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BGP Classful Transport Planes

Abstract

This document specifies a mechanism, referred to as "service mapping", to express association of overlay routes with underlay routes satisfying a certain SLA, using BGP. The document describes a framework for classifying underlay routes into transport classes, and mapping service routes to specific transport class.

The "Transport class" construct maps to a desired SLA, and can be used to realize the "Topology Slice" in 5G Network slicing architecture.

This document specifies BGP protocol procedures that enable dissemination of such service mapping information that may span multiple co-operating administrative domains. These domains may be administetered by the same provider or closely co-ordinating provider networks.

It makes it possible to advertise multiple tunnels to the same destination address, thus avoiding need of multiple loopbacks on the egress node.

A new BGP transport layer address family (SAFI 76) is defined for this purpose that uses RFC-4364 technology and follows RFC-8277 NLRI encoding. This new address family is called "BGP Classful Transport", aka BGP CT.

It carries transport prefixes across tunnel domain boundaries (e.g. in Inter-AS Option-C networks), parallel to BGP LU (SAFI 4) . It disseminates "Transport class" information for the transport prefixes across the participating domains, which is not possible

with BGP LU. This makes the end-to-end network a "Transport Class" aware tunneled network.

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].

Status of This Memo

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1. Introduction

To facilitate service mapping, the tunnels in a network can be grouped by the purpose they serve into a "Transport Class". The tunnels could be created using any signaling protocol, such as LDP, RSVP, BGP LU or SPRING. The tunnels could also use native IP or IPv6, as long as they can carry MPLS payload. Tunnels may exist between different pair of end points. Multiple tunnels may exist between the same pair of end points.

Thus, a Transport Class consists of tunnels created by various protocols that satisfy the properties of the class. For example, a "Gold" transport class may consist of tunnels that traverse the shortest path with fast re-route protection, a "Silver" transport class may hold tunnels that traverse shortest paths without protection, a "To NbrAS Foo" transport class may hold tunnels that exit to neighboring AS Foo, and so on.

The extensions specified in this document can be used to create a BGP transport tunnel that potentially spans domains, while

preserving its Transport Class. Examples of domain are Autonomous System (AS), or IGP area. Within each domain, there is a second level underlay tunnel used by BGP to cross the domain. The second level underlay tunnels could be hetrogeneous: Each domain may use a different type of tunnel (e.g. MPLS, IP, GRE), or use a differnet signaling protocol. A domain boundary is demarcated by a rewrite of BGP nexthop to 'self' while re-advertising tunnel routes in BGP. Examples of domain boundary are inter-AS links and inter-region ABRs. The path uses MPLS label-switching when crossing domain boundary and uses the native intra-AS tunnel of the desired transport class when traversing within a domain.

Overlay routes carry sufficient indication of the Transport Classes they should be encapsulated over, in form of BGP community called the "Mapping community". Based on the mapping community, "route resolution" procedure on the ingress node selects from the corresponding Transport Class an appropriate tunnel whose destination matches (LPM) the nexthop of the overlay route. If the overlay route is carried in BGP, the protocol nexthop (or, PNH) is generally carried as an attribute of the route.

The PNH of the overlay route is also referred to as "service endpoint" (SEP). The service endpoint may exist in the same domain as the service ingress node or lie in a different domain, adjacent or non-adjacent. In the former case, reachability to the SEP is provided by an intra-domain tunneling protocol, and in the latter case, reachability to the SEP is via BGP transport families.

In this architecture, the intra-domain transport protocols (e.g. RSVP, SRTE) are also "Transport Class aware", and they publish ingress routes in Transport RIB associated with the Transport Class, at the tunnel ingress node. These routes are then redistributed into BGP CT to be advertised to adjacent domains. It is outside the scope of this document how exactly the transport protocols are made transport class aware, though configuration on the tunnel ingress node is a simple mechanism to achieve it.

This document describes mechanisms to:

- Model a "Transport Class" as "Transport RIB" on a router, consisting of tunnel ingress routes of a certain class.

- Enable service routes to resolve over an intended Transport Class by virtue of carrying the appropriate "Mapping community". Which results in using the corresponding Transport RIB for finding nexthop reachability.

- Advertise tunnel ingress routes in a Transport RIB via BGP without any path hiding, using BGP VPN technology and Add-path.

Such that overlay routes in the receiving domains can also resolve over tunnels of associated Transport Class.

Provide a way for co-operating domains to reconcile any differences in extended community namespaces, and interoperate between different transport signaling protocols in each domain.

In this document we focus mainly on MPLS as the intra-domain transport tunnel forwarding, but the mechanisms described here would work in similar manner for non-MPLS (e.g. IP, GRE, UDP) transport tunnel forwarding technologies too.

This document assumes MPLS forwarding when crossing domain boundaries, as that is the defacto standard in deployed networks today. But mechanisms specified in this document can also support different forwarding technologies (e.g. SRv6). Section [SRV6-INTER-DOMAIN]in this document describes adaptation of BGP CT over SRv6 data plane.

The document Seamless Segment Routing [Seamless-SR] describes various use cases and applications of procedures described in this document.

2. Terminology

LSP: Label Switched Path.

TE : Traffic Engineering.

SN : Service Node.

BN : Border Node.

TN : Transport Node, P-router.

BGP-VPN : VPNs built using RFC4364 mechanisms.

RT : Route-Target extended community.

RD : Route-Distinguisher.

PNH : Protocol-Nexthop address carried in a BGP Update message.

SEP : Service End point, the PNH of a Service route.

LPM : Longest Prefix Match.

Service Family : BGP address family used for advertising routes for "data traffic", as opposed to tunnels.

Transport Family : BGP address family used for advertising tunnels, which are in turn used by service routes for resolution.

Transport Tunnel : A tunnel over which a service may place traffic. These tunnels can be GRE, UDP, LDP, RSVP, or SR-TE.

Tunnel Domain : A domain of the network containing SN and BN, under a single administrative control that has a tunnel between SN and BN. An end-to-end tunnel spanning several adjacent tunnel domains can be created by "stitching" them together using labels.

Transport Class : A group of transport tunnels offering the same type of service.

