Authors: K. Vairavakkalai, Ed.   M. Jeyananth
         Juniper Networks, Inc.   Juniper Networks, Inc.
         P.R. Ramadenu   I. Means
         AT&T Services, Inc.   AT&T

BGP Signaled MPLS Namespaces

Abstract

The MPLS forwarding layer in a core network is a shared resource.
The MPLS FIB at nodes in this layer contains labels that are
dynamically allocated and locally significant at that node. These
labels are scoped in context of the global loopback address. Let us
call this the global MPLS namespace.

For some usecases like upstream label allocation, it is useful to
create private MPLS namespaces (virtual MPLS FIB) over this shared
MPLS forwarding layer. This allows installing deterministic label
values in the private FIBs created at nodes participating in the
private MPLS namespace, while preserving the "locally significant"
nature of the underlying shared global MPLS FIB.

This document defines new address families (AFI: 16399, SAFI: 128,
or 1) and associated signaling mechanisms to create and use MPLS
forwarding contexts in a network. Some example use cases are also
described.

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

This Internet-Draft is submitted in full conformance with the
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1. Introduction

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   The MPLS FIB at nodes in this layer contains labels that are
   dynamically allocated and locally significant at that node. These
   labels are scoped in context of the global loopback address. Let us
   call this the global MPLS namespace.

   For some usecases like upstream label allocation, it is useful to
   create private MPLS namespaces (virtual MPLS FIB) over this shared
   MPLS forwarding layer. This allows installing deterministic label
   values in the private FIBs created at nodes participating in the
   private MPLS namespace, while preserving the "locally significant"
   nature of the underlying shared global MPLS FIB.

   This document defines new address families (AFI: 16399, SAFI: 128,
   or 1) and associated signaling mechanisms to create and use MPLS
   forwarding contexts in a network.

   The mechanism described in this document reuse [RFC4364] and
   [RFC8277] procedures to implement Upstream label allocation. The
   MPLS Namespace family uses BGP VPN style NLRI where the FEC is a
   MPLS Label, instead of IP prefix. The concepts of MPLS Context
   tables and upstream allocation are described in [RFC5331].

   A BGP speakers participating in a private MPLS namespace creates
   instance of "MPLS forwarding context" FIB, which is identified using
   a "Context Protocol Nexthop (CPNH)". A Context label MAY be

advertised for the Context Protocol Nexthop (CPNH) using a transport layer protocol or BGP family to other nodes.

2. Terminology

LSR : Label Switch Router

PE : Provider Edge

SFH : Service Forwarding Helper

UHP : Ultimate Hop Pop

MPLS FIB : MPLS Forwarding table

NLRI: Network Layer Reachability Information

AFI: Address Family Identifier

SAFI: Subsequent Address Family Identifier

BN : Border Node

TN : Transport Node, P-router

PE : Provider Edge

BGP VPN : VPNs built using RFC4364 mechanisms

BGP LU: BGP Labeled Unicast family (AFI/SAFIs 1/4, 2/4)

BGP CT: BGP Classful Transport family (AFI/SAFIs, 1/76, 2/76)

RT : Route-Target extended community

RD : Route-Distinguisher

VRF: Virtual Router Forwarding Table

PNH : Protocol Next hop address carried in a BGP Update message

CPNH: Context Protocol Nexthop

MNH : BGP MultiNexthop attribute

FEC : Forwarding Equivalence Class

RSVP-TE : Resource Reservation Protocol - Traffic Engineering

SEP : Service Endpoint, the PNH of a Service route

MPLS: Multi Protocol Label Switching

VNF : Virtual Network Function

vCP : VNF Control Plane

vFP : VNF Forwarding Plane

2.1. Definitions

PLSR: a BGP CT or BGP LU transit node in a private MPLS plane, that does label-swap forwarding for Context label.

PLER: an edge node in a private MPLS plane. It has a forwarding context for private labels.

Global MPLS FIB : Global MPLS Forwarding table, to which shared-interfaces are connected

Private MPLS FIB : Private MPLS Forwarding table, to which private interfaces are connected

Private MPLS FIB Layer (Private MPLS plane): The group of Private MPLS FIBs in the network, connected together via Context labels

Context label : Locally-significant Non-reserved label pointing to a private MPLS FIB

Context nexthop IP-address (CPNH) : An IP-address that identifies the "Private MPLS FIB Layer". RD:CPNH identifies a Private MPLS FIB at a specific BGP node.

Global nexthop IP-address (GPNH) : Global Protocol Nexthop address. E.g. a loopback address used as transport tunnel end-point.

Detour-router : A BGP border node that is used as a loose-hop in a traffic-engineered path

Service Family : BGP address family used for advertising routes for "data traffic" as opposed to tunnels (e.g. AFI/SAFIs 1/1 or 1/128).

Transport Family : BGP address family used for advertising tunnels, which are in turn used by service routes for resolution (e.g. AFI/SAFIs 1/4 or 1/76).

3. Motivation

A provider's core network consists of a global-domain (default forwarding-tables in P and PE nodes) that is shared by all tenants

in the network and may also contain multiple private user-domains (e.g. VRF route tables).

The global MPLS forwarding-layer can be viewed as the collection of all default MPLS forwarding-tables. This global MPLS Fib layer contains labels locally significant to each node. The "local-significance of labels" gives the nodes freedom to participate in MPLS-forwarding with whatever label-ranges they can support in forwarding hardware.

In emerging usecases some applications using the MPLS-network may benefit from a "static labels" view of the MPLS-network. In some other usecases, a standard mechanism to do Upstream label-allocation is beneficial.

