The bridge to possible

White paper

Cisco public

Layer 4 to Layer 7 Service Redirection with Enhanced Policy-Based Redirect

Contents

Prerequisites

This document assumes that the reader is familiar with the configuration of VXLAN BGP EVPN data center fabric. The VXLAN BGP EVPN fabric can be provisioned using Cisco® Data Center Network Manager (DCNM). This document also assumes the end user is familiar with the policy-based routing constructs.

Background

Today, insertion of service appliances (also referred to as service nodes or service endpoints) such as firewalls, application delivery controllers, TCP optimizers, intrusion prevention systems and intrusion detection systems, are needed to secure and optimize applications within a data center. Typically, these Layer 4 to Layer 7 (L4-L7) service appliances are not inserted individually but as a chain. Traditional ways of accomplishing chaining of these service nodes include defining routing rules to influence the traffic path or using Policy-Based Routing (PBR).

This routing approach involves redirecting traffic to service appliances and forwarding all the traffic along the same path. While this approach works, all traffic traverses the service nodes, making them a potential bottleneck.

Alternatively, PBR can be used to selectively redirect traffic. The challenge with service chaining using PBR is that it requires the user to create unique policies per node and manage the redirection rules manually across all the nodes in the chain. Also, given the stateful nature of the service nodes, the PBR rules must ensure symmetry for the reverse traffic, and this adds additional complexity to the configuration and management of the PBR policies.

Further, in order to cater to the exponential growth in traffic, service chains need to scale up. Even though multiple service nodes of a given type are provisioned, efficient load-balancing mechanisms are required to regulate and distribute the traffic flowing toward these appliances. While PBR helps to some extent, it cannot entirely solve the problem.

A comprehensive solution involving selective traffic redirection along with load balancing is required. There is a need to empower users with the flexibility to influence such traffic flows with a simplified workflow to onboard service nodes, create traffic chains and load-balancing rules, and also ensure symmetry for reverse traffic.

Introduction

Cisco Nexus® 9000 NX-OS Enhanced Policy-Based Redirect (ePBR) is intended to help solve the challenges described above. ePBR in the Elastic Services Redirection (ESR) umbrella, provides the capability to selectively redirect and load-balance traffic across a data center network. This includes a data-center design using a VXLAN with BGP EVPN control plane with a distributed anycast gateway, as well as a three-tier core, aggregation/distribution, and access deployment with a centralized gateway.

ePBR completely automates the service chaining capability by creating multiple policies and by enabling hop-by-hop traffic steering using policy-based routing/redirection policies. These policies enforce traffic redirection by monitoring service-element health and reachability.

ePBR achieves service chaining without adding additional headers, and thus avoids any increased latency. All of the above is achieved at line rate, without any impact to throughput or performance. With the introduction of ePBR, the entire service onboarding, appliance monitoring using advanced probing mechanisms, service redirection, and load balancing are made flexible and easy to deploy.

Requirements

Table1 summarizes the hardware, software, and licensing requirements for the Cisco Nexus 9000 Series Switches that provide ePBR capability.

Table 1. Minimum hardware, software and licensing requirements for ePBR

Item	Requirement
Cisco NX-OS hardware	• Cisco Nexus 9300 EX platform • Cisco Nexus 9300 FX platform • Cisco Nexus 9300 FX2 platform • Cisco Nexus 9300 FX3 platform** • Cisco Nexus 9300 GX platform** • Cisco Nexus 9500 platform with X9700-EX line card* • Cisco Nexus 9500 platform with X9700-FX line card*
Cisco NX-OS software	Cisco NXOS Software Release 9.3(5) or later
Cisco NX-OS license	Cisco NX-OS Advantage package

This document does not cover the hardware and software requirements for the VXLAN EVPN site-internal network. The "References" section at the end of this document includes links that provide access to the Cisco websites specific to VXLAN BGP EVPN deployments.

* ePBRv6 over VXLAN is currently supported only on Cisco Nexus 9300 EX/FX/FX2/FX3/GX platforms.

** ePBR support on Cisco Nexus 9300 GX and FX3 platforms was introduced in Cisco NX-OS Release 10.1(1).

Deployment modes

ePBR currently supports the following deployment options with both IPV4 and IPV6 service endpoints:

- Fabric-based setup with VXLAN EVPN and appliances hosted on service leaves (Figure 1*).

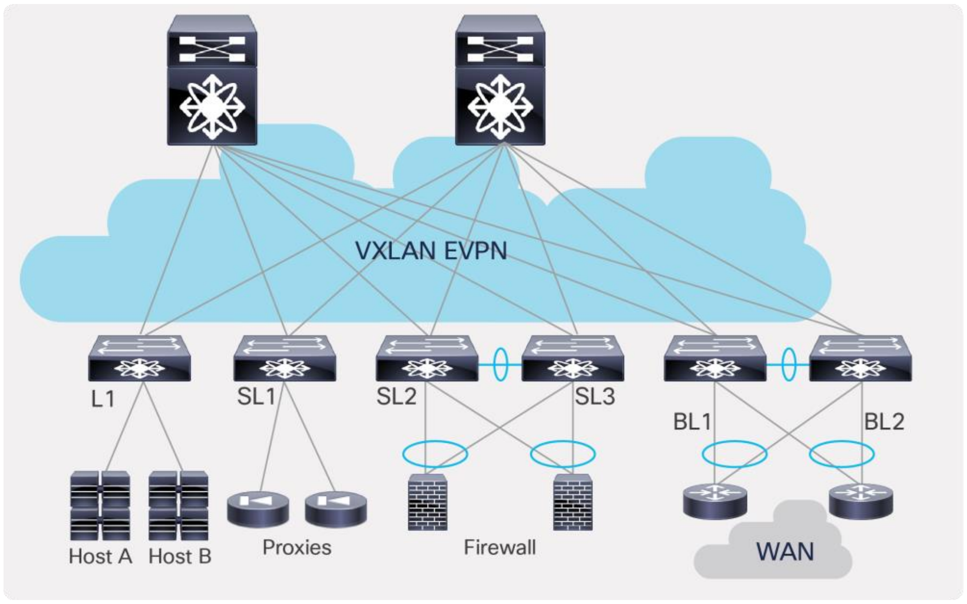


Figure 1.
Fabric-based setup with VXLAN EVPN

[*] Currently ePBR is supported within a single site in a VXLAN multisite fabric.

- Traditional centralized gateway deployment (Figure 2).

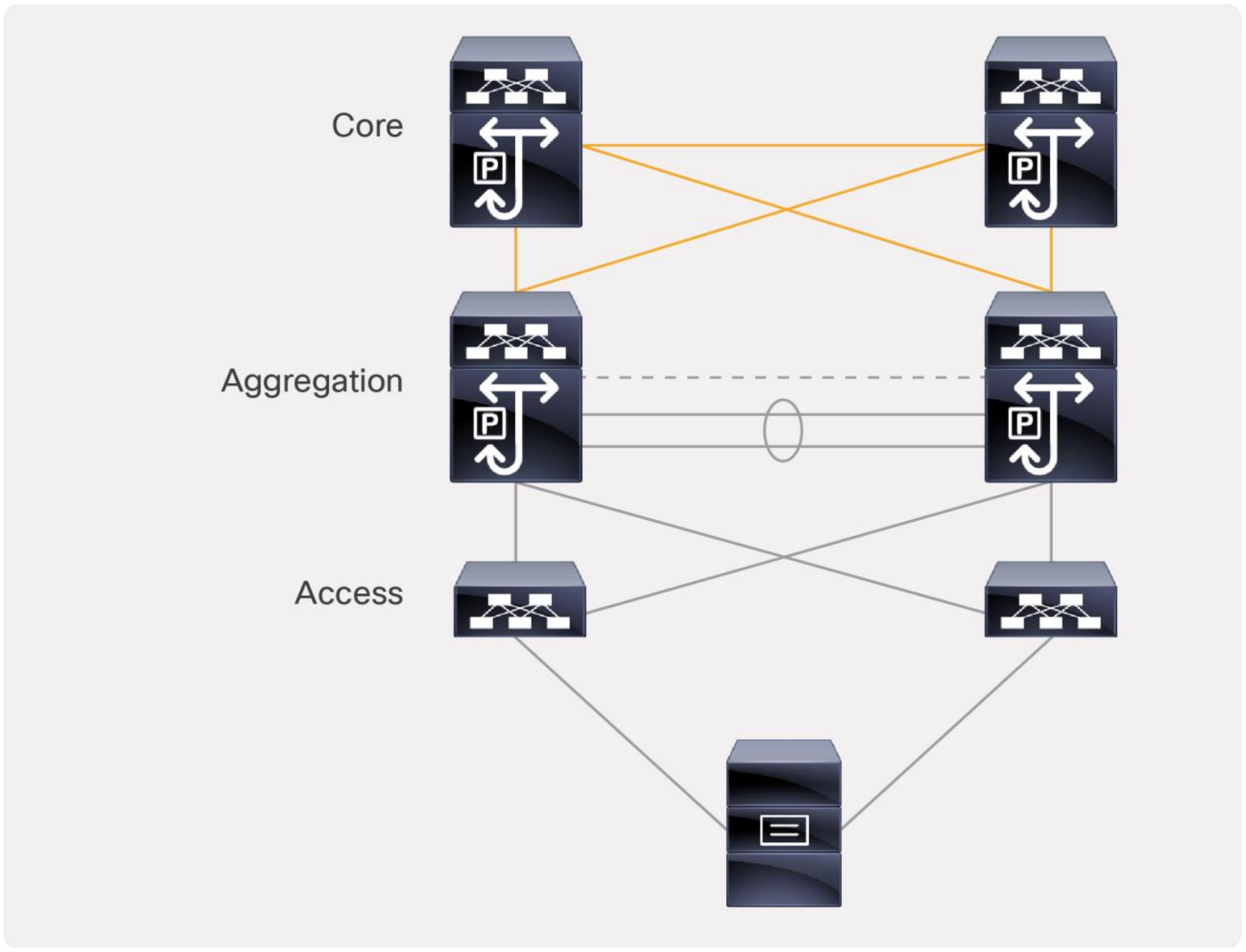


Figure 2.
Traditional centralized gateway deployment

Technology details

ePBR uses a combination of PBR with customized, bucket-based load sharing to achieve its load-balancing and traffic-steering capabilities. Once the user defines a policy with service chaining and load-balancing rules, ePBR automatically creates multiple PBR policies and applies them on the service interface belonging to the service nodes, and also creates IP SLA-based probes to monitor the health of the service nodes. Refer to the use cases for detailed configuration examples.

ePBR dependencies

- Prior to feature “epbr” enablement, feature “pbr” and feature “sla sender” need to be enabled as a prerequisite.
- In the case of a fabric-based deployment with VXLAN EVPN, feature HMM (host mobility manager) is required to track the locality of the service endpoint in the fabric.
- All redirection rules are programmed in ACL TCAM using the ingress RACL region. This region needs to be carved and allocated prior to the application of ePBR policies.