Transport Class RT : A Route-Target extended community used to identify a specific Transport Class.

Transport RIB : At the SN and BN, a Transport Class has an associted Transport RIB that holds its tunnel routes.

Transport Plane : An end to end plane comprising of transport tunnels belonging to same transport class. Tunnels of same transport class are stitched together by BGP route readvertisements with nexthop-self, to span across domain boundaries using Label-Swap forwarding mechanism similar to Inter-AS option-b.

Mapping Community : BGP Community/Extended-community on a service route, that maps it to resolve over a Transport Class.

3. Transport Class

A Transport Class is defined as a set of transport tunnels that share certain characteristics useful for underlay selection.

On the wire, a transport class is represented as the Transport Class RT, which is a new Route-Target extended community.

A Transport Class is configured at SN and BN, along with attributes like RD and Route-Target. Creation of a Transport Class instantiates the associated Transport RIB and a Transport routing instance to contain them all.

The operator may configure a SN/BN to classify a tunnel into an appropriate Transport Class, which causes the tunnel's ingress routes to be installed in the corresponding Transport RIB. At a BN, these tunnel routes may then be advertised into BGP CT.

Alternatively, a router receiving the transport routes in BGP with appropriate signaling information can associate those ingress routes to the appropriate Transport Class. E.g. for Classful Transport

family (SAFI 76) routes, the Transport Class RT indicates the Transport Class. For BGP LU family(SAFI 4) routes, import processing based on Communities or inter-AS source-peer may be used to place the route in the desired Transport Class.

When the ingress route is received via SRTE [SRTE], which encodes the Transport Class as an integer 'Color' in the NLRI as "Color:Endpoint", the 'Color' is mapped to a Transport Class during import processing. SRTE ingress route for 'Endpoint' is installed in that transport class. The SRTE route when advertised out to BGP speakers will then be advertised in Classful Transport family with Transport Class RT and a new label. The MPLS swap route thus installed for the new label will pop the label and deliver decapsulated traffic into the path determined by SRTE route.

RFC8664 [RFC8664] extends PCEP to carry SRTE Color. This color association thus learnt is also mapped to a Transport Class thus associating the PCEP signaled SRTE LSP with the desired Transport Class.

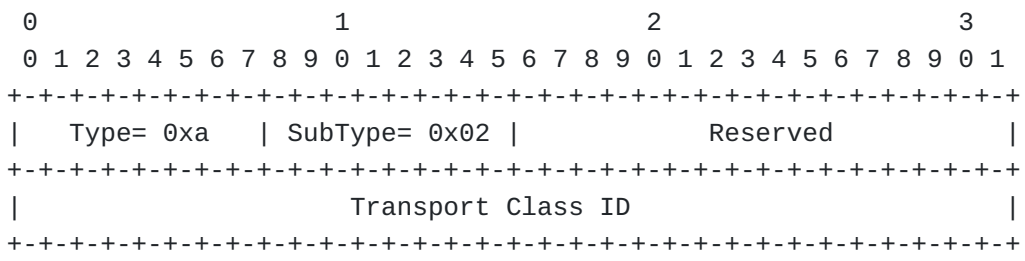
Similarly, PCEP-RSVP-COLOR [PCEP-RSVP-COLOR] extends PCEP to carry RSVP Color. This color association thus learnt is also mapped to a Transport Class thus associating the PCEP signaled RSVP LSP with the desired Transport Class.

4. "Transport Class" Route Target Extended Community

This document defines a new type of Route Target, called "Transport Class" Route Target Extended Community.

"Transport Class" Route Target extended community is a transitive extended community EXT-COMM [RFC4360] of extended-type, with a new Format (Type high = 0xa) and SubType as 0x2 (Route Target).

This new Route Target Format has the following encoding:



"Transport Class" Route Target Extended Community

Type: 1 octet

Type field contains value 0xa.

SubType: 1 octet

Subtype field contain 0x2. This indicates 'Route Target'.

Transport Class ID: 4 octets

The least significant 32-bits of the value field contain the "Transport Class" identifier, which is a 32-bit integer.

The remaining 2 octets after SubType field are Reserved, they MUST be set to zero by originator, and ignored, left unaltered by receiver.

The "Transport class" Route Target Extended community follows the mechanisms for VPN route import, export as specified in BGP-VPN [RFC4364], and follows the Route Target Contrain mechanisms as specified in VPN-RTC [RFC4684]

A BGP speaker that implements RT Constraint VPN-RTC [RFC4684] MUST apply the RT Constraint procedures to the "Transport class" Route Target Extended community as-well.

The Transport Class Route Target Extended community is carried on Classful Transport family routes, and allows associating them with appropriate Transport RIBs at receiving BGP speakers.

Use of the Transport Class Route Target Extended community with a new Type code avoids conflicts with any VPN Route Target assignments already in use for service families.

5. Transport RIB

A Transport RIB is a routing-only RIB that is not installed in forwarding path. However, the routes in this RIB are used to resolve reachability of overlay routes' PNH. Transport RIB is created when the Transport Class it represents is configured.

Overlay routes that want to use a specific Transport Class confine the scope of nexthop resolution to the set of routes contained in the corresponding Transport RIB. This Transport RIB is the "Routing Table" referred in Section 9.1.2.1 RFC4271

Routes in a Transport RIB are exported out in 'Classful Transport' address family.

6. Transport Routing Instance

A BGP VPN routing instance that is a container for the Transport RIB. It imports, and exports routes in this RIB with Transport Class RT. Tunnel destination addresses in this routing instance's context come from the "provider namespace". This is different from user VRFs for e.g., which contain prefixes in "customer namespace"

The Transport Routing instance uses the RD and RT configured for the Transport Class.

7. Nexthop Resolution Scheme

An implementation may provide an option for the service route to resolve over less preferred Transport Classes, should the resolution over preferred, or "primary" Transport Class fail.

To accomplish this, the set of service routes may be associated with a user-configured "resolution scheme", which consists of the primary Transport Class, and optionally, an ordered list of fallback Transport Classes.

A community called as "Mapping Community" is configured for a "resolution scheme". A Mapping community maps to exactly one resolution scheme. A resolution scheme comprises of one primary transport class and optionally one or more fallback transport classes.