It is desirable to leave the global MPLS FIB layer intact, and build private MPLS FIB-layers on top of it to achieve these requirements. The private MPLS FIBs can then be used by the applications as desired. The private MPLS FIBs need to be created only at the nodes in the network where predictable label-values (external label allocation) is desired. E.g. BNs that need to act as a "Detour-nodes" or "Service-Forwarding-Helpers" that need to mirror service-labels.

In other words, provisioning of these private MPLS FIBs can be gradual and can co-exist with nodes not supporting the feature described in this document. These private MPLS FIBs can be stitched together using either the Context labels over the existing shared MPLS-network tunnels, or 'private' context-interfaces - to form the "private MPLS FIB layer".

An application can then install the routes with desired label-values in the private forwarding contexts with desired forwarding-semantics.

4. Constructs and Building Blocks

The building-blocks that construct a private MPLS plane are described in this section.

4.1. Context Protocol Nexthop Address

A private MPLS plane (just "MPLS plane" here-after) is identified by an IP-address called Context Protocol Nexthop (CPNH). This address is unique in the core-network, like any other loopback address.

A loopback-address uniquely identifies a specific node in the network, and we call it Global Protocol Nexthop (GPNH) in this document. The CPNH address uniquely identifies a MPLS plane, aka "MPLS Namespace".

Each node that has forwarding context for a MPLS plane MUST be
configured with the same CPNH but a different RD, such that the
RD:CPNH will uniquely identify that node in the MPLS plane.

4.2. MPLS Context FIB

An instance of a MPLS forwarding-table at a node in the private MPLS
plane. This Private MPLS FIB contains the private label routes.

A node can have context FIB for multiple MPLS planes. The same
label-value can have a different forwarding-semantic in each MPLS
plane. Thus the applications using that MPLS plane get a
deterministic label-value independent of other applications using
other MPLS planes.

The terms "MPLS Namespace", "MPLS FIB-layer" and "MPLS plane" are
used interchangeably in this document.

4.3. Context Label

A Context label is a non-reserved dynamically allocated label, that
is installed in the global MPLS FIB, and points to a MPLS-context
FIB. The Context Label have forwarding semantics as follows in the
global MPLS FIB:

Context Label -> Pop and Lookup in MPLS-context FIB

Advertising the "context label in conjunction with the GPNH" tells
the network how to reach a "RD:CPNH".

4.4. Roles of Nodes in a MPLS Plane

The node roles in a MPLS plane can be classified into "edge nodes"
(call them PLER) or "transit-nodes" (call them PLSR).

4.4.1. Edge Nodes (PLER)

Private Label Edge-routers (PLER) have MPLS context FIB that belong
to the MPLS plane. They advertise the presence of this context FIB
using transport layer address families like BGP CT (SAFI 76) or BGP
LU (SAFI 4), and private label routes from this FIB are advertused
using new BGP AFI/SAFI described in this document.

4.4.2. Transit Nodes (PLSR)

These are just Border-nodes that do label-swap forwarding for the
context labels they see in the Context-Protocol-Nexthop
advertisement routes (BGP CT or BGP LU) going thru them. They
basically stitch/extend the label switched path to a PLER's CPNH
when they re-advertise the CPNH routes with next hop as self.

PLSRs dont have MPLS context FIBs. PLSRs dont have Context Protocol-Nexthop. Because they dont have Private label routes to originate.

However a node in the network can play both roles, of PLER and PLSR.

4.5. Sending Traffic into a MPLS Plane

At a PLER, MPLS-traffic arriving with private label hits the correct private MPLS FIB by virtue of either arriving on a "private network-interface" that is attached to the MPLS context FIB, or arriving with a "Context label" on a network-interface attached to the global MPLS FIB.

To send data traffic into this private MPLS plane, the sender MUST use as handle either a "Context label" advertised by a node or a "Private interface" owned by the MPLS context FIB at the node. The MPLS context FIB is created for an application that needs a private MPLS plane.

The Context label is the only dynamic label-value the application needs to learn from the network (PLER node it is connected to), to be able to use the private MPLS plane. The application can chose predictable value for the labels to be programmed in the private MPLS FIBs.

Once the packet enters the private MPLS plane at an edge-node (PLER), the node will forward the packet to the next node (PLSR or PLER), by pushing the Context label advertised by that next-node, and the transport-label to reach that node's GPNH. This will repeat until the packet reaches the PLER's private MPLS FIB that originated that private MPLS-label.

At each PLER in the MPLS plane, the private label value remains the same, and points towards the same resource attached to the MPLS plane. This allows the applications using the MPLS-network a static-labels view of the resourses attached to the private MPLS plane.

At each PLSR in the MPLS plane, the Context label value will change (be swapped in forwarding), but is transparent to the application.

5. BGP Families, Routes and Encoding

This section describes the new constructs defined by this document.

5.1. New Address Families for "MPLS Namespace Signaling"

This document defines a new AFI: "MPLS Namespaces" (IANA code 16399). And two new address-families, using SAFIs 128 and 1. These address families are used to signal MPLS namespaces in BGP. To send or receive routes of these address families, these AFI, SAFI pair of

values MUST be negotiated in Multiprotocol Extensions capability
described in RFC4760 [RFC4760]

5.1.1. AFI: 16399, SAFI: 128

This address-family is used to exchange private label-routes in
private MPLS FIBs at routers that are connected using a common
network interface. The private label route has NLRI prefix format
"RD:PrivateLabel" and contains Route-Target extended-community
identifying the private FIB Layer (VPN) the route belongs to. The
nexthop of these routes is set to either the GPNH or the CPNH of the
BGP-speaker advertising the RFC-8277 label.