Configuration constructs

The ePBR configuration consists, essentially, of four simple steps:

Step 1: Onboard the service appliance

Step 2: Create the traffic-selection rules

Step 3: Define the ePBR traffic-redirect policy

Step 4: Apply the ePBR policy on the relevant interfaces

Step 1: Onboard the service appliance

This step enables the definition of service and its endpoints. The service-endpoint is the IP address of the service node itself, which ePBR in turn utilizes as a next-hop to redirect the traffic. The service interface is the SVI on the switch facing the service node. The reverse IP refers to the second arm of the service node. For service nodes that are single-arm, define the reverse IP with the same parameters as the service endpoint.

The following aspects of a service can be defined by the user:

1) IPV4/IPv6 address of the service endpoint along with reverse IP.
2) Forward and reverse interface details for single and dual-arm appliances, respectively.
3) Tenant or VRF membership.
4) Probing mechanism with flexible timers to monitor health of nodes.

   Note: A variety of probes, such as ICMP, TCP, UDP, HTTP, DNS, and user-defined custom probes, are supported. The source loopback interface can be specified to receive the probe responses.

5) Additional service endpoints in the case of an appliance cluster.

Service-definition example for an active/active firewall cluster

```
epbr service FIREWALL_CLUSTER
   probe icmp frequency 4 timeout 2 source-interface loopback9
   vrf TENANT_A
   ! fw1 definition
   !! Interface facing the firewall
   service-endpoint ip 172.16.1.200 interface VLAN100
   probe icmp frequency 4 timeout 2 source-interface loopback9
   !!! Reverse interface applies for two arm device
   reverse ip 172.16.2.200 interface VLAN101
   probe icmp frequency 4 timeout 2 source-interface loopback10
   !fw2 definition
   service-endpoint ip 172.16.1.201 interface VLAN100
     reverse ip 172.16.2.201 interface VLAN101
```

Step 2: Create the traffic-selection rules

Using an Access Control List (ACL), the user must define traffic that needs to be redirected. Users can match application traffic using a source IP, a destination IP, and L4 ports to define redirection rules. Only Access Control Entries (ACEs) that are prefix-based and use permit method are supported in the ACL. ACEs with any other method (such as deny or remark) are ignored.

Example for ACL creation:

```
# Custom_app rule1
ip access-list custom_app
10 permit tcp 172.16.10.0/24 eq 7800 any
20 permit tcp 192.168.20.0/24 eq 7800 any

#Web based application rule2
ip access-list web
10  permit tcp 172.16.10.0/24 any eq 80
20  permit tcp 192.168.20.0/24 any eq 80
```

Step 3: Define the ePBR traffic-redirect policy

This step enables the definition of ePBR traffic redirection policy, which gives the user the flexibility to create a service chain along with various fail-action mechanisms on service health failure. The following properties of ePBR policy can be defined by the user:

1) Predefined match ACLs (refer to step 2). The ePBR policy supports multiple ACL match definitions
   a. Redirect: default action for matching traffic and redirecting to a service chain
   b. Drop: match specific traffic and drop the traffic on the incoming interface
   c. Exclude: exclude certain traffic flows from the service chain on the incoming interface
2) Load-balance method (The section "Load balancing using ePBR" in this document explains how load balancing is achieved in ePBR.)
   a. Source IP or destination IP based
   b. Number of buckets to be configured in order to have granular load balancing of traffic
3) Service prefixed by sequence number to redirect selected traffic of interest to a service or across a chain
4) Fail-action methods to invoke on service reachability failure
   a. Forward: default option where traffic should use the regular routing tables
   b. Drop: traffic is dropped when service becomes unreachable
   c. Bypass: traffic is redirected to the next service sequence when there is a failure of the current sequence

Note: In the case of an appliance cluster, the fail-action mechanism will be invoked only when all service endpoints that belong to a service fail.

Example for policy definition:

```
epbr policy Tenant_A-Redirect
   match ip address WEB  !!! ACL matches web traffic
    load-balance method src-ip
    10 set service FIREWALL fail-action drop
    20 set service TCP_Optimizer fail-action bypass
  match ip address custom_app !!! ACL matches custom APP traffic
  load-balance method src-ip
    10 set service FIREWALL fail-action drop
```

Step 4: Apply the ePBR policy on the relevant interfaces

Once the ePBR policy is defined (refer to step 3), the policy needs to be applied on the ingress interface through which traffic flows into the fabric. Essentially, the policy is applied to any ingress interface from which the chaining starts. In the case of a VXLAN EVPN fabric, we would also need to apply the policy to all the L3 VNI interfaces on the service leaves hosting the appliances.

In order to maintain the traffic flow symmetry in the opposite direction, the end user would just need to apply the policy on the relevant interface along with the "reverse" keyword. If the reverse policy is enabled, ePBR autogenerates reverse rules for return traffic. It reverses the order in which the traffic traverses the chain, and also reverses the ACL matching the traffic.

Example for policy application

```
interface Vlan 2010
  !L3 VNI SVI
  epbr ip policy Tenant_A-Redirect
  epbr ip policy Tenant_A-Redirect reverse
```

Load balancing using ePBR

ePBR load balances by using a bucket-based load-sharing algorithm using a source or destination IP address. In the load-balance command, we provide the flexibility to the end user to specify the number of buckets, which allows the user to specify how granular the traffic should be distributed (refer step 3). If this option is not configured internally, we create default buckets higher or equal to the number of service nodes configured as part of the ePBR service.

The example below shows a bucket distribution of 2. An IP address ending with binary 00 is redirected to bucket 1, 01 to bucket 2, 10 to bucket 3, and 11 to bucket 4.