A BGP route is associated with a resolution scheme during import processing. The first community on the route that matches a mapping community of a locally configured resolution scheme is considered the effective mapping community for the route. The resolution scheme thus found is used when resolving the route's PNH. If a route contains more than one mapping community, it indicates that the

route considers these multiple mapping communities as equivalent. So the first community that maps to a resolution scheme is chosen.

A transport route received in BGP Classful Transport family SHOULD use a resolution scheme that contains the primary Transport Class without any fallback to best effort tunnels. The primary Transport Class is identified by the Transport Class RT carried on the route. Thus Transport Class RT serves as the Mapping Community for Classful Transport routes.

A service route received in a BGP service family MAY map to a resolution scheme that contains the primary Transport Class identified by the mapping community on the route, and a fallback to best effort tunnels transport class. The primary Transport Class is identified by the Mapping community carried on the route. For e.g. the Extended Color community may serve as the Mapping Community for service routes. Color:0:<n> MAY map to a resolution scheme that has primary transport class <n>, and a fallback to best-effort transport class.

8. BGP Classful Transport Family NLRI

The Classful Transport (CT) family will use the existing AFI of IPv4 or IPv6, and a new SAFI 76 "Classful Transport" that will apply to both IPv4 and IPv6 AFIs. These AFI, SAFI pair of values MUST be negotiated in Multiprotocol Extensions capability described in [RFC4760] to be able to send and receive BGP CT routes.

The "Classful Transport" SAFI NLRI itself is encoded as specified in https://tools.ietf.org/html/rfc8277#section-2 [RFC8277].

When AFI is IPv4 the "Prefix" portion of Classful Transport family NLRI consists of an 8-byte RD followed by an IPv4 prefix. When AFI is IPv6 the "Prefix" consists of an 8-byte RD followed by an IPv6 prefix.

Attributes on a Classful Transport route include the Transport Class Route-Target extended community, which is used to leak the route into the right Transport RIBs on SNs and BNs in the network.

SAFI 76 routes can be sent with either IPv4 or IPv6 nexthop. The type of nexthop is inferred from the length of nexthop.

When the length of Next Hop Address field is 24 (or 48) the nexthop address is of type VPN-IPv6 with 8-octet RD set to zero (potentially followed by the link-local VPN-IPv6 address of the next hop with an 8-octet RD set to zero).

When the length of Next Hop Address field is 12 the nexthop address is of type VPN-IPv4 with 8-octet RD set to zero.

9. Comparison with other families using RFC-8277 encoding

SAFI 128 (Inet-VPN) is a RF8277 encoded family that carries service prefixes in the NLRI, where the prefixes come from the customer namespaces, and are contexualized into separate user virtual service RIBs called VRFs, using RFC4364 procedures.

SAFI 4 (BGP LU) is a RFC8277 encoded family that carries transport prefixes in the NLRI, where the prefixes come from the provider namespace.

SAFI 76 (Classful Transport) is a RFC8277 encoded family that carries transport prefixes in the NLRI, where the prefixes come from the provider namespace, but are contexualized into separate Transport RIBs, using RFC4364 procedures.

It is worth noting that SAFI 128 has been used to carry transport prefixes in "L3VPN Inter-AS Carrier's carrier" scenario, where BGP LU/LDP prefixes in CsC VRF are advertised in SAFI 128 towards the remote-end baby carrier.

In this document a new AFI/SAFI is used instead of reusing SAFI 128 to carry these transport routes, because it is operationally advantageous to segregate transport and service prefixes into separate address families, RIBs. E.g. It allows to safely enable "per-prefix" label allocation scheme for Classful Transport prefixes without affecting SAFI 128 service prefixes which may have huge scale. "per prefix" label allocation scheme keeps the routing churn local during topology changes.

A new family also facilitates having a different readvertisement path of the transport family routes in a network than the service route readvertisement path. viz. Service routes (Inet-VPN) are exchanged over an EBGP multihop session between Autonomous systems with nexthop unchanged; whereas Classful Transport routes are readvertised over EBGP single hop sessions with "nexthop-self" rewrite over inter-AS links.

The Classful Transport family is similar in vein to BGP LU, in that it carries transport prefixes. The only difference is, it also carries in Route Target an indication of which Transport Class the transport prefix belongs to, and uses RD to disambiguate multiple instances of the same transport prefix in a BGP Update.

10. Protocol Procedures

This section summarizes the procedures followed by various nodes speaking Classful Transport family

Preparing the network for deploying Classful Transport planes

Operator decides on the Transport Classes that exist in the network, and allocates a Route-Target to identify each Transport Class.

Operator configures Transport Classes on the SNs and BNs in the network with unique Route-Distinguishers and Route-Targets.

Implementations may provide automatic generation and assignment of RD, RT values for a transport routing instance; they MAY also provide a way to manually override the automatic mechanism, in order to deal with any conflicts that may arise with existing RD, RT values in the different network domains participating in a deployment.

Origination of Classful Transport route:

At the ingress node of the tunnel's home domain, the tunneling protocols install routes in the Transport RIB associated with the Transport Class the tunnel belongs to.

The ingress node then advertises this tunnel destination into BGP as a Classful Transport family route with NLRI RD:TunnelEndpoint, attaching a 'Transport Class' Route Target that identifies the Transport Class. This BGP CT route is advertised to EBGP peers and IBGP peers which are RR-clients. This route MUST NOT be advertised to the IBGP peers who are not RR-clients.

Alternatively, the egress node of the tunnel i.e. the tunnel endpoint can originate the same BGP Classful Transport route, with NLRI RD:TunnelEndpoint and PNH TunnelEndpoint, which will resolve over the tunnel route at the ingress node. When the tunnel is up, the Classful Transport BGP route will become usable and get re-advertised.

Unique RD SHOULD be used by the originator of a Classful Transport route to disambiguate the multiple BGP advertisements for a transport end point.