Any transport layer protocol is used to advertise the Context label
that the receiving router uses to send traffic into the private MPLS
FIB. The Context label installed in the global MPLS FIB points to
the private MPLS FIB. The Context label is required when the
connecting-interface is a shared common interface that terminates
into the global MPLS FIB.

Routes of this address-family can be sent with either IPv4 or IPv6
nexthop. The type of nexthop is inferred from the length of the
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).

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

5.1.2. AFI: 16399, SAFI: 1

This address-family is used to exchange private label-routes in
private MPLS FIBs to routers that are connected using a private
network-interface.

Because the interface is private, and terminates directly into the
private MPLS FIB, a Context label is not required to access the
private MPLS FIB and NLRI prefix format is just "PrivateLabel/24",
without the RD.

Routes of this address-family can be sent with either IPv4 or IPv6
nexthop. The type of nexthop is inferred from the length of the
nexthop.

When the length of Next Hop Address field is 16 (or 32) the nexthop
address is of type IPv6 (potentially followed by the link-local IPv6
address of the next hop).

When the length of Next Hop Address field is 4 the nexthop address
is a 4 octet IPv4 address.

5.2. Routes and Operational Procedures

5.2.1. "Context-Nexthop" Discovery Route

The Context-NH discovery route may be a BGP LU or [BGP-CT] family
route that carries CPNH in the "Prefix" portion of the NLRI. And the
Context label is carried in the "Label" field in the [RFC8277]
format NLRI.

This route is advertised with the following path-attributes:

  *BGP Nexthop attribute (code 14, MP_REACH) carrying GPNH address.

  *Route-Target extended community, identifying the Transport class,
   if applicable.

The "Context-Nexthop discovery route" is originated by each speaker
who acts as a PLER. The "RD:Context-nexthop" uniquely identifies the
private MPLS FIB at the speaker. The "Context-nexthop address"
uniquely identifies the private MPLS plane in the network. The
Context label advertised in this route has a local forwarding
semantic of "Pop, Lookup in Private MPLS FIB".

A BGP speaker readvertising a BGP CT Context-Nexthop for RD:CPNH
discovery-route MUST follow the mechanisms described in [BGP-CT].
Specifically when re-advertising with "next-hop self" MUST allocate
a new Label with a forwarding semantic of "Swap Received-Context-
Label, Forward to Received-GPNH". This extends reachability to the
CPNH across tunnel domains.

5.2.2. MPLS Namespace "Private Label" Routes

The Private Label routes are carried in the new address-family "MPLS
VpnUnicast" (AFI:16399, SAFI:128) aka "MPLS namespace signaling",
defined in this document.

The NLRI format follows the specifications in [RFC8277], with the
"Prefix" portion of the NLRI comprising of the RD and "Private MPLS
Label" encoded as shown below.

In a MP_REACH_NLRI attribute whose AFI/SAFI is MPLS/128, the
"Length" field will be 112 bits or less, comprising of the Label, RD
and "Private MPLS Label".

In a MP_REACH_NLRI attribute whose AFI/SAFI is MPLS/1, the "Length"
field will be 48 bits or less, comprising of the Label, and "Private
MPLS Label".

NLRI Prefix (Private Label route, AFI:16399, SAFI:128)

