy is outside the scope of this document.

For editorial reason, the solution is described for IPv4. A later section describes how the same solution is applicable to IPv6.

1.1. Segment Routing Documents

The main references for this document are:

- o SR Problem Statement: [[I-D.ietf-spring-problem-statement](#)].
- o SR Architecture: [[I-D.filsfils-spring-segment-routing](#)].
- o Distribution of External Topology and TE Information using BGP: [[I-D.previdi-idr-bgppls-segment-routing-epe](#)].

The SR instantiation in the MPLS dataplane is described in [[I-D.filsfils-spring-segment-routing-mpls](#)].

The SR IGP protocol extensions are defined in [[I-D.ietf-isis-segment-routing-extensions](#)], [[I-D.ietf-ospf-segment-routing-extensions](#)] and [[I-D.psenak-ospf-segment-routing-ospfv3-extension](#)].

The Segment Routing PCE protocol extensions are defined in [[I-D.sivabalan-pce-segment-routing](#)].

1.2. Problem Statement

The EPE problem statement is defined in [[I-D.ietf-spring-problem-statement](#)].

A centralized controller should be able to instruct an ingress PE or a content source within the domain to use a specific egress PE and a specific external interface to reach a particular destination.

We call this solution "EPE" for "Egress Peer Engineering". The centralized controller is called the "EPE Controller". The egress border router where the EPE traffic-steering functionality is implemented is called an EPE-enabled border router. The input policy programmed at an ingress border router or at a source host is called an EPE policy.

The requirements that have motivated the solution described in this document are listed here below:

- o The solution MUST apply to the Internet use-case where the Internet routes are assumed to use IPv4 unlabeled or IPv6 unlabeled. It is not required to place the internet routes in a VRF and allocate labels on a per route, or on a per-path basis.

- o The solution MUST NOT make any assumption on the currently deployed iBGP schemes (RRs, confederations or iBGP full meshes) and MUST be able to support all of them.
- o The solution SHOULD minimize the need for new BGP capabilities at the ingress PE's.
- o The solution MUST accommodate an ingress EPE policy at an ingress PE or directly at a source host within the domain.
- o The solution MUST support automated FRR and fast convergence.

The following reference diagram is used throughout this document.

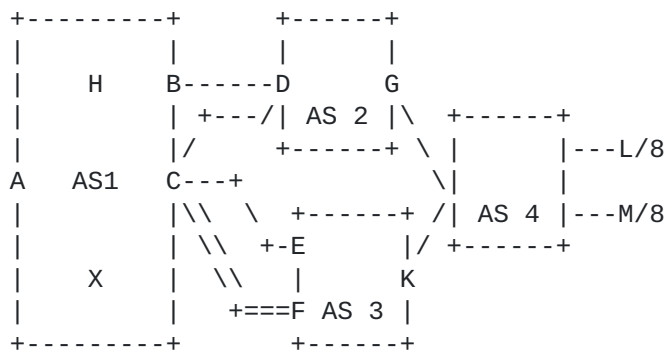


Figure 1: Reference Diagram

IPv4 addressing:

- o C's interface to D: 1.0.1.1/24, D's interface: 1.0.1.2/24
- o C's interface to E: 1.0.2.1/24, E's interface: 1.0.2.2/24
- o C's upper interface to F: 1.0.3.1/24, F's interface: 1.0.3.2/24
- o C's lower interface to F: 1.0.4.1/24, F's interface: 1.0.4.2/24
- o Loopback of F used for eBGP multi-hop peering to C: 1.0.5.2/32
- o C's loopback is 3.3.3.3/32 with SID 64

C's BGP peering:

- o Single-hop eBGP peering with neighbor 1.0.1.2 (D)
- o Single-hop eBGP peering with neighbor 1.0.2.2 (E)

- o Multi-hop eBGP peering with F on ip address 1.0.5.2 (F)

C's resolution of the multi-hop eBGP session to F:

- o Static route 1.0.5.2/32 via 1.0.3.2
- o Static route 1.0.5.2/32 via 1.0.4.2

C is configured with local policy that defines a BGP PeerSet as the set of peers (1.0.2.2 and 1.0.5.2)

X is the EPE controller within AS1 domain.

H is a content source within AS1 domain.

2. BGP Peering Segments

AS defined in [[I-D.filsfils-spring-segment-routing](#)], Segments are defined by a Egress Peer Engineering (EPE) capable node and corresponding to its attached peers. These segments are called BGP peering segments or BGP Peering SIDs. They enable the expression of source-routed inter-domain paths.