Ingress node receiving Classful Transport route

On receiving a BGP Classful Transport route with a PNH that is not directly connected, e.g. an IBGP-route, a mapping community on the route (the Transport Class RT) indicates which Transport Class this route maps to. The routes in the associated Transport RIB are used to resolve the received PNH. If there does not exist a route in the Transport RIB matching the PNH, the Classful Transport route is considered unusable, and MUST NOT be re-advertised further.

Border node readvertising Classful Transport route with nexthop self:

The BN allocates an MPLS label to advertise upstream in Classful Transport NLRI. The BN also installs an MPLS swap-route for that label that swaps the incoming label with a label received from the downstream BGP speaker, or pops the incoming label. And then pushes received traffic to the transport tunnel or direct interface that the Classful Transport route's PNH resolved over.

The label SHOULD be allocated with "per-prefix" label allocation semantics. RD is stripped from the BGP CT NLRI prefix when a BGP CT route is leaked to a Transport RIB. The IP prefix in the transport RIB context (IP-prefix, Transport-Class) is used as the key to do per-prefix label allocation. This helps in avoiding BGP CT route churn through out the CT network when a failure happens in a domain. The failure is not propagated further than the BN closest to the failure.

The value of advertised MPLS label is locally significant, and is dynamic by default. The BN may provide option to allocate a value from a statically carved out range. This can be achieved using locally configured export policy, or via mechanisms described in BGP Prefix-SID [RFC8669].

Border node receiving Classful Transport route on EBGP :

If the route is received with PNH that is known to be directly connected, e.g. EBGP single-hop peering address, the directly connected interface is checked for MPLS forwarding capability. No other nexthop resolution process is performed, as the inter-AS link can be used for any Transport Class.

If the inter-AS links should honor Transport Class, then the BN SHOULD follow procedures of an Ingress node described above, and perform nexthop resolution process. The interface routes SHOULD be installed in the Transport RIB belonging to the associated Transport Class.

Avoiding path-hiding through Route Reflectors

When multiple BNs exist that advertise a RDn:PEn prefix to RRs, the RRs may hide all but one of the BNs, unless ADDPATH [RFC7911] is used for the Classful Transport family. This is similar to L3VPN option-B scenarios. Hence ADDPATH SHOULD be used for Classful Transport family, to avoid path-hiding through RRs.

Avoiding loop between Route Reflectors in forwarding path

Pair of redundant ABRs acting as RR with nexthop-self may chose each other as best path instead of the upstream ASBR, causing a traffic forwarding loop.

Implementations SHOULD provide a way to alter the tie-breaking rule specified in BGP RR [RFC4456] to tie-break on CLUSTER_LIST step before ROUTER-ID step, when performing path selection for BGP CT routes. RFC4456 considers pure RR which is not in forwarding path. When RR is in forwarding path and reflects routes with nexthop-self, which is the case for ABR BNs in a BGP transport network, this rule may cause loops. This document suggests the following modification to the BGP Decision Process Tie Breaking rules (Sect. 9.1.2.2, [RFC4271]) when doing path selection for BGP CT family routes:

The following rule SHOULD be inserted between Steps e) and f): a BGP Speaker SHOULD prefer a route with the shorter CLUSTER_LIST length. The CLUSTER_LIST length is zero if a route does not carry the CLUSTER_LIST attribute.

Some deployment considerations can also help in avoiding this problem:

- IGP metric should be assigned such that "ABR to redundant ABR" cost is inferior than "ABR to upstream ASBR" cost.

- Tunnels belonging to special Transport classes SHOULD NOT be provisioned between ABR to ABRs. This will ensure that the route received from an ABR with nexthop-self will not be usable at a redundant ABR.

This avoids possibility of such loops altogether, irrespective of whether the path selection modification mentioned above is implemented.

Ingress node receiving service route with mapping community

Service routes received with mapping community resolve using Transport RIBs determined by the resolution scheme. If the resolution process does not find an usable Classful Transport route or tunnel route in any of the Transport RIBs, the service route MUST be considered unusable for forwarding purpose.

Coordinating between domains using different community namespaces.

Cooperating option-C domains may sometimes not agree on RT, RD, Mapping-community or Transport Route Target values because of differences in community namespaces; e.g. during network mergers

or renumbering for expansion. Such deployments may deploy mechanisms to map and rewrite the Route-target values on domain boundaries, using per ASBR import policies. This is no different than any other BGP VPN family. Mechanisms employed in inter-AS VPN deployments may be used with the Classful Transport family also.

The resolution schemes SHOULD allow association with multiple mapping communities. This helps with renumbering, network mergers, or transitions.

Though RD can also be rewritten on domain boundaries, deploying unique RDs is strongly RECOMMENDED, because it helps in trouble shooting by uniquely identifying originator of a route, and avoids path-hiding.

This document defines a new format of Route-Target extended-community to carry Transport Class, this avoids collision with regular Route Target namespace used by service routes.

11. Scaling considerations

11.1. Avoiding unintended spread of CT routes across domains.

RFC8212 [RFC8212] suggests BGP speakers require explicit configuration of both BGP Import and Export Policies for any EBGP sessions, in order to receive or send routes on EBGP sessions.

It is recommended to follow this for BGP CT routes. It will prohibit unintended advertisement of transport routes through out the BGP CT transport domain which may span multiple AS. This will conserve usage of MPLS label and nexthop resources in the network. An ASBR of a domain can be provisioned to allow routes with only the Transport targets that are required by SNs in the domain.

11.2. Constrained distribution of PNHs to SNs (On Demand Nexthop)

This section describes how the number of Protocol Nexthops advertised to a SN or BN can be constrained using BGP Classsful Transport and VPN RTC [RFC4684]

An egress SN MAY advertise BGP CT route for RD:eSN with two Route Targets: transport-target:0:<TC> and a RT carrying <eSN>:<TC>. Where TC is the Transport Class identifier, and eSN is the IP-address used by SN as BGP nexthop in it's service route advertisements.

transport-target:0:<TC> is the new type of route target (Transport Class RT) defined in this document. It is carried in BGP extended community attribute (BGP attribute code 16).