This picture shows NLRI format when the RFC-8277 Multiple Labels
Capability is not used:

```
     0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |    Length     |                Label               |Rsrv |S|
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |              Route Distinguisher (RD) (8 octets)            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |               Route Distinguisher (RD cont.)                |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |       Private MPLS Label           |Rsrv |S|
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
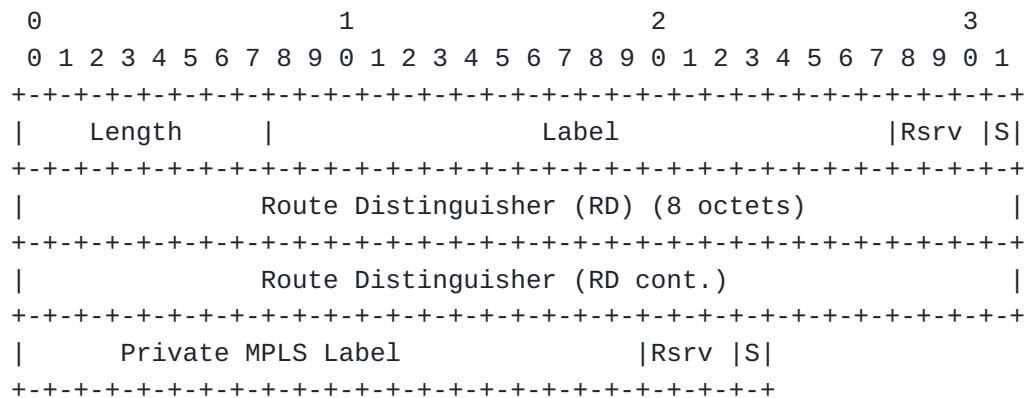
                  Fig 1: RFC-8277 NLRI with one Label.

- Length:
      The Length field consists of a single octet. It specifies the
      length in bits of the remainder of the NLRI field.

      In a MP_REACH_NLRI attribute whose AFI/SAFI is MPLS/128, the
      "Length" field will be 112 bits or less, comprising of the
      Label, RD and "Private MPLS Label".

      As specified in [RFC4760], the actual length of the NLRI field
      will be the number of bits specified in the Length field,
      rounded up to the nearest integral number of octets.

- Label:
      The Label field is a 20-bit field containing an MPLS label value
      (see [RFC3032]). This label is locally significant, downstream
      allocated at the speaker identified in the BGP Nexthop field
      in MP_REACH_NLRI (code 14). This label is pushed in nexthop of
      the route installed in MPLS context FIB at receiving router.

- Route Distinguisher (RD):
      The 8 byte Route Distinguisher as specified in [RFC4760].

- Private MPLS Label:
      The "Private MPLS Label" field is a 20-bit field containing an
      MPLS label value (see [RFC3032]). This is an upstream assigned
      MPLS label, used as destination of route installed in MPLS
      context FIB at the receiving router.

- Rsrv:
      This 3-bit field SHOULD be set to zero on transmission and
      MUST be ignored on reception.

- S:

    This 1-bit field MUST be set to one on transmission and MUST
    be ignored on reception.

Attributes on this route:

  *BGP Nexthop attribute (code 14, MP_REACH) carrying a GPNH
   address. (OR)

  *The MultiNextHop attribute [MNH] with forwarding-semantic:

     -"Forward to RD:CPNH"

  *Route-Target extended-community, identifying the private FIB-
   layer

MultiNexthop BGP-attribute (Private Label route)

                +--+
                | MultiNH.Num-Nexthops = 1 |
                +--+
                | FwdSemanticsTLV.FwdAction = Forward |
                +--+
                | NHDescrTLV.NhopDescrType = RD:CPNH or GPNH|
                +--+

           Fig 2: MultiNexthop attr of Private Label route

A speaker MAY readvertise a private label route without changing the
Nexthop (RD:CPNH) carried in it, if the speaker is a pure PLSR.

If it does alter the nexthop to SelfRD:CPNH, it SHOULD act as a
PLER, and for e.g. originate a "Context-Nexthop discovery route" for
prefix "SelfRD:CPNH".

Even if the speaker sets nexthop-address to Self because of regular
BGP readvertisement-rules, Label Prefix MUST NOT be altered, and the
received NLRI "RD:Private-Label1" MUST be re-advertised as-is. Such
that value of label "Private-Label1" doesn't change while the packet
traverses multiple nodes in the private MPLS FIB layer.

The Route target attached to the route is the one identifying the
private MPLS FIB layer (VPN). The Private label routes resolve over
the Context-nexthop route that belong to the same VPN.

A node receiving a "Private Label route" RD:L1 MUST install the
label L1 in the private MPLS Forwarding-context idenfied by the
Route-Target attached to the route.

The label route MUST be installed with forwarding-semantic as
specified in the received MultiNextHop attribute. As an example, a
Detour node MAY receive the private label route with a forwarding-
semantic of "Forward to RD:CPNH" operation. And an Egress node MAY

receive a private label route with a forwarding-semantic pointing to
a resource it houses. Note that such a Private label BGP route MAY
be received from external-application also.

5.2.2.1. Resolving Received Private Label Routes

A node receiving a "Context-nexthop discovery route" MUST be capable
of using either the CPNH or the RD:CPNH carried in the NLRI, to
resolve other routes received with this CPNH address or RD:CPNH in
the "Nexthop-attributes".

The receiver of a private label route MUST recursively resolve the
received nexthop (RD:CPNH) over the Context-Nexthop discovery-route
for prefix "RD:CPNH" to determine the label stack "Context Label,
Transport Label" to push, so that the MPLS packet with private label
reaches the private MPLS FIB originating the route.

If a node receives multiple "Context-nexthop discovery route" for a
CPNH, it SHOULD run path-selection after stripping the RD, to find
the closest ingress to the private MPLS plane identified by the
CPNH. This best path SHOULD be used to resolve a received private
label route.

6. Example of Usecases

6.1. Label Spoof Protection in Inter-AS Option C Network

In certain deployments, some domains of an Inter AS Option C network
may be located in an untrusted geography. Even though such domains
are administered by the same operator, employing security mechanisms
may be desirable on interfaces connecting such domains.

This section describes how an Inter domain Option C MPLS network can
be protected against Label spoofing, using MPLS Namespaces
technology.

The inter-AS labeled traffic will be protected against spoofing,
such that the transport ASBRs will accept labeled traffic on inter-
AS links only if the MPLS label stack matches the transport and
service MPLS labels that have been advertised in BGP (LU and L3VPN)
families to the peers in untrusted zone.

In order to achieve this security, new functionality is required on
only the BNs, PEs or RRs in the trusted zone.

This section illustrates the mechanisms using BGP LU as transport
family and L3VPN as service family. But the mechanisms described
will work in similar manner for other labeled transport families
(e.g., BGP CT) and service families (e.g., L3VPNv6, EVPN, VPLS) as-
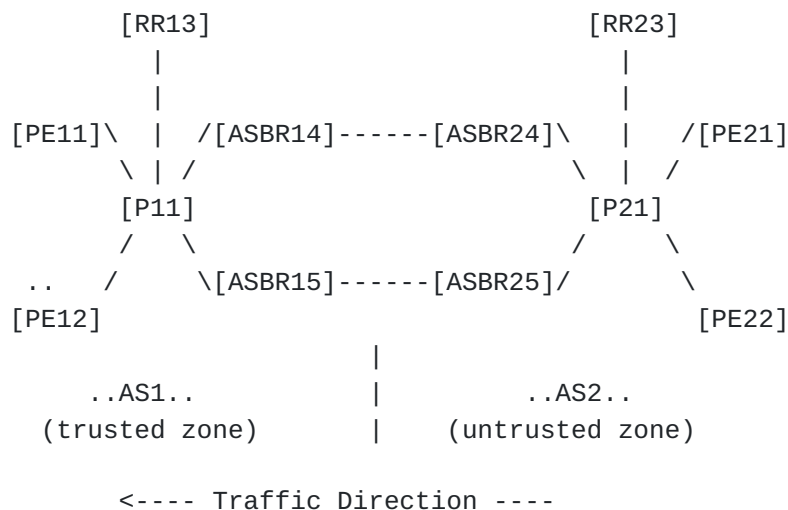well.

6.1.1. Reference Topology