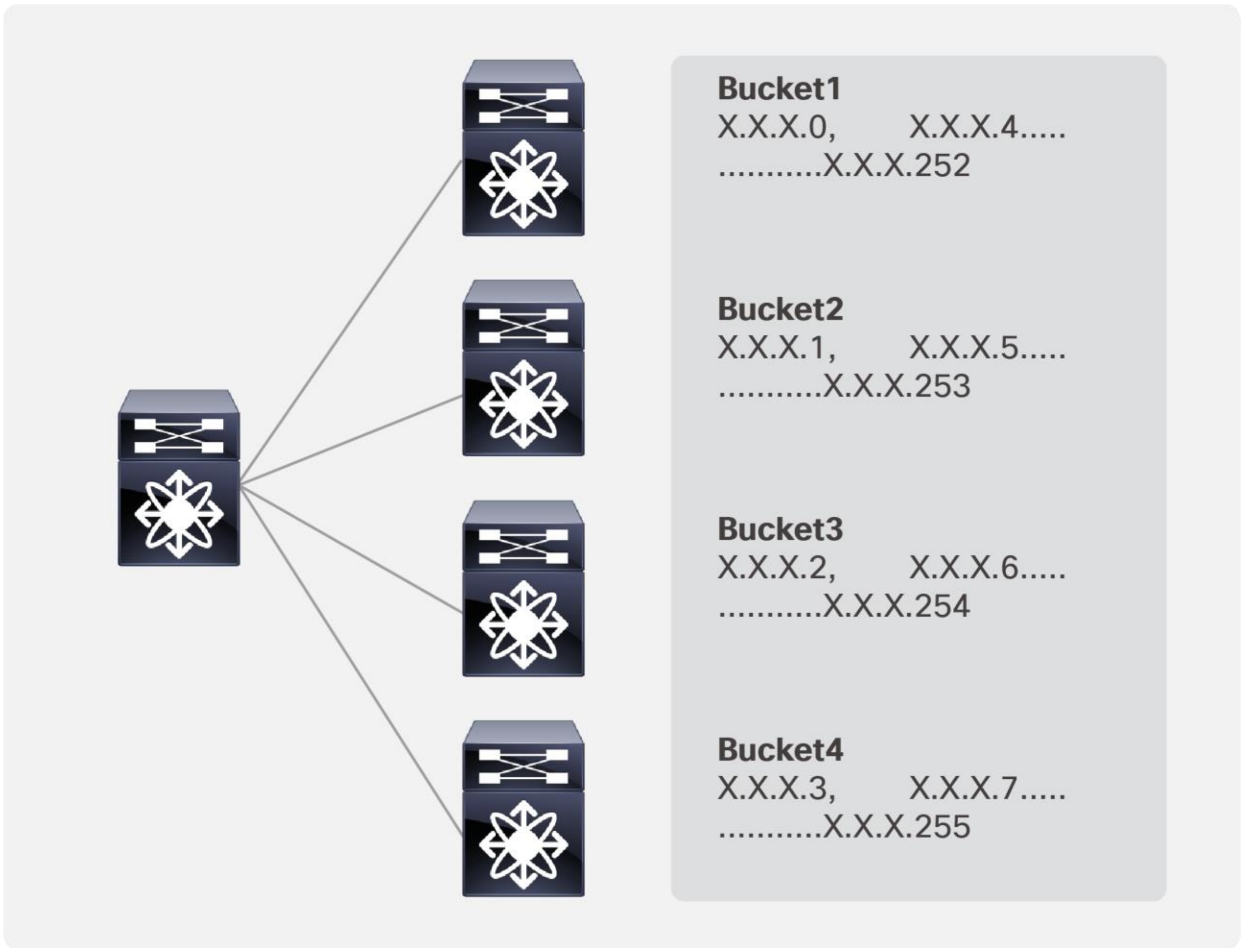


Figure 3.
Load balancing using ePBR

Example for load balancing:

```
epbr service fw_cluster
! 4 firewalls in this cluster to which the traffic needs to be load-balanced
  service-end-point ip 1.1.1.1
  service-end-point ip 2.2.2.2
  service-end-point ip 3.3.3.3
  service-end-point ip 4.4.4.4

ip access-list acl1
        10 permit ip 10.1.1.1/24 20.1.1.1/24
```

```
epbr policy p1
  match ip address acl1
   load-balance buckets 8 method src-ip
    10 set service fw_cluster

interface Vlan100
epbr ip policy p1
```

Autogenerated access list based on the algorithm to segregate traffic into multiple buckets

```
IP access list epbr_p1_1_fwd_bucket_1
        10 permit ip 10.1.1.0 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_2
        10 permit ip 10.1.1.1 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_3
        10 permit ip 10.1.1.2 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_4
        10 permit ip 10.1.1.3 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_5
        10 permit ip 10.1.1.4 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_6
        10 permit ip 10.1.1.5 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_7
        10 permit ip 10.1.1.6 0.0.0.248 20.1.1.1 0.0.0.255
IP access list epbr_p1_1_fwd_bucket_8
        10 permit ip 10.1.1.7 0.0.0.248 20.1.1.1 0.0.0.255
```

Changes and modification to service nodes or policy

ePBR sessions enable users to make modifications to ePBR policy non-disruptively. Using this capability, we are able to onboard new service nodes efficiently and make modifications to existing service chains with minimal traffic disruption.

ePBR sessions allow addition, deletion, or modification of the following aspects of in-service policies or services.

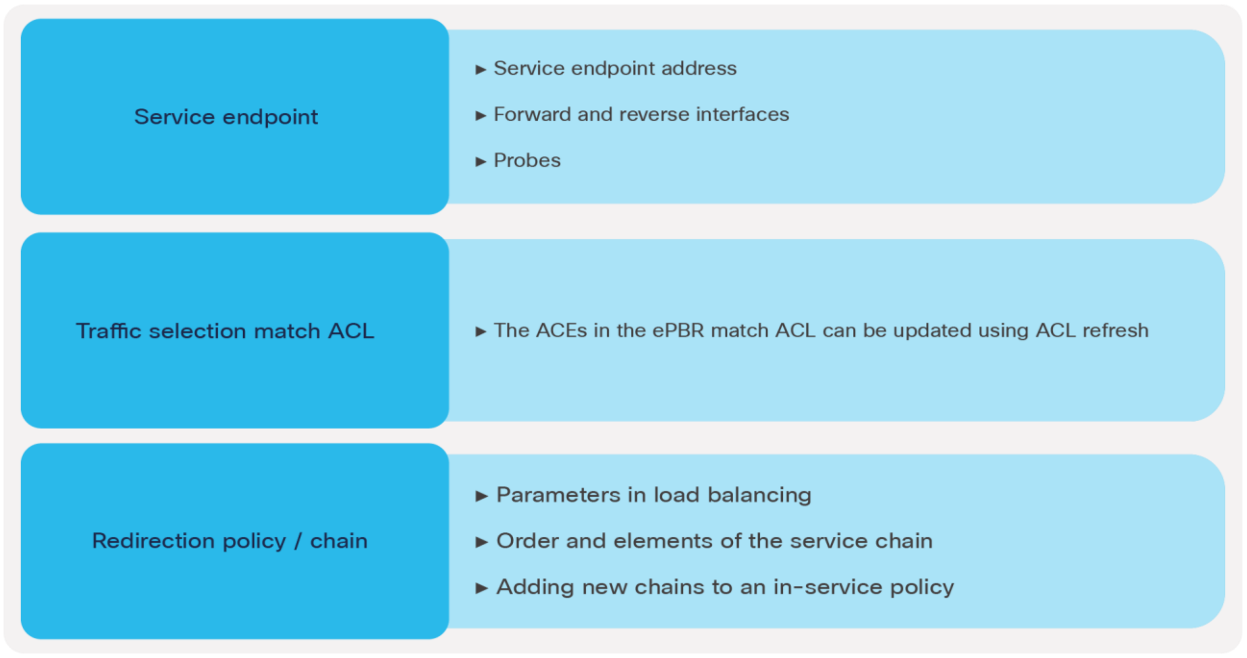

Service endpoint
► Service endpoint address
► Forward and reverse interfaces
► Probes
Traffic selection match ACL
► The ACEs in the ePBR match ACL can be updated using ACL refresh
Redirection policy / chain
► Parameters in load balancing
► Order and elements of the service chain
► Adding new chains to an in-service policy

Figure 4.
Non disruptive in-service config updates

Automating ePBR configuration using model-driven programmability

To configure, update, and automate the ePBR configuration in Cisco Nexus 9000 Series Switches, the following network configuration protocols are supported using XML and JSON payloads:

- REST
- NETCONF
- RESTCONF

External scripts and tools can be used to leverage the above configuration protocols to automate ePBR network provisioning. The “References” section at the end of this document includes a link to the ePBR NX-API REST user guide.

Use cases for ePBR

Note: All of the use cases listed below are supported on both VXLAN EVPN distributed anycast gateway deployment as well as core, aggregation, and access centralized gateway deployment.

Use case 1: ePBR for multidevice service chaining

This use case covers a deployment model where different applications in the data center need to traverse different service chains or service nodes.

Use case 1 deployment example:

The deployment here is that of a centralized gateway model (non VXLAN). In this scenario, client traffic for application App1 needs to be redirected to the firewall, IPS, and proxy and then sent to their destination, whereas application App 2 only requires redirection and load balancing to the cluster of caching services. The rest of the traffic must simply follow the default routing path.

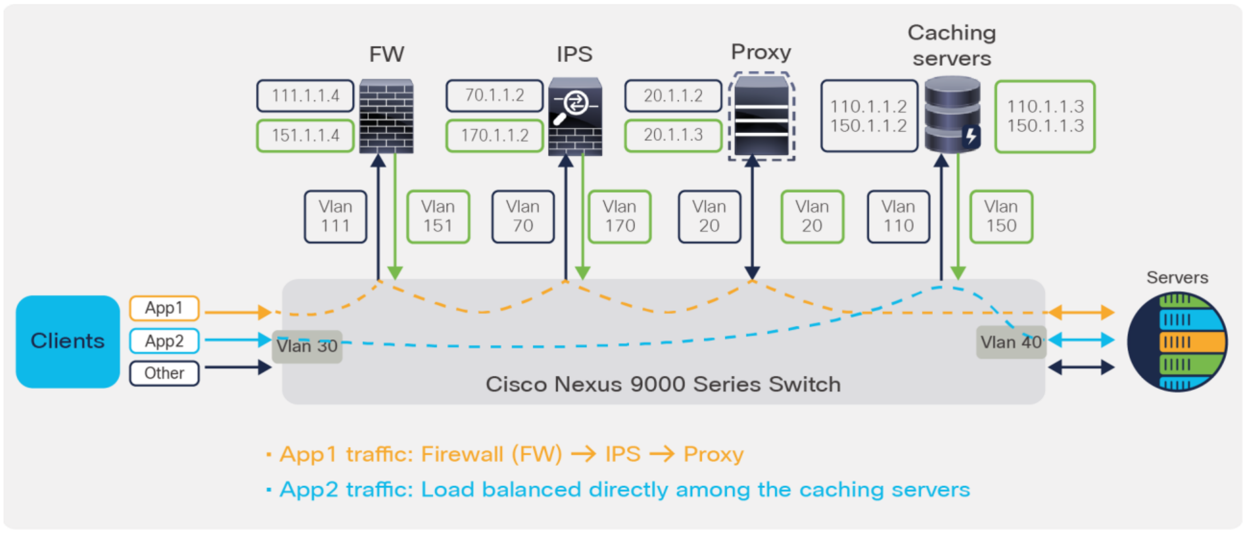


Figure 5.
Use case 1: ePBR for multidevice service chaining

Configuration:

```
Step 1: Onboard the appliances


epbr service firewall
  service-end-point ip 111.1.1.4 interface Vlan111
     probe icmp source-interface loopback0
    reverse ip 151.1.1.4 interface Vlan151
       probe icmp source-interface loopback1


epbr service ips
  service-end-point ip 70.1.1.2 interface Vlan70
     probe udp 45000
    reverse ip 170.1.1.2 interface Vlan170
       probe udp 45001
```

```
epbr service proxy
  service-interface Vlan20
   probe http get index.html
  service-end-point ip 20.1.1.2
    reverse ip 20.1.1.3

epbr service caching_servers
! traffic will be load-balanced between the servers
! server1
  service-end-point ip 110.1.1.2 interface Vlan110
     probe icmp source-interface loopback0
    reverse ip 150.1.1.2 interface Vlan150
       probe icmp source-interface loopback1
! server2
  service-end-point ip 110.1.1.3 interface Vlan110
     probe icmp source-interface loopback0
    reverse ip 150.1.1.3 interface Vlan150
       probe icmp source-interface loopback1
```