An ingress border router of an AS may compose a list of segments to steer a flow along a selected path within the AS, towards a selected egress border router C of the AS and through a specific peer. At minimum, a BGP Peering Engineering policy applied at an ingress PE involves two segments: the Node SID of the chosen egress PE and then the BGP Peering Segment for the chosen egress PE peer or peering interface.

[[I-D.filsfils-spring-segment-routing](#)] defines three types of BGP peering segments/SID's: PeerNodeSID, PeerAdjSID and PeerSetSID.

The BGP extensions to signal these BGP peering segments are outlined in the following section.

3. Distribution of External Topology and TE Information using BGP-LS

In ships-in-the-night mode with respect to the pre-existing iBGP design, a BGPLS session is established between the EPE-enabled border router and the EPE controller.

As a result of its local configuration and according to the behavior described in [[I-D.previdi-idr-bgpls-segment-routing-epe](#)], node C allocates the following BGP Peering Segments ([\[I-D.filsfils-spring-segment-routing\]](#)):

- o A PeerNode segment for each of its defined peer (D, E and F).
- o A PeerAdj segment for each recursing interface to a multi-hop peer (e.g.: the upper and lower interfaces from C to F in figure 1).
- o A PeerSet segment to the set of peers (E and F).

C programs its forwarding table accordingly:

Incoming Label	Operation	Outgoing Interface
1012	POP	link to D
1022	POP	link to E
1032	POP	upper link to F
1042	POP	lower link to F
1052	POP	loadbalance on any link to F
1060	POP	loadbalance on any link to E or to F

C signals the related BGP-LS NLRI's to the EPE controller. Each such BGP-LS route is described in the following sub-sections according to the encoding details defined in [draft-previdi-idr-bgpl-segment-routing-epe-00](#).

3.1. EPE Route advertising the Peer D and its PeerNode SID

Descriptors:

- o Node Descriptors (router-ID, ASN): 3.3.3.3 , AS1
- o Peer Descriptors (peer ASN): AS2
- o Link Descriptors (IPv4 interface address, neighbor IPv4 address): 1.0.1.1, 1.0.1.2

Attributes:

- o Adj-SID: 1012

3.2. EPE Route advertising the Peer E and its PeerNode SID

Descriptors:

- o Node Descriptors (router-ID, ASN): 3.3.3.3 , AS1
- o Peer Descriptors (peer ASN): AS3

- o Link Descriptors (IPv4 interface address, neighbor IPv4 address):
1.0.2.1, 1.0.2.2

Attributes:

- o Adj-SID: 1022
- o PeerSetSID: 1060
- o Link Attributes: see section 3.3.2 of [\[I-D.ietf-idr-ls-distribution\]](#)

3.3. EPE Route advertising the Peer F and its PeerNode SID

Descriptors:

- o Node Descriptors (router-ID, ASN): 3.3.3.3 , AS1
- o Peer Descriptors (peer ASN): AS3
- o Link Descriptors (IPv4 interface address, neighbor IPv4 address):
3.3.3.3, 1.0.5.2

Attributes:

- o Adj-SID: 1052
- o PeerSetSID: 1060

3.4. EPE Route advertising a first PeerAdj to Peer F

Descriptors:

- o Node Descriptors (router-ID, ASN): 3.3.3.3 , AS1
- o Peer Descriptors (peer ASN): AS3
- o Link Descriptors (IPv4 interface address, neighbor IPv4 address):
1.0.3.1 , 1.0.3.2

Attributes:

- o Adj-SID: 1032
- o LinkAttributes: see section 3.3.2 of [\[I-D.ietf-idr-ls-distribution\]](#)

3.5. EPE Route advertising a second PeerAdj to Peer F

Descriptors:

- o Node Descriptors (router-ID, ASN): 3.3.3.3 , AS1
- o Peer Descriptors (peer ASN): AS3
- o Link Descriptors (IPv4 interface address, neighbor IPv4 address):
1.0.4.1 , 1.0.4.2

Attributes:

- o Adj-SID: 1042
- o LinkAttributes: see section 3.3.2 of
[\[I-D.ietf-idr-ls-distribution\]](#)

3.6. FRR

An EPE-enabled border router should allocate a FRR backup entry on a per BGP Peering SID basis:

- o PeerNode SID
 1. If multi-hop, backup via the remaining PeerADJ SID's to the same peer.
 2. Else backup via local PeerNode SID to the same AS.
 3. Else pop the PeerNode SID and IP lookup (with potential BGP PIC fall-back).
- o PeerAdj SID
 1. If to a multi-hop peer, backup via the remaining PeerADJ SID's to the same peer.
 2. Else backup via PeerNode SID to the same AS.
 3. Else pop the PeerNode SID and IP lookup (with potential BGP PIC fall-back).
- o PeerSet SID
 1. Backup via remaining PeerNode SID in the same PeerSet.