```
         [RR13]                        [RR23]
            |                             |
            |                             |
    [PE11]\  |  /[ASBR14]------[ASBR24]\   |   /[PE21]
         \ | /                      \  |  /
          [P11]                      [P21]
         /    \                     /      \
     ..   /      \[ASBR15]------[ASBR25]/        \
   [PE12]                                   [PE22]
                           |
       ..AS1..             |          ..AS2..
     (trusted zone)        |     (untrusted zone)

           <---- Traffic Direction ----
```

Figure 1: Inter-AS Option C Network with a domain in untrusted zone

Figure 1 shows an Inter-AS Option C network with two domains. AS1 is in a trusted geography, and AS2 is in an untrusted geography.

BGP LU (AFI/SAFI: 1/4) is negotiated on EBGP sessions between ASBR14 - ASBR24 and ASBR15 - ASBR25. BGP LU is also negotiated on IBGP sessions in AS1 between RR13 and the nodes PE11, PE12, ASBR13, and ASBR14; also in AS2 between RR23 and the nodes PE21, PE22, ASBR24, and ASBR25. The ASBRs readvertise the BGP LU routes rewriting next hop to self. The RRs readvertise the BGP LU routes with the next hop unchanged.

L3VPN Service routes are present only at PEs and RRs in the two ASes. L3VPN family (AFI/SAFI: 1/128) is negotiated between PE11, PE12 and RR13. RR13 has multihop EBGP peering with RR23 and negotiates AFI/SAFI: 1/128. RR23 further peers with PE21, PE22 in AS2. The RRs readvertise the L3VPN service routes with next hop unchanged.

In this example loopback addresses of all PEs in one AS are reachable via BGP LU to the other AS.

Following sections describe the control plane and forwarding plane mechanics to deploy label spoofing protection using MPLS Namespaces in this network.

Traffic direction being described is AS2 to AS1, since focus is on traffic entering a trusted zone from an untrusted zone.

6.1.2. Spoof protection for Transport Labels

6.1.2.1. MPLS Namespace to Confine Untrusted Interfaces

At ASBR14 and ASBR15, the interfaces connecting to the BGP peers in
untrusted zone are provisioned to terminate in a separate MPLS
Namespace, lets call it "From-AS2" namespace. It identifies traffic
that is allowed from AS2. This namespace contains a distinct MPLS
FIB, which is different from the global MPLS FIB. MPLS packets
received on these interfaces are forwarded based on lookup in this
MPLS FIB.

ASBR14 and ASBR15 advertise BGP LU routes for PE11, PE12 loopbacks
to peers in AS2 with next hop self. Routes for the labels advertised
in these routes are installed in the "From-AS2" MPLS namespace.
Thus, MPLS packets received on these interfaces will be accepted
only if the outermost label is installed in this MPLS namespace FIB.
Packets with unknown labels will be discarded.

This provides spoof protection for the transport labels advertised
in BGP LU.

6.1.2.2. UHP Labels for PE Loopbacks

The border nodes ASBR14 and ASBR15 use UHP labels in BGP LU routes
when advertising a AS1 PE loopback to neighbors in AS2. This label
serves as Context Label that identifies traffic sent by AS2 towards
that PE in AS1.

The route for Context Label advertised to AS2 neighbors is installed
in the "From-AS2" MPLS namespace FIB. This route is installed with a
nexthop which has the forwarding semantic as "Pop, Lookup in MPLS-
namespace for the PE".

In this manner, the incoming MPLS traffic is validated against the
outermost label to match an advertised PE label, and then sent for
futher processing in context of the corresponding PE MPLS namespace.

6.1.3. Spoof protection for Service Labels

6.1.3.1. MPLS Namespace for Traffic Destined to a PE

At ASBR14 and ASBR15, a separate MPLS Namespace is created for PE11
and PE12. Lets call them "To-PE1" and "To-PE2" namespaces.

The namespace "To-PE11" identifies traffic direction towards PE11.
MPLS packets destined towards PE11 are forwarded based on lookup in
this MPLS namespace FIB.

The namespace "To-PE12" identifies traffic direction towards PE12.
MPLS packets destined towards PE12 are forwarded based on lookup in
this MPLS namespace FIB.

Packets are directed to these namespaces after being processed in
the "From-AS2" MPLS namespace FIB.

6.1.3.2. BGP MPLS Namespaces Family Routes

Correspondingly, MPLS Namespaces "To-PE11" and "To-PE12" are created
at RR13 which acts as an external label allocator for these
namespaces at these ASBRs. The namespace To-PE11 has an associated
Route Target RT-PE11. The namespace To-PE12 has an associated Route
Target RT-PE12. These Route Targets are exported by the RR and
imported by the ASBRs.

In AS1, the route reflector RR13 negotiates MPLS Namespace Signaling
family (AFI/SAFI: 16399/128) with the border nodes ASBR14 and
ASBR15.

Using the MPLS namespace signaling family, the RR13 insalls the VPN
service labels advertised by PE11 and PE12 into their corresponding
namespaces at the ASBRs.

Consider PE11 advertising to RR13 a VPN prefix RD:Pfx1 with VPN
label VL1, next hop as PE11. RR13 advertises this route with next
hop and label unchanged to RR23. When doing so, RR13 originates a
MPLS namespace signaling family (AFI/SAFI: 16399/128) route with
NLRI RDx:VL1, next hop as PE11, label field containing VL1, and the
Route Target RT-PE11.

ASBR14 receives this route and installs in the "To-PE11" MPLS
namespace FIB, based on matching import route target RT-PE11. The