Step 2: Create traffic selection rules

Here 2 different match criteria (app1 and app2) are defined based on which our service redirection takes place.

```
ip access-list app1
        10 permit tcp 172.16.10.0/24 eq 7800 any
        20 permit tcp 192.168.20.0/24 eq 7800 any
ip access-list app2
        10 permit tcp 172.16.10.0/24 any eq www
        20 permit tcp 192.168.20.0/24 any eq www
```

Step 3: Define ePBR traffic redirect policy

In this policy defined below, on the event of firewall failure, the traffic is dropped. On the event of IPS failure, traffic bypasses this service element and is forwarded to the next element in chain which is Proxy in this case. Finally, on the event of Proxy failure, traffic is forwarded through routing table, which is also the default fail-action mechanism

```
epbr policy redirect_and_loadbalance
  statistics
  match ip address app1
    ! Traffic matching app1 takes FW→IPS→Proxy chain
    10 set service firewall fail-action drop
    20 set service ips fail-action bypass
    30 set service proxy fail-action forward
  match ip address app2
    ! Traffic matching app2 is load-balanced across caching servers
    load-balance buckets 8 method src-ip
    10 set service caching_servers
```

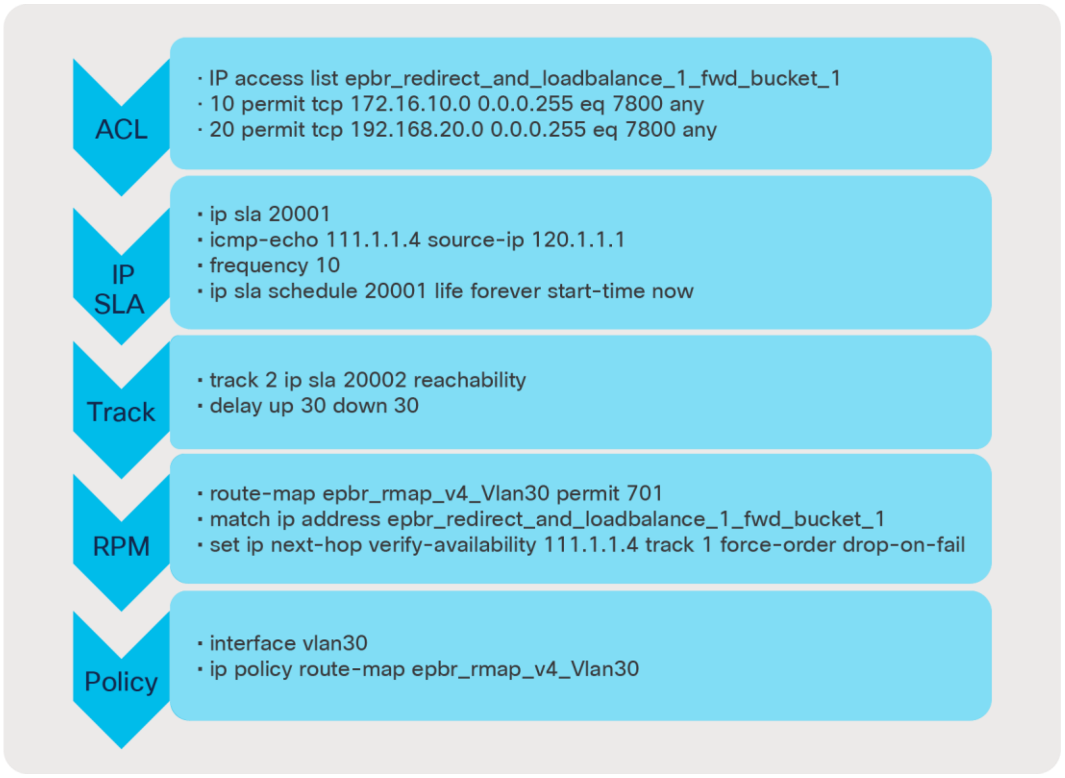
Step 4: Apply the ePBR Policy on relevant interfaces

```
interface Vlan30
  !forward policy applied to ingress interface facing clients
  no shutdown
  ip address 30.1.1.1/24
  ipv6 address 2030::1/24
  epbr ip policy redirect_and_loadbalance

interface Vlan40
! Reverse policy applied to egress interface facing server farm for reverse flow
  no shutdown
  ip address 40.1.1.1/24
  ipv6 address 2040::1/24
   epbr ip policy redirect_and_loadbalance reverse
```

Dynamic configuration snippet generated for forward chain with match ACL “app1”

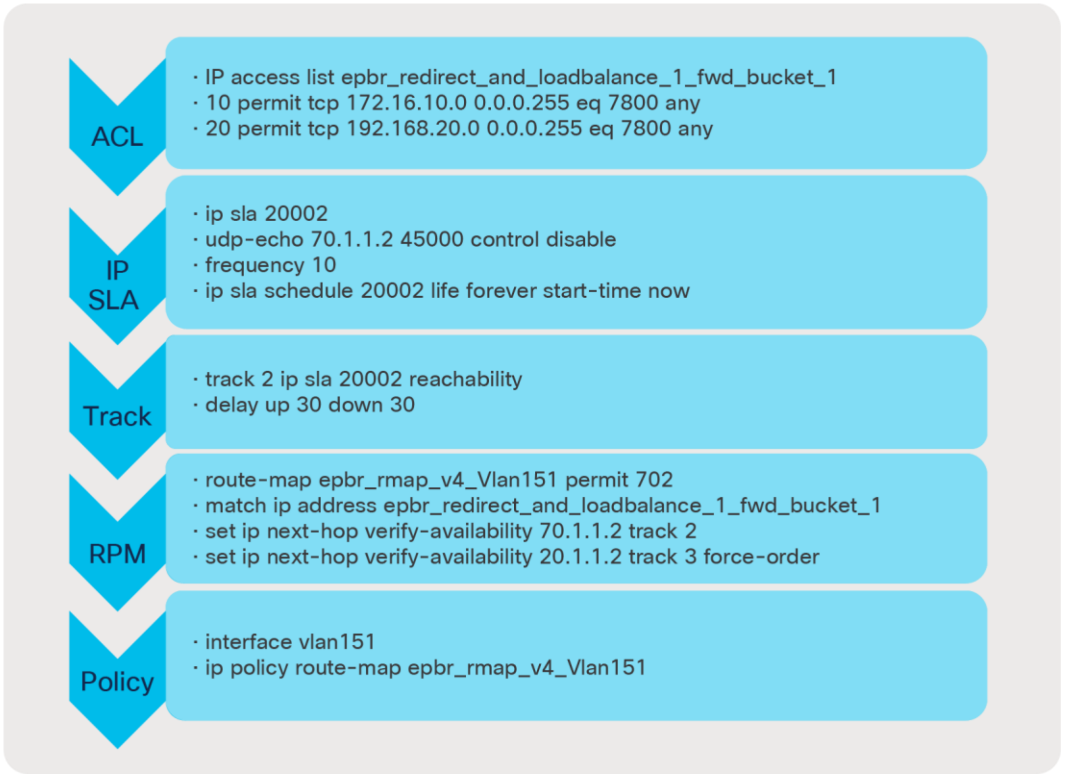
The configuration below gives a preview of how the ACLs, IP SLAs, tracks, route-maps, and PBR policies are autogenerated on a policy application; This in turn helps in traversing the chain from FW→IPS→Proxy.

1st Element in chain → corresponds to service firewall with fail-action drop.



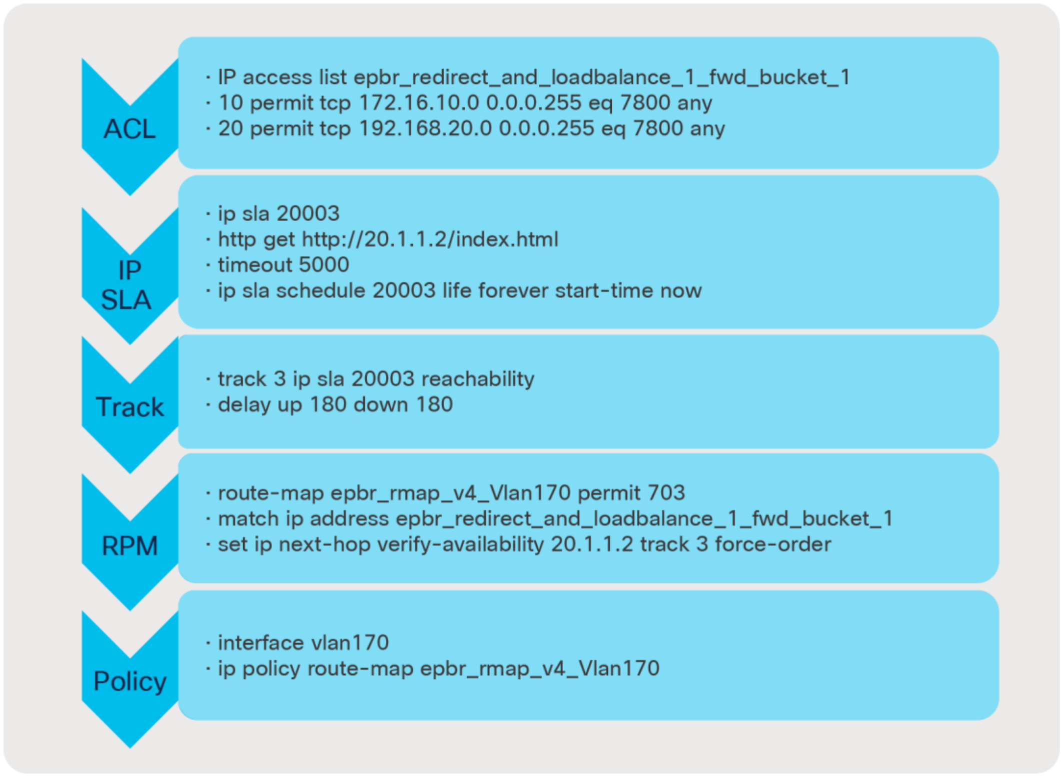
```
· IP access list epbr_redirect_and_loadbalance_1_fwd_bucket_1
· 10 permit tcp 172.16.10.0 0.0.0.255 eq 7800 any
· 20 permit tcp 192.168.20.0 0.0.0.255 eq 7800 any

· ip sla 20001
· icmp-echo 111.1.1.4 source-ip 120.1.1.1
· frequency 10
· ip sla schedule 20001 life forever start-time now

· track 2 ip sla 20002 reachability
· delay up 30 down 30

· route-map epbr_rmap_v4_Vlan30 permit 701
· match ip address epbr_redirect_and_loadbalance_1_fwd_bucket_1
· set ip next-hop verify-availability 111.1.1.4 track 1 force-order drop-on-fail

· interface vlan30
· ip policy route-map epbr_rmap_v4_Vlan30
```