2. Else pop the PeerSet SID and IP lookup (with potential BGP PIC fall-back).

We illustrate the different types of possible backups using the reference diagram and considering the Peering SID's allocated by C.

PeerNode SID 1052, allocated by C for peer F:

- o Upon the failure of the upper connected link CF, C can reroute all the traffic onto the lower CF link to the same peer (F).

PeerNode SID 1022, allocated by C for peer E:

- o Upon the failure of the connected link CE, C can reroute all the traffic onto the link to PeerNode SID 1052 (F).

PeerNode SID 1012, allocated by C for peer D:

- o Upon the failure of the connected link CD, C can pop the PeerNode SID and lookup the IP destination address in its FIB and route accordingly.

PeerSet SID 1060, allocated by C for the set of peers E and F:

- o Upon the failure of a connected link in the group, the traffic to PeerSet SID 1060 is rerouted on any other member of the group.

For specific business reasons, the operator might not want the default FRR behavior applied to a PeerNode SID or any of its depending PeerADJ SID.

The operator should be able to associate a specific backup PeerNode SID for a PeerNode SID: e.g. 1022 (E) must be backed up by 1012 (D) which over-rides the default behavior which would have preferred F as a backup for E.

4. EPE Controller

In this section, we provide a non-exhaustive set of inputs that an EPE controller would likely collect such as to perform the EPE policy decision.

The exhaustive definition is outside the scope of this document.

4.1. Valid Paths From Peers

The EPE controller should collect all the paths advertised by all the engineered peers.

This could be realized by setting an iBGP session with the EPE-enabled border router, with "add-path all" and original next-hop preserved.

In this case, C would advertise the following Internet routes to the EPE controller:

- o NLRI <L/8>, nhop 1.0.1.2, AS Path {AS 2, 4}
 - * X (i.e.: the EPE controller) knows that C receives a path to L/8 via neighbor 1.0.1.2 of AS2.
- o NLRI <L/8>, nhop 1.0.2.2, AS Path {AS 3, 4}
 - * X knows that C receives a path to L/8 via neighbor 1.0.2.2 of AS2.
- o NLRI <L/8>, nhop 1.0.5.2, AS Path {AS 3, 4}
 - * X knows that C has an eBGP path to L/8 via AS3 via neighbor 1.0.5.2

An alternative option consists in Adj-RIB-In BMP from EPE-enabled border router to the EPE collector.

4.2. Intra-Domain Topology

The EPE controller should collect the internal topology and the related IGP SID's.

This could be realized by collecting the IGP LSDB of each area or running a BGP-LS session with a node in each IGP area.

4.3. External Topology

Thanks to the collected BGP-LS routes described in the [section 2](#) (BGPLS advertisements), the EPE controller is able to maintain an accurate description of the egress topology of node C. Furthermore, the EPE controller is able to associate BGP Peering SID's to the various components of the external topology.

4.4. SLA characteristics of each peer

The EPE controller might collect SLA characteristics across peers. This requires an EPE solution as the SL A probes need to be steered via non-best-path peers.

Uni-directional SLA monitoring of the desired path is likely required. This might be possible when the application is controlled at the source and the receiver side. Uni-directional monitoring dissociates the SLA characteristic of the return path (which cannot usually be controlled) from the forward path (the one of interest for pushing content from a source to a consumer and the one which can be controlled).

Alternatively, Extended Metrics, as defined in [[I-D.ietf-isis-te-metric-extensions](#)] could also be advertised using new bgpls attributes.

4.5. Traffic Matrix

The EPE controller might collect the traffic matrix to its peers or the final destinations. IPFIX is a likely option.

An alternative option consists in collecting the link utilization statistics of each of the internal and external links, also available in current definition of [[I-D.ietf-idr-ls-distribution](#)].

4.6. Business Policies

The EPE controller should collect business policies.

4.7. EPE Policy

On the basis of all these inputs (and likely other), the EPE Controller decides to steer some demands away from their best BGP path.

The EPE policy is likely expressed as a two-entry segment list where the first element is the IGP prefix SID of the selected egress border router and the second element is a BGP Peering SID at the selected egress border router.

A few examples are provided hereafter:

- o Prefer egress PE C and peer AS AS2: {64, 1012}.
- o Prefer egress PE C and peer AS AS3 via ebgp peer 1.0.2.2: {64, 1022}.