received next hop PE11 is resolved to map to available tunnel from
ASBR14 to PE11. The MPLS route for label VL1 is installed to the
"To-PE11" MPLS namespace FIB. This ensures that packets sent by AS2
with VPN label as VL1 will be forwarded properly to PE11. But if an
unknown inner label was sent by AS2, such a packet will be dropped
after lookup in "To-PE11" MPLS FIB.

Similar mechanism works for labels advertised by PE12, using "To-
PE12" MPLS namespace RIB and FIB at RR and ASBRs.

In this manner, protection is provided against nodes in AS2 spoofing
service label also.

6.1.4. Applicability to Inter-AS Option B

These mechanisms can be used in Inter-AS Option B scenarios as-well.
In such cases, the procedures specified in are

applied to L3VPN family routes instead of BGP LU routes. MPLS
namespace signaling family (AFI/SAFI: 16399/128) is not used in this
case.

In Inter-AS Option B scenarios, ASBR14 and ASBR15 re-advertise BGP
L3VPN (AFI/SAFI: 1/128) routes from PE11, PE12 to peers in AS2 with
next hop self. Routes for the labels advertised in these routes are
installed in the "From-AS2" MPLS namespace. Thus, MPLS packets
received on these interfaces will be accepted only if the outermost
label is installed in this MPLS namespace FIB. Packets with unknown
labels will be discarded.

This provides spoof protection for the L3VPN service labels
advertised in BGP L3VPN (AFI/SAFI: 1/128) family.

6.2. Improve Scaling and Convergence of a Seamless MPLS Network

MPLS Namespaces can be used to improve scaling and convergence
properties of a scaled BGP MPLS network. It acts like a Mezanine
transport layer that decouples the service layer from the actual
transport layer.

Typically service routes in a MPLS network bind to the following
entities that identify point-of-presence of a service:

  *Protocol Nexthop - PE loopback address (GPNH)

  *Service Label - PE advertised locally signifcant label that
   identifies the service

In such a model, whenever a PE is taken out of service the GPNH
changes, and Service-Label changes - which makes maintenance a heavy
convergence event. Because the service routes with massive-scale
need to be readvertised with new service-label or PE-address.

An alternate model could be: to advertise the service routes with a
protocol-nexthop of CPNH identifying a namespace, with a forwarding-
semantic of:

  *"Push <Private-Label>, and Forward to CPNH"

This model fully decouples the service-layer from the transport-
layer identifiers, by making the Service routes refer to the CPNH
and Private Labels. Thus the underlying transport layer can change
(nodes representing a Private label can be added or removed) without
any changes to the service routes. This presents good convergence
scaling properties for the network.

This model also allows anycast traffic forwarding to any resource in
the network. Multiple PEs can advertise the same Private label to

identify a specific service (e.g. peering with an AS) they are offering.

Once the service route traffic enters the private FIB layer, at the closest entry-point determined by path-selection of CPNH auto-discovery routes; then the Private Labels (with pre determined values) pushed will determine the loose hop path taken by the traffic and also the destination-resource.

This section describes how scaling is achieved in an inter-domain MPLS network, where a domain is an AS or IGP area. Domain boundary is demarcated by a BN performing BGP next hop self action on the transport route.

It considers the scenario suggested in Section 6.3.2.1 of [Intent-Routing-Color] where 300K nodes exist in the network with 5 transport classes.

This may result in 1.5M transport layer routes and MPLS transit routes in all Border Nodes in the network, which may overwhelm the nodes' MPLS forwarding resources.

This section explains how "MPLS Namespaces" is used to scale such a network. This approach reduces the number of PNHs that are globally visible in the network, thus reducing forwarding resource usage network wide. Service route state is kept confined closer to network edge, and any churn is confined within the region containing the point of failure, which improves convergence.

In order to achieve these scaling benefits, new functionality is required only at a Region's Border Nodes and the Regional RRs. All other nodes can remain legacy nodes, and still get the scaling and convergence benefits of this mechanism. This is mainly advantageous to ingress and egress PE devices which may be low end devices not capable of pushing deep label stacks or supporting large number of ECMP next hops. They can enjoy the scaling benefits without needing software upgrades.

6.2.1. Illustration

Let us consider the decomposition of this example network with 300K nodes to be such that there are 300 domains containing 1000 nodes each. The mechanism described here will reduce the forwarding resource usage in all Border Nodes to become a function of number of domains (300) instead of number of nodes (300K). Thus, drastically reducing MPLS transit routes from 1.5M to 1500. The Border Nodes and Regional RRs in a Region do the job of abstracting the 1000 PE loopbacks from the rest of the network. The rest of the network sees this region as 1 BGP next hop, and not as 1000 BGP next hops.
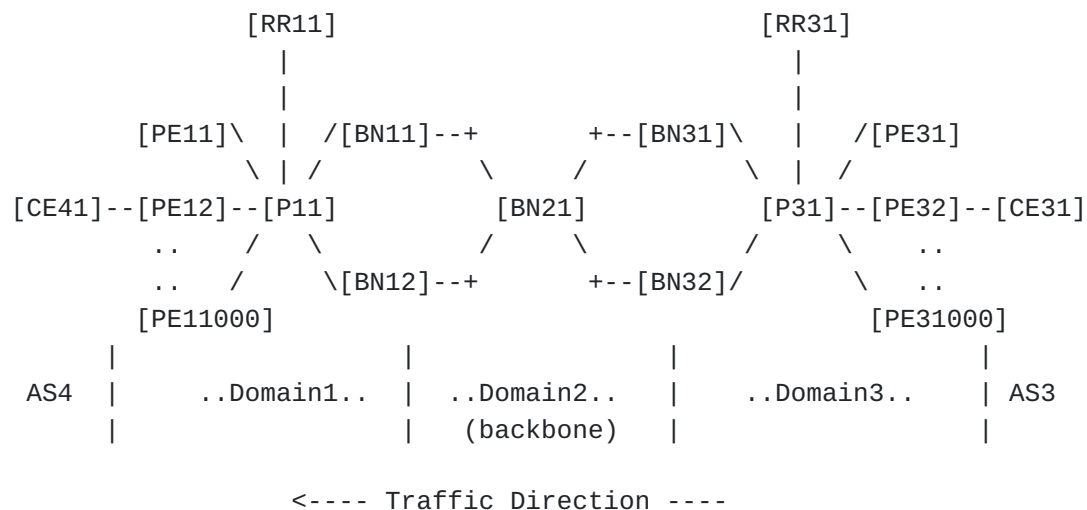
6.2.2. Topology