2nd Element in chain → corresponds to service IPS with fail-action bypass.



```
· IP access list epbr_redirect_and_loadbalance_1_fwd_bucket_1
· 10 permit tcp 172.16.10.0 0.0.0.255 eq 7800 any
· 20 permit tcp 192.168.20.0 0.0.0.255 eq 7800 any

· ip sla 20002
· udp-echo 70.1.1.2 45000 control disable
· frequency 10
· ip sla schedule 20002 life forever start-time now

· track 2 ip sla 20002 reachability
· delay up 30 down 30

· route-map epbr_rmap_v4_Vlan151 permit 702
· match ip address epbr_redirect_and_loadbalance_1_fwd_bucket_1
· set ip next-hop verify-availability 70.1.1.2 track 2
· set ip next-hop verify-availability 20.1.1.2 track 3 force-order

· interface vlan151
· ip policy route-map epbr_rmap_v4_Vlan151
```

3rd Element in chain → corresponds to service Proxy with fail-action forward



```
· IP access list epbr_redirect_and_loadbalance_1_fwd_bucket_1
· 10 permit tcp 172.16.10.0 0.0.0.255 eq 7800 any
· 20 permit tcp 192.168.20.0 0.0.0.255 eq 7800 any

· ip sla 20003
· http get http://20.1.1.2/index.html
· timeout 5000
· ip sla schedule 20003 life forever start-time now

· track 3 ip sla 20003 reachability
· delay up 180 down 180

· route-map epbr_rmap_v4_Vlan170 permit 703
· match ip address epbr_redirect_and_loadbalance_1_fwd_bucket_1
· set ip next-hop verify-availability 20.1.1.2 track 3 force-order

· interface vlan170
· ip policy route-map epbr_rmap_v4_Vlan170
```

Similarly, on applying the reverse policy the reverse ACLs and route-map configurations are auto-generated by ePBR. ePBR also reverses the order in which return traffic traverses the chain.

ePBR policy runtime state verification using show command:

```
switch# show epbr policy redirect_and_loadbalance !! indicates forward traffic flow


Policy-map : redirect_and_loadbalance
  Match clause:
    ip address (access-lists): app1
  Service chain:
    service firewall, sequence 10, fail-action Drop
      IP 111.1.1.4 track 1 [UP]
    service ips, sequence 20, fail-action Bypass
      IP 70.1.1.2 track 2 [UP]
    service proxy, sequence 30, fail-action forward
      IP 20.1.1.2 track 3 [UP]
  Match clause:
    ip address (access-lists): app2
  Service chain:
    service caching_servers, sequence 10, fail-action No fail-action
      IP 110.1.1.2 track 4 [UP]
      IP 110.1.1.3 track 5 [UP]
  Policy Interfaces:
    Vlan30

switch# show epbr policy redirect_and_loadbalance  reverse !! indicates reverse traffic flow
Policy-map : redirect_and_loadbalance
  Match clause:
    ip address (access-lists): app1
  Service chain:
    service proxy, sequence 30, fail-action forward
      IP 20.1.1.3 track 8 [UP]
    service ips, sequence 20, fail-action Bypass
      IP 170.1.1.2 track 7 [UP]
    service firewall, sequence 10, fail-action Drop
      IP 151.1.1.4 track 6 [UP]
  Match clause:
    ip address (access-lists): app2
  Service chain:
    service caching_servers, sequence 10, fail-action No fail-action
      IP 150.1.1.2 track 9 [UP]
      IP 150.1.1.3 track 10 [UP]
  Policy Interfaces:
    Vlan40
```

ePBR policy statistics and traffic count verification using show commands :

```
switch# show epbr statistics policy redirect_and_loadbalance

Policy-map redirect_and_loadbalance, match app1
    Bucket count: 1
      traffic match : epbr_redirect_and_loadbalance_1_fwd_bucket_1
        firewall : 10
        ips : 10
        proxy : 10
Policy-map redirect_and_loadbalance, match app2
    Bucket count: 8
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_1
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_2
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_3
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_4
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_5
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_6
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_7
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_fwd_bucket_8
        caching_servers : 5


switch# show epbr statistics policy redirect_and_loadbalance reverse

Policy-map redirect_and_loadbalance, match app1
    Bucket count: 1
      traffic match : epbr_redirect_and_loadbalance_1_rev_bucket_1
        proxy : 10
        ips : 10
        firewall : 10
Policy-map redirect_and_loadbalance, match app2
    Bucket count: 8
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_1
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_2
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_3
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_4
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_5
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_6
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_7
        caching_servers : 5
      traffic match : epbr_redirect_and_loadbalance_2_rev_bucket_8
        caching_servers : 5
```

Use case 2: Selective traffic redirection across active/standby service appliances

In order to increase network reliability, provisioning two identical service appliances as a high-availability pair in active/standby fashion is a common deployment mode. In this use case, traffic from clients is selectively filtered based on match criteria and redirected to the firewall and load-balancer chain, before being sent to the server. ePBR intelligently tracks which node in each cluster is active and automatically redirects the traffic to the new active node in case the original active node fails.

Use case 2 deployment example:

In this example, we are using a two-tiered VXLAN EVPN spine-and-leaf network deployment.

The forward and reverse traffic flow from and to clients is always redirected to the active firewall and then to the active load-balancer. The solution automatically takes care of detecting which service node is active, so no additional configuration is necessary. Note that in Figure 6:

- BL is a border leaf or edge device
- L1 and L2 are server leaf switches hosting servers A and B
- SL A1, SL A2, SL B1, and SL B2 are VPC service-leaf switches hosting the firewall and load-balancer appliances in active/standby fashion.

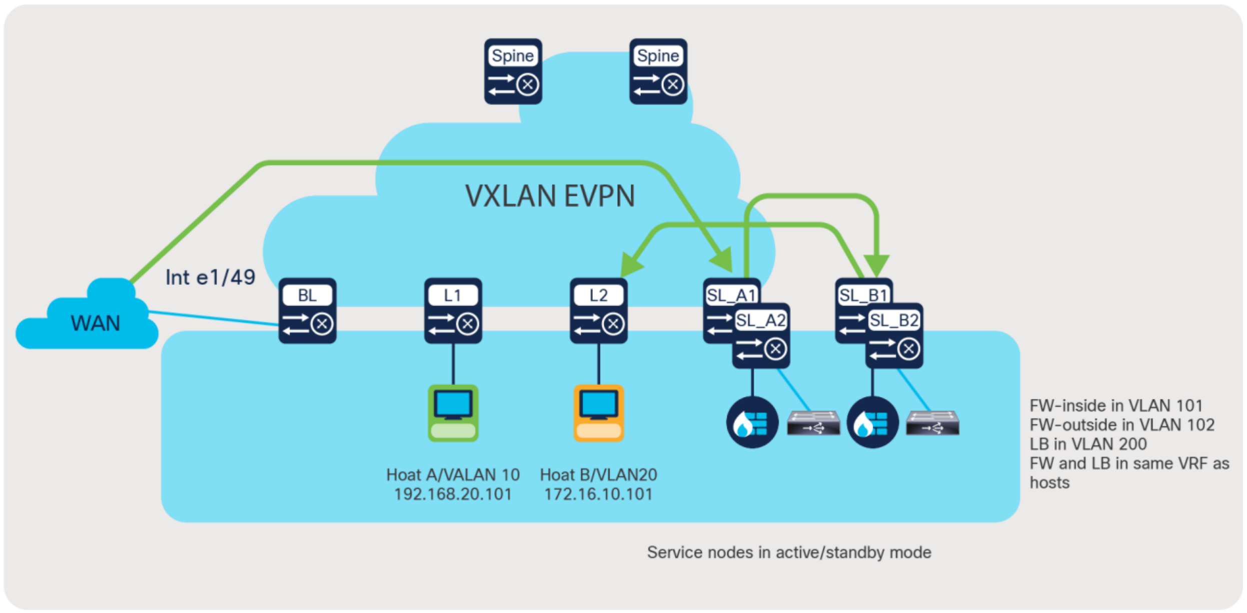


Figure 6.
Use case 2: Selective traffic redirection across active/standby service appliances

Here is a brief description of the intent of the use case depicted in Figure 6:

- Firewall is a dual-arm appliance, and the load balancer is a single-arm appliance.
- Traffic enters the border leaf on interface e1/49 from WAN.
- We need selective segregation of the traffic based on two match criteria, namely:
  - Custom application (which uses destination port 7800)
  - Web-based application (which uses destination port 80)

- Custom-application-based traffic needs to be redirected to the active firewall followed by the active load-balancer before going to the server.
- Web-application-based traffic needs to reach the firewall only and before being processed by the server.
- All other traffic uses routing table rules.
- The following fail-action rules need to be applied in the service-chain:
    - If LB is down, bypass the load-balancer.
    - If FW is down, drop the traffic.
- Symmetry must be maintained for return traffic.