The RT carrying <eSN>:<TC> MAY be an IP-address specific regular RT (BGP attribute code 16), IPv6-address specific RT (BGP attribute code 25), or a Wide-communities based RT (BGP attribute code 34) as described in RTC-Ext [RTC-Ext]

An ingress SN MAY import BGP CT routes with Route Target carrying: <eSN>:<TC>. The ingress SN MAY learn the eSN values either by configuration, or it MAY discover them from the BGP nexthop field in the BGP VPN service routes received from eSN. A BGP ingress SN receiving a BGP service route with nexthop of eSN SHOULD generate a RTC/Extended-RTC route for Route Target prefix <Origin ASN>:<eSN>/[80|176] in order to learn BGP CT transport routes to reach eSN. This allows constrained distribution of the transport routes to the PNHs actually required by iSN.

When path of route propogation of BGP CT routes is same as the RTC routes, a BN would learn the RTC routes advertised by ingress SNs and propagate further. This will allow constraining distribution of BGP CT routes for a PNH to only the necessary BNs in the network, closer to the egress SN.

This mechanism provides "On Demand Nexthop" of BGP CT routes, which help with scaling of MPLS forwarding state at SN and BN.

But the amount of state carried in RTC family may become proportional to number of PNHs in the network. To strike a balance, the RTC route advertisements for <Origin ASN>:<eSN>/[80|176] MAY be confined to the BNs in home region of ingress-SN, or the BNs of a super core.

Such a BN in the core of the network SHOULD import BGP CT routes with Transport Class Route Target: 0:<TC>, and generate a RTC route for <Origin ASN>:0:<TC>/96, while not propagating the more specific RTC requests for specific PNHs. This will let the BN learn transport routes to all eSN nodes. But confine their propagation to ingress-SNs.

11.3. Limiting scope of visibility of PE loopback as PNHs

It may be even more desirable to limit the number of PNHs that are globaly visible in the network. This is possible using mechanism described in MPLS Namespaces [MPLS-NAMESPACES]

Such that advertisement of PE loopback addresses as next-hop in BGP service routes is confined to the region they belong to. An anycast IP-address called "Context Protocol Nexthop Address" abstracts the PEs in a region from other regions in the network, swapping the PE scoped service label with a CPNH scoped private namespace label.

This provides much greater advantage in terms of scaling and convergence. Changes to implement this feature are required only on the region's BNs and RR.

12. OAM considerations

Standard MPLS OAM procedures specified in [RFC8029] also apply to BGP Classful Transport.

The 'Target FEC Stack' sub-TLV for IPv4 Classful Transport has a Sub-Type of [TBD], and a length of 13. The Value field consists of the RD advertised with the Classful Transport prefix, the IPv4 prefix (with trailing 0 bits to make 32 bits in all), and a prefix length, encoded as follows:

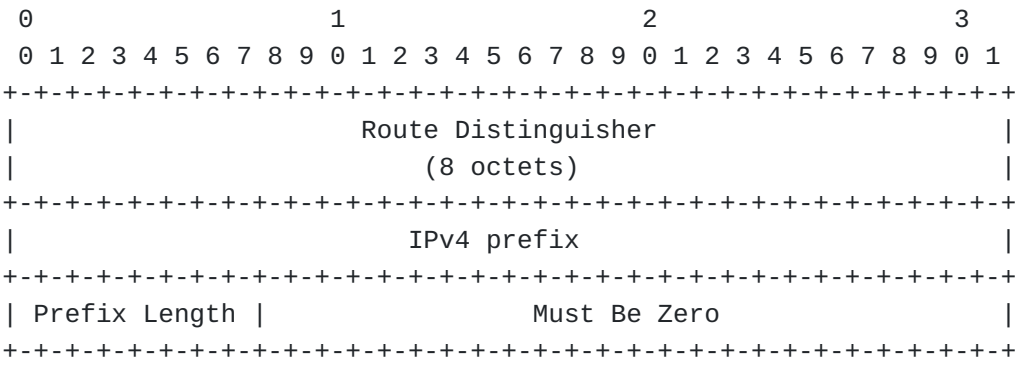


Figure 1: Classful Transport IPv4 FEC

The 'Target FEC Stack' sub-TLV for IPv6 Classful Transport has a Sub-Type of [TBD], and a length of 25. The Value field consists of the RD advertised with the Classful Transport prefix, the IPv6 prefix (with trailing 0 bits to make 128 bits in all), and a prefix length, encoded as follows:

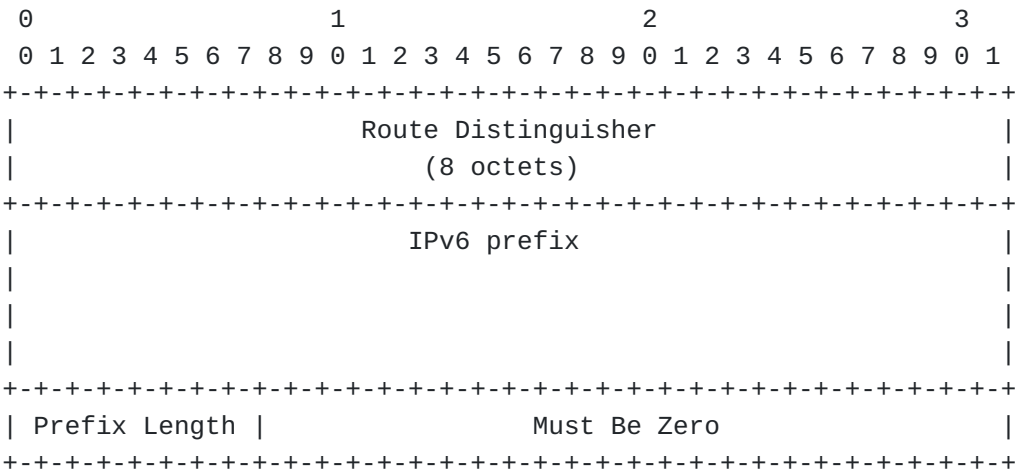


Figure 2: Classful Transport IPv6 FEC

13. Applicability to Network Slicing

In Network Slicing, the Transport Slice Controller (TSC) sets up the Topology (e.g. RSVP, SR-TE tunnels with desired characteristics) and resources (e.g. polices/shapers) in a transport network to create a Transport slice. The Transport class construct described in this document represents the "Topology Slice" portion of this equation.