```
          [RR11]                            [RR31]
             |                                 |
             |                                 |
      [PE11]\  |  /[BN11]--+       +--[BN31]\   |   /[PE31]
            \ | /          \      /          \  | /
[CE41]--[PE12]--[P11]         [BN21]         [P31]--[PE32]--[CE31]
       ..    /   \          /     \          /    \    ..
       ..    /     \[BN12]--+       +--[BN32]/       \    ..
       [PE11000]                               [PE31000]
          |               |               |               |
  AS4  |      ..Domain1..  |  ..Domain2..   |    ..Domain3..    | AS3
       |               |  (backbone)    |               |


              <---- Traffic Direction ----
```

Figure 2: BGP MPLS Namespaces.

This topology in Figure 2 shows a cross section of the network with
focus on two domains Domain1 and Domain3 connected via a backbone
domain Domain2. Rest of the domains are not shown for brevity. The
border nodes have forwarding state pertaining to all domains in the
network. The control plane and forwarding plane state in node BN21
can be examined to determine the MPLS scaling characteristics of the
network.

L3VPN Service routes are present only at ingress and egress PEs.
L3VPN family (AFI/SAFI 1/128) is negotiated between PE11..PE11000
and regional route reflector RR11. RR11 has multihop EBGP peering
with RR31 and negotiates AFI/SAFI 1/128. RR31 further peers with all
PEs PE31..PE31000 in Domain3.

At the Transport layer - in Domain1, PE11..PE11000 negotiate BGP
families (AFI/SAFI 1/4, AFI/SAFI 1/76) with BN11, BN12. In Domain2,
BN11 and BN12 similarly negotiate the transport families with BN21,
which in turn peers with BN31 and BN32. In Domain3, BN31 and BN32
peer with PEs PE31..PE31000. Each of these BNs change BGP next hop
to self, when re advertising the AFI/SAFI 1/4, AFI/SAFI 1/76
transport routes.

When all nodes loopback addresses are visible throughout the
network, it will result in 1.5M transport layer routes and MPLS
transit routes in BN21.

Following sections describe the control plane and forwarding plane
mechanics to reduce this to 1500 routes, when MPLS Namespaces is
deployed in this network.

Traffic direction being described is CE41 to CE31. Reverse direction
would work in similar way.

6.2.3. Context Protocol Nexthop Address (CPNH)

A MPLS Namespace is identified by a Context PNH address. In MPLS
forwarding, labels are locally significant to the node advertising
it. E.g. labels in default/global MPLS Namespace are scoped by the
node's loopback address. The labels belonging to a MPLS Namespace
are locally significant in scope of the Context PNH address.

A UHP label called as "Context Label" is advertised for the CPNH in
a transport protocol, which points to the MPLS Namespace forwarding
context. When Context label is received as outer label in a MPLS
packet, it is Popped, and lookup is performed for the MPLS label
that appears in the MPLS Namespace identified by the CPNH.

In this example, CPNH is an anycast IP address that represents set
of PEs in a domain. E.g. CPNH1 represent all PEs in Domain1. And
CPNH3 represents all PEs in Domain3.

6.2.4. Service Forwarding Helper, and Changes to Transport Layer

The border nodes BN11, BN12 maintain the forwarding context for MPLS
Namespace identified by CPNH1. They advertise CPNH1 in transport
layer routes like AFI/SAFI 1/4 or AFI/SAFI 1/76 with a UHP Context
Label CL1. Any transport layer protocol may be used to advertise the
UHP Context Label for the CPNH.

In this way, BN11 and BN12 serve as Service Forwarding Helpers for
CPNH1 MPLS Namespace. They attract traffic that remote devices send
towards the BGP next hop CPNH1, and forward the MPLS packets
received with the MPLS labels belonging to the MPLS Namespace
identified by CPNH1.

The individual loopback addresses of the PEs need not be advertised
outside the local region. E.g. PE11..PE11000 are not advertised
beyond BN11, BN12. Only CPNH1 and RR11 addresses are advertised out.
RR1 is used for the control plane peering and CPNH1 is used as a
forwarding anchor point.

Similarly, Domain3 advertises only RR31 and CPNH3 to Domain2. This
significantly reduces the transport route scale and MPLS forwarding
resource usage at the border nodes throughout the network.

6.2.5. BGP MPLS Namespace Address family (AFI:16399, SAFI:128)

In Domain1, the regional route reflector RR11 negotiates MPLS
Namespace Signaling address family with the border nodes BN11, BN12.
RR11 is an external label allocator for the MPLS Namespace
identified by CPNH1. RR1 advertises in the MPLS Namespace address
family, the labels it allocated in scope of CPNH1. These routes are
advertised with a route target that identifies CPNH1. BN11 and BN12