Configuration on service leaves:

Step 1: Onboard appliances

```
epbr service firewall
  vrf tenant_a
  service-end-point ip 10.1.1.2 interface Vlan10
     probe icmp frequency 4 timeout 2 source-interface loopback9
    reverse ip 50.1.1.2 interface Vlan50
       probe icmp frequency 4 timeout 2 source-interface loopback10

epbr service load-balancer
  service-interface Vlan20
  vrf tenant_a
   probe http get index.html source-interface loopback9
  service-end-point ip 20.1.1.2
    reverse ip 20.1.1.2
! reverse ip for the load-balancer is same as the end-point ip as it is a single arm device
```

Step 2: Create traffic selection rules

```
ip access-list custom_app
        10 permit tcp 172.16.10.0/24 any eq 7800
        20 permit tcp 192.168.20.0/24 any eq 7800

ip access-list web
        10 permit tcp 172.16.10.0/24 any eq www
        20 permit tcp 192.168.20.0/24 any eq www
```

Step 3: Define ePBR traffic redirect policy

```
 epbr policy service_chain
  statistics
  match ip address custom_app
    load-balance buckets 4 method src-ip
    10 set service firewall fail-action drop
    20 set service load-balancer fail-action bypass
  match ip address web
    load-balance buckets 2 method src-ip
    10 set service firewall fail-action drop
```

Step 4: Apply the ePBR Policy on L3vni interfaces for forward and return traffic

```
interface Vlan100
  ! L3 VNI SVI
  vrf member tenant_a
    ip forward
  ipv6 forward
  epbr ip policy service_chain
  epbr ip policy service_chain reverse
```

Configuration on leaves hosting the servers:

Step 1,Step 2 and Step 3 are similar to configuring a service leaf

Step 4: Apply the ePBR Policy on relevant anycast gateway interfaces for return traffic from the servers to be redirected back to the WAN maintaining the symmetry

```
  Interface Vlan10
  vrf member tenant_a
  fabric forwarding mode anycast gateway
  epbr ip policy service_chain reverse
```

Configuration on border leaf:

Step 1: Onboard appliances – The end point definition need not necessarily have the SVI definition along if the endpoint is not local

```
pbr service firewall
  vrf tenant_a
  service-end-point ip 10.1.1.2
     probe icmp frequency 4 timeout 2 source-interface loopback9
    reverse ip 50.1.1.2
     probe icmp frequency 4 timeout 2 source-interface loopback10
```

```
epbr service load-balancer
  vrf tenant_a
  probe http get index.html source-interface loopback9
  service-end-point ip 20.1.1.2
    reverse ip 20.1.1.2
```

Step 2: Create traffic selection rules

```
ip access-list custom_app
        10 permit tcp 172.16.10.0/24 any eq 7800
        20 permit tcp 192.168.20.0/24 any eq 7800

ip access-list web
        10 permit tcp 172.16.10.0/24 any eq www
        20 permit tcp 192.168.20.0/24 any eq www
```

Step 3: Define EPBR traffic redirect policy

```
 epbr policy service_chain
  statistics
  match ip address custom_app
    load-balance buckets 4 method src-ip
    10 set service firewall fail-action drop
    20 set service load-balancer fail-action bypass
  match ip address web
    load-balance buckets 2 method src-ip
    10 set service firewall fail-action drop
```

Step 4: Apply the ePBR Policy on external interface connecting to the WAN

```
interface e1/49
  ! Interface facing the WAN
  vrf member tenant_a
  epbr ip policy service_chain
```

Note: In this case traffic hitting the border leaf is the forward traffic which needs to be redirected to the firewall before being processed by the servers. Hence only forward policy is applied here

ePBR policy runtime state verification using show commands:

```
show epbr policy service_chain

Policy-map : service_chain
  Match clause:
    ip address (access-lists): custom_app
  Service chain:
    service firewall, sequence 10, fail-action Drop
      IP 10.1.1.2 track 1 [UP]
    service load-balancer, sequence 20, fail-action Bypass
      IP 20.1.1.2 track 2 [UP]
  Match clause:
    ip address (access-lists): web
  Service chain:
    service firewall, sequence 10, fail-action Drop
      IP 10.1.1.2 track 1 [UP]
  Policy Interfaces:
    Eth1/49
Note: Use reverse keyword in show command to view reverse service chain


show epbr statistics policy service_chain

Policy-map service_chain, match custom_app

    Bucket count: 4
      traffic match : epbr_service_chain_1_fwd_bucket_1
        firewall : 10
        load-balancer : 0
      traffic match : epbr_service_chain_1_fwd_bucket_2
        firewall : 10
        load-balancer : 0
      traffic match : epbr_service_chain_1_fwd_bucket_3
        firewall : 10
        load-balancer : 0
      traffic match : epbr_service_chain_1_fwd_bucket_4
        firewall : 10
        load-balancer : 0
```

```
Policy-map service_chain, match web

    Bucket count: 2
      traffic match : epbr_service_chain_2_fwd_bucket_1
        firewall : 10
      traffic match : epbr_service_chain_2_fwd_bucket_2
        firewall : 10
```

Use case 3: Service chaining and load balancing in 5G deployments

Due to the exponential growth for wireless services over the years, the mobile packet core has one of the most demanding packet processing workloads. Mobile network operators have the need to classify traffic flows and redirect them as necessary to specific service nodes in order to meet certain security and optimization requirements.

ePBR service chaining and load-balancing capability together enable mobile network operators to flexibly insert and scale various network services in mobile packet core in order to deliver a high-quality and secure data-service experience for subscribers. ePBR can load balance across different service endpoints, enabling operators to horizontally scale their network.

Use case 3 deployment example:

The example below shows how traffic inside a mobile packet core can be load balanced first across a cluster of TCP optimizers and then service chained to firewall/IPS and CG-NAT devices, using ePBR. ePBR ensures that symmetry is maintained for a given flow by making sure that traffic in both forward and reverse direction is redirected to the same service endpoint in the cluster of TCP optimizers.

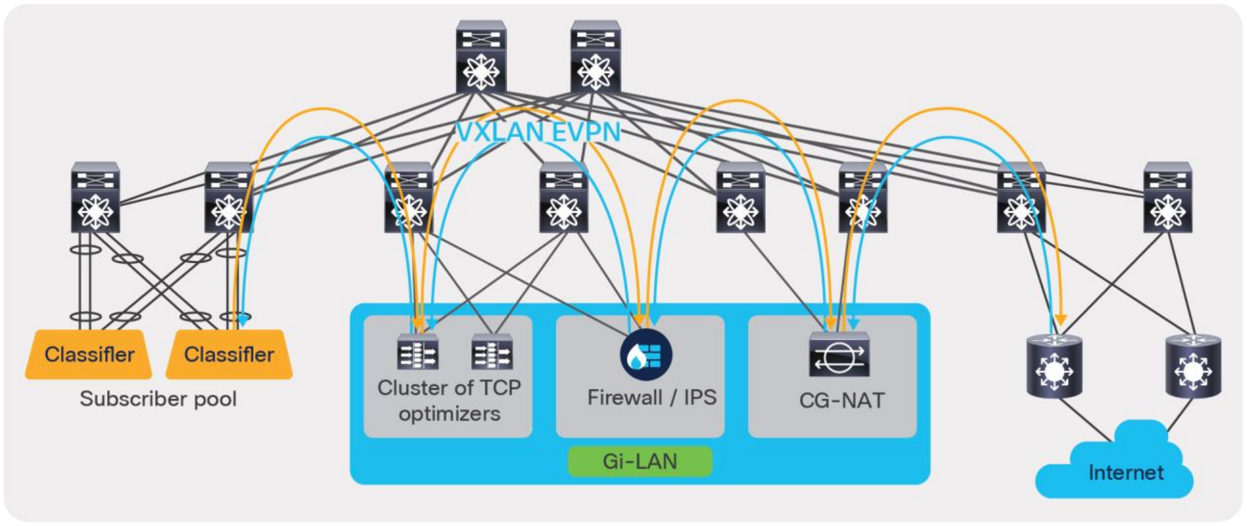


Figure 7.
Use case 3: Service chaining and load balancing in 5G deployments

Configuration on service leaves:

Step 1: Onboard the appliances

```
epbr service firewall
vrf tenant_a
  service-end-point ip 111.1.1.4 interface Vlan111
     probe icmp source-interface loopback0
    reverse ip 151.1.1.4 interface Vlan151
       probe icmp source-interface loopback1

epbr service cg_nat
vrf tenant_a
  service-interface Vlan20
   probe http get index.html
  service-end-point ip 20.1.1.2
    reverse ip 20.1.1.3

epbr service tcp_optimizers
vrf tenant_a
! traffic will be load-balanced between the optimizers
! optimizer1
  service-end-point ip 110.1.1.2 interface Vlan110
     probe icmp source-interface loopback0
    reverse ip 150.1.1.2 interface Vlan150
       probe icmp source-interface loopback1
! optimizer2
  service-end-point ip 110.1.1.3 interface Vlan110
     probe icmp source-interface loopback0
    reverse ip 150.1.1.3 interface Vlan150
       probe icmp source-interface loopback1
```