The TSC can use the Transport Class Identifier (Color value) to provision a transport tunnel in a specific Topology Slice.

Further, Network slice controller can use the Mapping community on the service route to map traffic to the desired Transport slice.

14. SRv6 support

This section describes how BGP CT may be used to set up inter domain tunnels of a certain Transport Class, when using Segment Routing over IPv6 (SRv6) data plane on the inter AS links or as intra-AS tunneling mechanism.

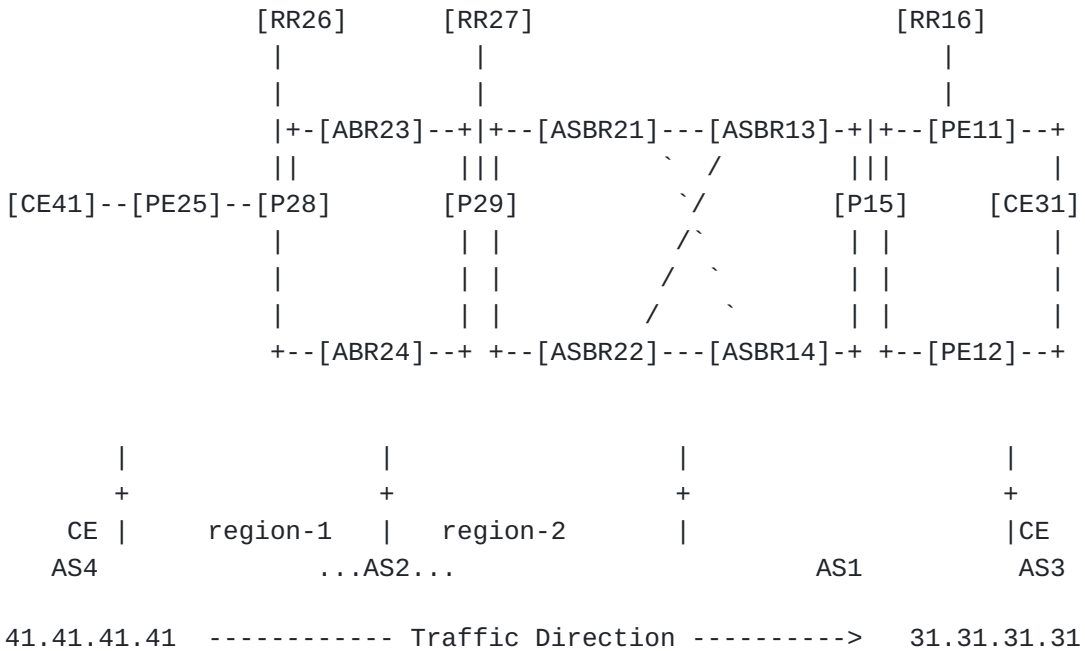
RFC8986, [SRV6-INTER-DOMAIN] specify the SRv6 Endpoint behaviors (End USD, End.BM, End.B6.Encaps and End.Replace, End.ReplaceB6, respectively). These are leveraged for BGP CT with SRv6 data plane.

The BGP Classful Transport route update for SRv6 MUST include the BGP Prefix-SID attribute along with SRv6 SID information as specified in [SRV6-SERVICES]. It may also include SRv6 SID structure for Transposition as specified in [SRV6-SERVICES]. It should be noted that prefixes carried in BGP CT family are transport layer end-points, e.g. PE loopback addresses. Thus the SRv6 SID carried in a BGP CT route is also a transport layer identifier.

This document extends the usage of "SRv6 label route tunnel" TLV to AFI=1/2 SAFI 76. "SRv6 label route tunnel" is the TLV of the BGP Prefix-SID Attribute as specified in [SRV6-MPLS-AGRWL].

15. Illustration of procedures with example topology

15.1. Topology



This example shows a provider network that comprises of two Autonomous systems, AS1, AS2. They are serving customers AS3, AS4 respectively. Traffic direction being described is CE41 to CE31. CE31 may request a specific SLA, e.g. Gold for this traffic, when traversing these provider networks.

AS2 is further divided into two regions. So there are three tunnel domains in provider space. AS1 uses ISIS Flex-Algo intra-domain tunnels, whereas AS2 uses RSVP intra-domain tunnels.

The network has two Transport classes: Gold with transport class id 100, Bronze with transport class id 200. These transport classes are provisioned at the PEs and the Border nodes (ABRs, ASBRs) in the network.

Following tunnels exist for Gold transport class.

PE25_to_ABR23_gold - RSVP tunnel

PE25_to_ABR24_gold - RSVP tunnel

ABR23_to_ASBR22_gold - RSVP tunnel

ASBR13_to_PE11_gold - ISIS FlexAlgo tunnel

ASBR14_to_PE11_gold - ISIS FlexAlgo tunnel

Following tunnels exist for Bronze transport class.

PE25_to_ABR23_bronze - RSVP tunnel

ABR23_to_ASBR21_bronze - RSVP tunnel

ABR23_to_ASBR22_bronze - RSVP tunnel

ABR24_to_ASBR21_bronze - RSVP tunnel

ASBR13_to_PE12_bronze - ISIS FlexAlgo tunnel

ASBR14_to_PE11_bronze - ISIS FlexAlgo tunnel

These tunnels are either provisioned or auto-discovered to belong to transport class 100 or 200.

15.2. Service Layer route exchange

Service nodes PE11, PE12 negotiate service families (SAFI 1, 128) on the BGP session with RR16. Service helpers RR16, RR26 have multihop EBGP session to exchange service routes between the two AS. Similarly PE25 negotiates service families with RR26.

Forwarding happens using service routes at service nodes PE25, PE11, PE12 only. Routes received from CEs are not present in any other nodes' FIB in the network.

CE31 advertises a route for example prefix 31.31.31.31 with nexthop self to PE11, PE12. CE31 can attach a mapping community Color:0:100 on this route, to indicate its request for Gold SLA. Or, PE11 can attach the same using locally configured policies. Let us assume CE31 is getting VPN service from PE25.