use this route target to import the label route into the forwarding
context associated with CPNH1.

Similarly, in Domain3, RR31 negotiates MPLS Namespace Signaling
address family with the border nodes BN31, BN32.

6.2.6. Changes to Service Layer Route Exchange

When RR11 re-advertises to RR31 a VPN route RD:Pfx1 received with
label VL1 from egress PE11 in Domain1, it sets BGP next hop to
CPNH1, and advertises a new label PL1. This label PL1 is allocated
within the scope of CPNH1 namespace.

The label PL1 is advertised to BN1, BN2 in MPLS Namespace address
family with a route target identifying CPNH1, and BGP next hop PE11
and label VL1 that were received from the egress PE. BN1 and BN2
resolve the path to that BGP next hop PE11 and use as next hop for
the PL1 route installed in CPNH1 forwarding context.

The remote PEs in Domain3 consume the BGP updates from Domain1
following regular procedures for AFI/SAFI 1/128. When resolving the
BGP next hop CPNH1, they will push the context label that lands the
traffic into the correct forwarding context in one of the border
nodes.

6.2.7. Analysis of Forwarding Behavior

The forwarding behavior thus achieved is similar to Inter-AS Option
B, without carrying any service routes at the border nodes.
Furthermore, the MPLS namespace labels are installed in all the
border nodes, which allows for quicker traffic convergence in case
of border node failure. The number of border nodes can be increased
in a scale out manner, which gives a cookie cutter template to scale
a network region.

In conclusion, this mechanism provides both scaling and convergence
benefits for the MPLS network, and allows to support huge scale
networks.

6.3. VNF Service Forwarding Helper usecase

In a virtualized environment a Service PE node (that comprises of a vCP and multiple vFPs) can mirror MPLS labels (GL1) in its global MPLS FIB to a private forwarding context at an upstream node (SFH) with information on which vFPs are optimal exit-points for that label. Such that the SFH can optimally forward traffic to GL1 to the right vFPs, thus avoiding intra fabric traffic hops.

To do this, the service PE advertises a private label route with RD:GL1 to the SFH node. The route is advertised with a MultiNextHop attribute with one or more legs that have a "Forward to SEPx" semantics. Where SEPx is one of many exit-points at the Service-PE node.

6.4. BGP Based Standard API to Network's MPLS Forwarding Plane

This mechanism facilitates predictable (external allocator) label values, using a standard BGP family as the API. This gives the external applications a separate MPLS FIB to play with, totally separate from other applications.

This also avoids vendor specific API dependencies between external label allocators (e.g., Controller software), and network routers.

This mechanism also increases the overal MPLS label space available in the network. Because it creates per application label forwarding contexts (namespaces), instead of reserving ranges and splitting the global MPLS FIB among various applications.

6.5. Traffic Engineering and Service Chaining

MPLS namespaces provide an ingress PE the ability to steer MPLS traffic thru specific detour loose hop nodes using predictable label stack.

Labels in a MPLS namespace may be used to identify service chain hops, thus allowing to create a Service Chain consisting of multiple service functions.

Allows private MPLS label usage to spread across multiple domains(e.g., ASes) and works seamlessly with existing technologies like Inter-AS VPN option C.

7. IANA Considerations

This document makes following requests of IANA.

New BGP AFI code ("Address Family Numbers" registry):

   *16399 for "MPLS Namespaces"

Note to RFC Editor: this section may be removed on publication as an RFC.

8. Security Considerations

Using separate mpls forwarding contexts for separate applications and stitching them into separate MPLS planes increases the security attributes of the MPLS network.

9. Acknowledgements

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Contributors

Moshiko Nayman
Juniper Networks, Inc.
18 Buckingham Dr
Manalapan, New Jersey 07726
United States of America

Email: mnayman@juniper.net

Authors' Addresses

Kaliraj Vairavakkalai (editor)
Juniper Networks, Inc.
1133 Innovation Way,
Sunnyvale, CA 94089
United States of America

Email: kaliraj@juniper.net

Minto Jeyananth
Juniper Networks, Inc.
1133 Innovation Way,
Sunnyvale, CA 94089
United States of America

Email: minto@juniper.net

Praveen Ramadenu
AT&T Services, Inc.
3538 Torrance Blvd, Unit 124
Torrance, CA 90503
United States of America

Email: pr9637@att.com

Israel Means
AT&T
2212 Avenida Mara,
Chula Vista, California 91914
United States of America

Email: israel.means@att.com