Step 2: Create traffic selection rules

```
ip access-list web
        10 permit tcp 172.16.10.0/24 any eq www
        20 permit tcp 192.168.20.0/24 any eq www
IP access list exclude_traffic
        10 permit tcp 172.16.10.10/32 any
        20 permit tcp 172.16.10.11/32 any
```

Step 3: Define ePBR traffic redirect policy

In the policy defined below, Traffic destined to web based application(filtered thru 'web' ACL), will be service chained. Additionally we exclude certain traffic flows from the service chain (filtered by 'exclude_traffic' ACL). On the event of TCP_optimizer cluster failure, the traffic is bypassed and is forwarded to the next element in chain. On the event of firewall or CG_NAT service node failure, traffic is dropped.

```
epbr policy servicechain_and_loadbalance
  statistics
  match ip address exclude_traffic exclude
  match ip address web
    ! TCP optimizer→firewall→cg_nat chain
    10 set service tcp_optimizers fail-action bypass
    20 set service firewall fail-action drop
    30 set service cg_nat fail-action drop
```

Step 4: Apply the ePBR Policy on ingress interface connecting to the classifier for forward traffic and apply policy with reverse keyword on egress interfaces connecting to the internet

```
interface Vlan30
  !forward policy applied to ingress interface facing classifier
  no shutdown
  ip address 30.1.1.1/24
  ipv6 address 2030::1/24
  vrf member tenant_a
  epbr ip policy servicechain_and_loadbalance

interface Vlan40
! Reverse policy applied to egress interface facing WAN for reverse flow
  no shutdown
  vrf member tenant_a
  ip address 40.1.1.1/24
  ipv6 address 2040::1/24
   epbr ip policy servicechain_and_loadbalance reverse

interface vlan100
! L3vni interface on service leafs
ip forward
no ip redirect
```

```
vrf member tenant_a
epbr ip policy servicechain_and_loadbalance
epbr ip policy servicechain_and_loadbalance reverse
```

ePBR policy runtime state verification using show commands:

```
show epbr policy servicechain_and_loadbalance

Policy-map : servicechain_and_loadbalance
  Match clause:
    ip address (access-lists): exclude_traffic
action:Deny
  Match clause:
    ip address (access-lists): web
action:Redirect
    service tcp_optimizers, sequence 10, fail-action Bypass
      IP 110.1.1.2 track 1 [UP]
      IP 110.1.1.3 track 2 [UP]
    service firewall, sequence 20, fail-action Drop
      IP 111.1.1.4 track 3 [UP]
    service cg_nat, sequence 30, fail-action Drop
      IP 20.1.1.2 track 4 [UP]
  Policy Interfaces:
    Vlan100

show epbr policy servicechain_and_loadbalance reverse

Policy-map : servicechain_and_loadbalance
  Match clause:
    ip address (access-lists): exclude_traffic
action:Deny
  Match clause:
    ip address (access-lists): web
action:Redirect
    service cg_nat, sequence 30, fail-action Drop
      IP 20.1.1.3 track 8 [UP]
    service firewall, sequence 20, fail-action Drop
      IP 151.1.1.4 track 7 [UP]
    service tcp_optimizers, sequence 10, fail-action Bypass
      IP 150.1.1.2 track 5 [UP]
      IP 150.1.1.3 track 6 [UP]
  Policy Interfaces:
    Vlan100
```

Figure 8 illustrates how ePBR can bypass the TCP optimizer on the event of a failure (ePBR detects the failure of a service node, using probes) and redirects the traffic to the next element in the chain, which is a firewall.

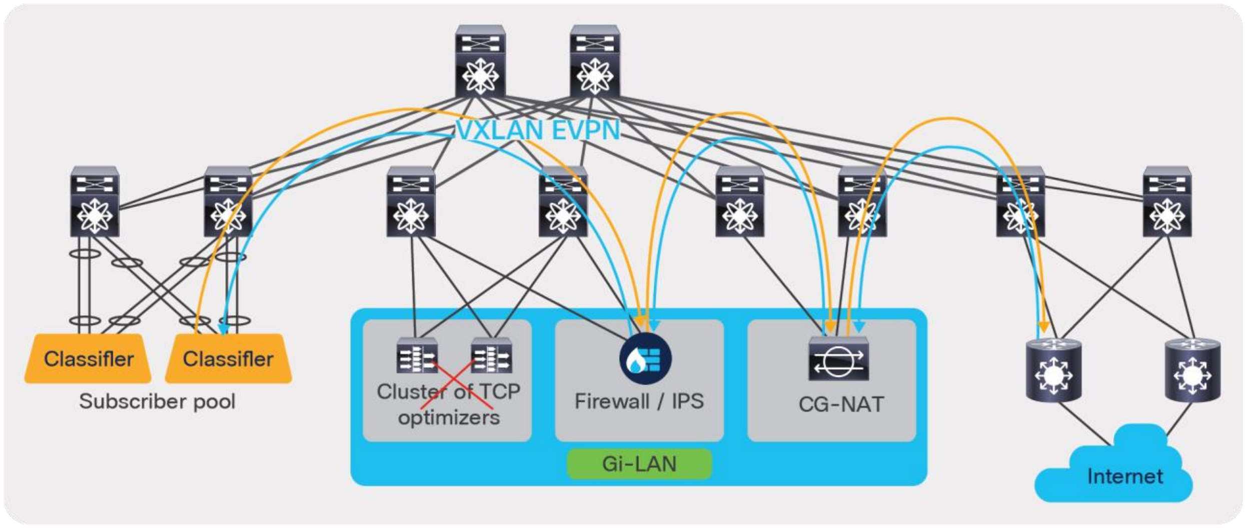
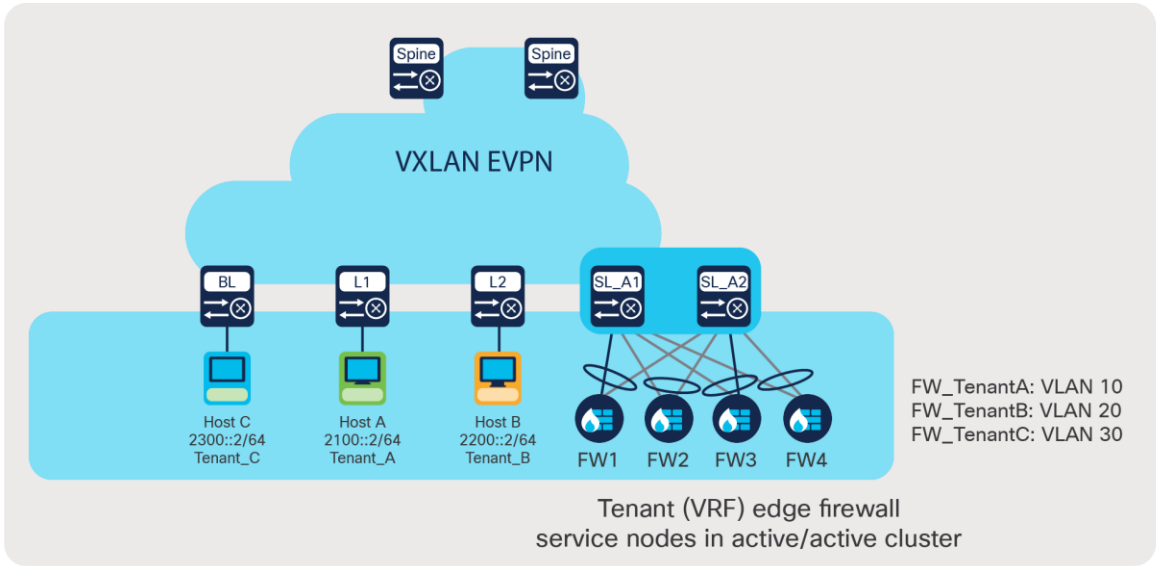


Figure 8.
ePBR bypass capability

Use case 4: Load share across a tenant edge firewall cluster

When integrating a Layer-3 firewall in a VXLAN EVPN fabric with a distributed anycast gateway, each of these zones must correspond to a VRF/tenant on the fabric. The traffic within a tenant is routed by the fabric. Traffic between the tenants is routed by a firewall. This scenario is often referred to as a tenant edge firewall. BGP or static route is typically used to peer between the firewall and the service leaf.

In a massively scaled data-center fabric, firewalls are becoming a bottleneck, and firewall clusters are provisioned to help alleviate this problem. ePBR can be leveraged to load share between the service nodes in the tenant edge firewall cluster. ePBR also helps in maintaining symmetry between forward and reverse traffic, thus supporting the stateful nature of the firewall.



Spine
Spine
VXLAN EVPN
BL
L1
L2
SL_A1
SL_A2
Host C 2300::2/64 Tenant_C
Host A 2100::2/64 Tenant_A
Host B 2200::2/64 Tenant_B
FW1
FW2
FW3
FW4
FW_TenantA: VLAN 10
FW_TenantB: VLAN 20
FW_TenantC: VLAN 30
Tenant (VRF) edge firewall service nodes in active/active cluster

Figure 9.
Use case 4: Load share across a tenant edge firewall cluster

Use case 4 deployment example:

- Traffic between different VRFs A, B, and C must be inspected by the tenant edge firewall.
- Forward and reverse traffic must land on the same firewall to maintain symmetry.