The 31.31.31.31 route is readvertised in SAFI 128 by PE11 with nexthop self (1.1.1.1) and label V-L1, to RR16 with the mapping community Color:0:100 attached. This SAFI 128 route reaches PE25 via RR16, RR26 with the nexthop unchanged, as PE11 and label V-L1. Now PE25 can resolve the PNH 1.1.1.1 using transport routes received in BGP CT or BGP LU.

The IP FIB at PE25 will have a route for 31.31.31.31 with a nexthop thus found, that points to a Gold tunnel in ingress domain.

15.3. Transport Layer route propagation

ASBR13 negotiates BGP CT family with transport ASBRs ASBR21, ASBR22. They negotiate BGP CT family with RR27 in region 2. ABR23, ABR24 negotiate BGP CT family with RR27 in region 2 and RR26 in region 1. PE25 receives BGP CT routes from RR26. BGP LU family is also

negotiated on these sessions alongside BGP CT family. BGP LU carries "best effort" transport class routes, BGP CT carries gold, bronze transport class routes.

ASBR13 is provisioned with transport class 100, RD value 1.1.1.3:10 and a transport route target 0:100. And a Transport class 200 with RD value 1.1.1.3:20, and transport route target 0:200.

Similarly, these transport classes are also configured on ASBRs, ABRs and PEs, with same transport route target, but unique RDs.

Ingress route for ASBR13_to_PE11_gold is advertised by ASBR13 in BGP CT family to ASBRs ASBR21, ASBR22. This route is sent with a NLRI containing RD prefix 1.1.1.3:10:1.1.1.1, Label B-L1 and a route target extended community transport-target:0:100. MPLS swap route is installed at ASBR13 for B-L1 with a nexthop pointing to ASBR13_to_PE11_gold tunnel.

Ingress route for ASBR13_to_PE11_bronze is advertised by ASBR13 in BGP CT family to ASBRs ASBR21, ASBR22. This route is sent with a NLRI containing RD prefix 1.1.1.3:20:1.1.1.1, Label B-L2 and a route target extended community transport-target:0:200. MPLS swap route is installed at ASBR13 for label B-L2 with a nexthop pointing to ASBR13_to_PE11_bronze tunnel

ASBR21 receives BGP CT route 1.1.1.3:10:1.1.1.1 over the single hop EBGP sesion, and readvertises with nexthop self (loopback adderss 2.2.2.1) to RR27, advertising a new label B-L3. MPLS swap route is installed for label B-L3 at ASBR21 to swap to received label B-L1 and forwards to ASBR13. RR27 readvertises this BGP CT route to ABR23, ABR24.

ASBR22 receives BGP CT route 1.1.1.3:10:1.1.1.1 over the single hop EBGP sesion, and readvertises with nexthop self (loopback adderss 2.2.2.2) to RR27, advertising a new label B-L4. MPLS swap route is installed for label B-L4 at ASBR22 to swap to received label B-L2 and forwards to ASBR13. RR27 readvertises this BGP CT route to ABR23, ABR24.

Addpath is enabled for BGP CT family on the sessions between RR27 and ASBRs, ABRs. Such that routes for 1.1.1.3:10:1.1.1.1 with the nexthops ASBR21 and ASBR22 are reflected to ABR23, ABR24 without any path hiding. Thus giving ABR23 visibiity of both available nexthops for Gold SLA.

ABR23 receives the route with nexthop 2.2.2.1, label B-L3 from RR27. The route target "transport-target:0:100" on this route acts as mapping community, and instructs ABR23 to strictly resolve the nexthop using transport class 100 routes only. ABR23 is unable to find a route for 2.2.2.1 with transport class 100. Thus it considers

this route unusable and does not propagate it further. This prunes ASBR21 from Gold SLA tunneled path.

ABR23 also receives the route with nexthop 2.2.2.2, label B-L4 from RR27. The route target "transport-target:0:100" on this route acts as mapping community, and instructs ABR23 to strictly resolve the nexthop using transport class 100 routes only. ABR23 successfully resolves the nexthop to point to ABR23_to_ASBR22_gold tunnel. ABR23 readvertises this route with nexthop self (loopback address 2.2.2.3) and a new label B-L5 to RR26. Swap route for B-L5 is installed by ABR23 to swap to label B-L4, and forward into ABR23_to_ASBR22_gold tunnel.

RR26 reflects the route from ABR23 to PE25. PE25 receives the BGP CT route for prefix 1.1.1.3:10:1.1.1.1 with label B-L5, nexthop 2.2.2.3 and transport-target:0:100 from RR26. And it similarly resolves the nexthop 2.2.2.3 over transport class 100, pushing labels associated with PE25_to_ABR23_gold tunnel.

In this manner, the Gold transport LSP "ASBR13_to_PE11_gold" in egress-domain is extended by BGP CT until the ingress-node PE25 in ingress domain, to create an end-to-end Gold SLA path. MPLS swap routes are installed at ASBR13, ASBR22 and ABR23, when propagating the PE11 BGP CT Gold transport class route 1.1.1.3:10:1.1.1.1 with nexthop self towards PE25.

The BGP CT LSP thus formed, originates in PE25, and terminates in ASBR13, traversing over the Gold underlay LSPs in each domain. ASBR13 uses UHP to stitch the BGP CT LSP into the "ASBR13_to_PE11_gold" LSP to traverse the last domain, thus satisfying Gold SLA end-to-end.

When PE25 receives service route with nexthop 1.1.1.1 and mapping community Color:0:100, it resolves over this BGP CT route 1.1.1.3:10:1.1.1.1. Thus pushing label B-L5, and pushing as top label the labels associated with PE25_to_ABR23_gold tunnel.

15.4. Data plane view

15.4.1. Steady state

This section describes how the data plane looks like in steady state.

CE41 transmits an IP packet with destination as 31.31.31.31. On receiving this packet PE25 performs a lookup in the IP FIB associated with the CE41 interface. This lookup yeids the service route that pushes the VPN service label V-L1, BGP CT label B-L5, and labels for PE25_to_ABR23_gold tunnel. Thus PE25 encapsulates the IP packet in MPLS packet with label V-L1(innermost), B-L5, and top

label as PE25_to_ABR23_gold tunnel. This MPLS packet is thus transmitted to ABR23 using Gold SLA.