- o Prefer egress PE C and peer AS AS3 via ebgp peer 1.0.5.2: {64, 1052}.
- o Prefer egress PE C and peer AS AS3 via interface 1.0.4.2 of multi-hop ebgp peer 1.0.5.2: {64, 1042}.
- o Prefer egress PE C and any interface to any peer in the group 1060: {64, 1060}.

Note that the first SID could be replaced by a list of segments. This is useful when an explicit path within the domain is required for traffic-engineering purpose. For example, if the Prefix SID of node B is 60 and the EPE controller would like to steer the traffic from A to C via B then through the external link to peer D then the segment list would be {60, 64, 1012}.

5. Programming an input policy

The detailed/exhaustive description of all the means to implement an EPE policy are outside the scope of this document. A few examples are provided in this section.

5.1. At a Host

A static IP/MPLS route can be programmed at the host H. The static route would define a destination prefix, a next-hop and a label stack to push. The global property of the IGP Prefix SID is particularly convenient: the same policy could be programmed across hosts connected to different routers.

5.2. At a router - SR Traffic Engineering tunnel

The EPE controller can configure the ingress border router with an SR traffic engineering tunnel T1 and a steering-policy S1 which causes a certain class of traffic to be mapped on the tunnel T1.

The tunnel T1 would be configured to push the require segment list.

The tunnel and the steering policy could be configured via PCEP according to [[I-D.sivabalan-pce-segment-routing](#)] and [[I-D.ietf-pce-pce-initiated-lsp](#)] or via Netconf ([[RFC6241](#)]).

Example: at A

```
Tunnel T1: push {64, 1042}
IP route L/8 set nhop T1
```

5.3. At a Router - BGP3107 policy route

The EPE Controller could build a BGP3107 ([\[RFC3107\]](#)) route (from scratch) and send it to the ingress router:

- o NLRI: the destination prefix to engineer: e.g. L/8.
- o Next-Hop: the selected egress border router: C.
- o Label: the selected egress peer: 1042.
- o AS path: reflecting the valid AS path of the selected.
- o Some BGP policy to ensure it be selected as best by the ingress router.

This BGP3107 policy route "overwrites" an equivalent or less-specific "best path". As the best-path is changed, this EPE input policy option influences the path propagated to the upstream peer/customers.

5.4. At a Router - VPN policy route

The EPE Controller could build a VPNv4 route (from scratch) and send it to the ingress router:

- o NLRI: the destination prefix to engineer: e.g. L/8.
- o Next-Hop: the selected egress border router: C.
- o Label: the selected egress peer: 1042.
- o Route-Target: selecting the appropriate VRF at the ingress router.
- o AS path: reflecting the valid AS path of the selected.
- o Some BGP policy to ensure it be selected as best by the ingress router in the related VRF.

The related VRF must be pre-configured. A VRF fall-back into main FIB might be beneficial to avoid replicating all the "normal" internet paths in each VRF.

5.5. At a Router - Flowspec route

EPE Controller builds a FlowSpec route and sends it to the ingress router to engineer:

- o Dissemination of Flow Specification Rules ([\[RFC5575\]](#)).

- o Destination/Source IP Addresses, IP Protocol, Destination/Source port (+1 component).
- o ICMP Type/Code, TCP Flags, Packet length, DSCP, Fragment.

6. IPv6

The described solution is applicable to IPv6, either with MPLS-based or IPv6-Native segments. In both cases, the same three steps of the solution are applicable:

- o BGP-LS-based signaling of the external topology and BGP Peering Segments to the EPE controller.
- o Collection of various inputs by the EPE controller to come up with a policy decision.
- o Programming at an ingress router or source host of the desired EPE policy which consists in a list of segments to push on a defined traffic class.

7. Benefits

The EPE solutions described in this document has the following benefits:

- o No assumption on the iBGP design with AS1.
- o Next-Hop-Self on the internet routes propagated to the ingress border routers is possible. This is a common design rule to minimize the number of IGP routes and to avoid importing external churn into the internal domain.
- o Consistent support for traffic-engineering within the domain and at the external edge of the domain.
- o Support host and ingress border router EPE policy programming.
- o EPE functionality is only required on the EPE-enabled egress border router and the EPE controller: an ingress policy can be programmed at the ingress border router without any new functionality.
- o Ability to deploy the same input policy across hosts connected to different routers (global property of the IGP prefix SID).

8. IANA Considerations

TBD

9. Manageability Considerations

TBD

10. Security Considerations

TBD

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