Step 1: Onboard appliances

- The order in which Firewall ip address are listed under each service should follow same order – FW1,FW2,FW3,FW4 . This will in turn ensure traffic in the forward and return direction hits the same firewall
- This below configuration is required only on the service leaf

```
epbr service FW_cluster_A
  service-interface Vlan10
  vrf Tenant_A
   probe icmp frequency 4 retry-down-count 1 retry-up-count 1 timeout 2 source-interface
loopback10
  service-end-point ipv6 2010::2
  service-end-point ipv6 2010::3
  service-end-point ipv6 2010::4
  service-end-point ipv6 2010::5

epbr service FW_cluster_B
  service-interface Vlan20
  vrf Tenant_B
   probe icmp frequency 4 retry-down-count 1 retry-up-count 1 timeout 2 source-interface
loopback20
  service-end-point ipv6 2020::2
  service-end-point ipv6 2020::3
  service-end-point ipv6 2020::4
  service-end-point ipv6 2020::5

epbr service FW_cluster_C
  service-interface Vlan30
  vrf Tenant_C
   probe icmp frequency 4 retry-down-count 1 retry-up-count 1 timeout 2 source-interface
loopback30
  service-end-point ipv6 2030::2
  service-end-point ipv6 2030::3
  service-end-point ipv6 2030::4
  service-end-point ipv6 2030::5
```

Step 2: Create traffic selection rules

```
IPv6 access list AtoB
        10 permit ipv6 2100::2/64 2200::2/64
IPv6 access list AtoC
        10 permit ipv6 2100::2/64 2300::2/64
IPv6 access list BtoA
        10 permit ipv6 2200::2/64 2100::2/64
IPv6 access list BtoC
        10 permit ipv6 2200::2/64 2300::2/64
IPv6 access list CtoA
        10 permit ipv6 2300::2/64 2100::2/64
IPv6 access list CtoB
        10 permit ipv6 2300::2/64 2200::2/64
```

Step 3: Define ePBR traffic redirect policy

- For forward traffic if source based load-balancing is chosen, return traffic must use destination based load-balancing as shown in example below

```
epbr policy Tenant_A
  match ipv6 address AtoB
    load-balance buckets 4 method src-ip
    10 set service FW_cluster_A
  match ipv6 address AtoC
    load-balance buckets 4 method src-ip
    10 set service FW_cluster_A

epbr policy Tenant_B
  match ipv6 address BtoA
    load-balance buckets 4 method dst-ip
    10 set service FW_cluster_B
  match ipv6 address BtoC
    load-balance buckets 4 method src-ip
    10 set service FW_cluster_B

epbr policy Tenant_C
  match ipv6 address CtoA
    load-balance buckets 4 method dst-ip
    10 set service FW_cluster_C
  match ipv6 address CtoB
    load-balance buckets 4 method dst-ip
    10 set service FW_cluster_C
```

```
Step 4: Apply the ePBR Policy on L3vni interfaces for forward and return traffic on
respective VRFs
Note: If there are servers on same leaf, the policy needs to be applied on the Tenant SVI as
well

interface Vlan110
  no shutdown
  vrf member Tenant_A
  ip forward
  ipv6 forward
  epbr ipv6 policy Tenant_A

interface Vlan120
 no shutdown
  vrf member Tenant_B
  ip forward
  ipv6 forward
  epbr ipv6 policy Tenant_B

interface Vlan130
 no shutdown
  vrf member Tenant_C
  ip forward
  ipv6 forward
  epbr ipv6 policy Tenant_C
```

ePBR policy runtime state verification using show commands:

```
show epbr policy Tenant_A
Policy-map : Tenant_A
  Match clause:
    ipv6 address (access-lists): AtoB
  Service chain:
    service FW_cluster_A, sequence 10, fail-action No fail-action
      IPV6 2010::2 track 1 [UP]
      IPV6 2010::3 track 2 [UP]
      IPV6 2010::4 track 3 [UP]
      IPV6 2010::5 track 4 [UP]
  Match clause:
    ipv6 address (access-lists): AtoC
  Service chain:
    service FW_cluster_A, sequence 10, fail-action No fail-action
      IPV6 2010::2 track 1 [UP]
      IPV6 2010::3 track 2 [UP]
      IPV6 2010::4 track 3 [UP]
      IPV6 2010::5 track 4 [UP]
  Policy Interfaces:
    Vlan110

show epbr policy Tenant_B
Policy-map : Tenant_B
  Match clause:
    ipv6 address (access-lists): BtoA
  Service chain:
    service FW_cluster_B, sequence 10, fail-action No fail-action
      IPV6 2020::2 track 5 [UP]
      IPV6 2020::3 track 6 [UP]
      IPV6 2020::4 track 7 [UP]
      IPV6 2020::5 track 8 [UP]
  Match clause:
    ipv6 address (access-lists): BtoC
  Service chain:
    service FW_cluster_B, sequence 10, fail-action No fail-action
      IPV6 2020::2 track 5 [UP]
      IPV6 2020::3 track 6 [UP]
      IPV6 2020::4 track 7 [UP]
      IPV6 2020::5 track 8 [UP]
  Policy Interfaces:
    Vlan120

show epbr policy Tenant_C
Policy-map : Tenant_C
  Match clause:
    ipv6 address (access-lists): CtoA
  Service chain:
    service FW_cluster_C, sequence 10, fail-action No fail-action
      IPV6 2030::2 track 10 [UP]
      IPV6 2030::3 track 11 [UP]
      IPV6 2030::4 track 12 [UP]
      IPV6 2030::5 track 13 [UP]
  Match clause:
    ipv6 address (access-lists): CtoB
  Service chain:
    service FW_cluster_C, sequence 10, fail-action No fail-action
      IPV6 2030::2 track 10 [UP]
      IPV6 2030::3 track 11 [UP]
      IPV6 2030::4 track 12 [UP]
      IPV6 2030::5 track 13 [UP]
  Policy Interfaces:
    Vlan130
```

Hardware resource utilization

ePBR leverages PBR (policy-based routing) to redirect traffic and hence uses "Ingress RACL" space in TCAM. Here is a brief explanation of the logic regarding how TCAM is calculated:

- Each match entry in ACL uses one TCAM entry.
- If the same policy is applied on multiple interfaces within a VRF, the TCAM is shared.
- When load balancing is enabled, the TCAM allocation is a multiplier of the number of ACEs used with the number of buckets specified in the policy.

  Example: If eight buckets are configured, TCAM usage = 8x No. of ACEs in the match ACL.
- If both forward and reverse ePBR policies are enabled, twice the resources should be accounted and accordingly allocated.

```
switch# show hardware access-list resource utilization | I RACL

ACL Hardware Resource Utilization (Mod 1)
--------------------------------------------------------------------------
                                                   Used    Free    Percent
                                                                        Utilization
--------------------------------------------------------------------------
             Ingress RACL                            2       1790    0.11
              Ingress RACL IPv4                      0               0.00
              Ingress RACL IPv6                      0               0.00
              Ingress RACL MAC                       0               0.00
              Ingress RACL ALL                       2               0.11
              Ingress RACL OTHER                     0               0.00
             Egress RACL                             2       1790    0.11
              Egress RACL IPv4                       0               0.00
              Egress RACL IPv6                       0               0.00
              Egress RACL MAC                        0               0.00
              Egress RACL ALL                        2               0.11
              Egress RACL OTHER                      0               0.00
             Ingress RACL                            2       1790    0.11
              Ingress RACL IPv4                      0               0.00
```

```
     Ingress RACL IPv6                      0               0.00
     Ingress RACL MAC                       0               0.00
     Ingress RACL ALL                       2               0.11
     Ingress RACL OTHER                     0               0.00
    Egress RACL                             2       1790    0.11
     Egress RACL IPv4                       0               0.00
     Egress RACL IPv6                       0               0.00
     Egress RACL MAC                        0               0.00
     Egress RACL ALL                        2               0.11
     Egress RACL OTHER                      0               0.00
```

Best practices

- It is recommended to not share the same traffic selection ACL and overlapping subnets across multiple match statements in the ePBR configuration.
- On the event of service or entire appliance cluster failure, symmetry in traffic can be achieved by using a fail-action bypass.
- For enabling health monitoring and probes in the fabric deployment, loopback interfaces must be configured as source interfaces in service endpoints.
- There can be only one drop and/or exclude ACL match statement per policy.
- In a VXLAN fabric, an active/standby chain with three or more service nodes in the chain requires that no two nodes of different types can be behind the same service leaf.

Conclusion

The Cisco Nexus 9000 Series Switches with ePBR enables users to optimize their data center by providing them simplified workflows to onboard service nodes and redirect traffic to them. The solution allows users to horizontally scale their service node deployment, ensuring that the network is never a bottleneck. This not only ensures application performance is optimal, but also ensures the network complies with security requirements. ePBR is an innovative solution and caters to the emerging needs of service chaining in modern data-center networks.

References

Additional documentation and related topics can be found at the sites listed below.

ePBR configuration guide: https://www.cisco.com/c/en/us/td/docs/dcn/nx-os/nexus9000/101x/configuration/epbr/cisco-nexus-9000-series-nx-os-epbr-configuration-guide-101x/m-configuring-epbr.html.

Table 2 from the link below provides ePBR verified scale numbers: https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus9000/sw/93x/scalability/guide-936/cisco-nexus-9000-series-nx-os-verified-scalability-guide-936.html.

ePBR NX-API REST API reference and user guide: https://developer.cisco.com/docs/cisco-nexus-3000-and-9000-series-nx-api-rest-sdk-user-guide-and-api-reference-release-9-3x/#!configuring-epbr/configuring-epbr.

VXLAN EVPN deployment and configuration information: https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus9000/sw/93x/vxlan/configuration/guide/b-cisco-nexus-9000-series-nx-os-vxlan-configuration-guide-93x.html.

L4 to L7 service integration and deployment using DCNM: https://www.cisco.com/c/en/us/td/docs/switches/datacenter/sw/11_4_1/config_guide/lanfabric/b_dcnm_fabric_lan/layer4_layer7_service.html.