ABR23 decapsulates the packet received on PE25_to_ABR23_gold tunnel as required, and finds the MPLS packet with label B-L5. It performs lookup for label B-L5 in the global MPLS FIB. This yields the route that swaps label B-L5 with label B-L4, and pushes top label provided by ABR23_to_ASBR22_gold tunnel. Thus ABR23 transmits the MPLS packet with label B-L4 to ASBR22, on a tunnel that satisfies Gold SLA.

ASBR22 similarly performs a lookup for label B-L4 in global MPLS FIB, finds the route that swaps label B-L4 with label B-L2, and forwards to ASBR13 over the directly connected MPLS enabled interface. This interface is a common resource not dedicated to any specific transport class, in this example.

ASBR13 receives the MPLS packet with label B-L2, and performs a lookup in MPLS FIB, finds the route that pops label B-L2, and pushes labels associated with ASBR13_to_PE11_gold tunnel. This transmits the MPLS packet with VPN label V-L1 to PE11, using a tunnel that preserves Gold SLA in AS 1.

PE11 receives the MPLS packet with V-L1, and performs VPN forwarding. Thus transmitting the original IP payload from CE41 to CE31. The payload has traversed path satisfying Gold SLA end-to-end.

15.4.2. Absorbing failure of primary path

This section describes how the data plane reacts when gold path experiences a failure.

Let us assume tunnel ABR23_to_ASBR22_gold goes down, such that now end-to-end Gold path does not exist in the network. This makes the BGP CT route for RD prefix 1.1.1.1:10:1.1.1.1 unusable at ABR23. This makes ABR23 send a BGP withdrawal for 1.1.1.1:10:1.1.1.1 to RR26, which then withdraws the prefix from PE25.

Withdrawal for 1.1.1.1:10:1.1.1.1 allows PE25 to react to the loss of gold path to 1.1.1.1. Let us assume PE25 is provisioned to use best-effort transport class as the backup path. This withdrawal of BGP CT route allows PE25 to adjust the nexthop of the VPN Service-route to push the labels provided by the BGP LU route. That repairs the traffic to go via best effort path. PE25 can also be provisioned to use Bronze transport class as the backup path. The repair will happen in similar manner in that case as-well.

Traffic repair to absorb the failure happens at ingress node PE25, in a service prefix scale independent manner. This is called PIC (Prefix scale Independent Convergence). The repair time will be proportional to time taken for withdrawing the BGP CT route.

16. IANA Considerations

This document makes following requests of IANA.

16.1. New BGP SAFI

New BGP SAFI code for "Classful Transport". Value 76.

This will be used to create new AFI,SAFI pairs for IPv4, IPv6 Classful Transport families. viz:

*"Inet, Classful Transport". AFI/SAFI = "1/76" for carrying IPv4 Classful Transport prefixes.

*"Inet6, Classful Transport". AFI/SAFI = "2/76" for carrying IPv6 Classful Transport prefixes.

16.2. New Format for BGP Extended Community

Please assign a new Format (Type high = 0xa) of extended community EXT-COMM [RFC4360] called "Transport Class" from the following registries:

the "BGP Transitive Extended Community Types" registry, and

the "BGP Non-Transitive Extended Community Types" registry.

Please assign the same low-order six bits for both allocations.

This document uses this new Format with subtype 0x2 (route target), as a transitive extended community.

The Route Target thus formed is called "Transport Class" route target extended community.

Taking reference of RFC7153 [RFC7153] , following requests are made:

16.2.1. Existing registries to be modified

16.2.1.1. Registries for the "Type" Field

16.2.1.1.1. Transitive Types

This registry contains values of the high-order octet (the "Type" field) of a Transitive Extended Community.

Registry Name: BGP Transitive Extended Community Types

	TYPE VALUE	NAME
+	0x0a	Transitive Transport Class Extended Community (Sub-Types are defined in the "Transitive Transport Class Extended Community Sub-Types" registry)

16.2.1.1.2. Non-Transitive Types

This registry contains values of the high-order octet (the "Type" field) of a Non-transitive Extended Community.

Registry Name: BGP Non-Transitive Extended Community Types

	TYPE VALUE	NAME
+	0x4a	Non-Transitive Transport Class Extended Community (Sub-Types are defined in the "Non-Transitive Transport Class Extended Community Sub-Types" registry)

16.2.2. New registries to be created

16.2.2.1. Transitive "Transport Class" Extended Community Sub-Types Registry

This registry contains values of the second octet (the "Sub-Type" field) of an extended community when the value of the first octet (the "Type" field) is 0x07.

Registry Name: Transitive Transport Class Extended Community Sub-Types

RANGE	REGISTRATION PROCEDURE
0x00-0xBF	First Come First Served
0xC0-0xFF	IETF Review

SUB-TYPE VALUE	NAME
0x02	Route Target

16.2.2.2. Non-Transitive "Transport Class" Extended Community Sub-Types Registry

This registry contains values of the second octet (the "Sub-Type" field) of an extended community when the value of the first octet (the "Type" field) is 0x47.

Registry Name: Non-Transitive Transport Class Extended Community Sub-Types

RANGE	REGISTRATION PROCEDURE
0x00-0xBF	First Come First Served
0xC0-0xFF	IETF Review

SUB-TYPE VALUE	NAME
0x02	Route Target

16.3. MPLS OAM code points

The following two code points are sought for Target FEC Stack sub-TLVs:

- *IPv4 BGP Classful Transport
- *IPv6 BGP Classful Transport

17. Security Considerations

Mechanisms described in this document carry Transport routes in a new BGP address family. That minimizes possibility of these routes leaking outside the expected domain or mixing with service routes.

When redistributing between SAFI 4 and SAFI 76 Classful Transport routes, there is a possibility of SAFI 4 routes mixing with SAFI 1 service routes. To avoid such scenarios, it is RECOMMENDED that implementations support keeping SAFI 4 routes in a separate transport RIB, distinct from service RIB that contain SAFI 1 service routes.

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