Virtual Routing and Forwarding

Feature Summary and Revision History

Summary Data

Table 1: Summary Data

Applicable Product(s) or Functional Area	SMF
Applicable Platform(s)	SMI
Feature Default Setting	Disabled – Configuration Required
Related Changes in this Release	Not Applicable
Related Documentation	Not Applicable

Revision History

Table 2: Revision History

Revision Details	Release
Added VRF support for Diameter interfaces.	2023.04.0
The following enhancements are introduced: • Extended the maximum number of VRFs to 129 • Static and Dynamic Policy Removal	2023.01.0

Revision Details	Release
Support overlapping AAA server addresses for PAPN use case	2022.04.0
First introduced.	2020.02.5

Feature Description

Virtual Routing and Forwarding (VRF) is a technology that allows multiple instances of a routing table to coexist within the same router at the same time. As the routing instances are independent, you can use the same or overlapping IP addresses without conflicting with each other.

In private APN (PAPN) deployments, the same SMF can support multiple PAPNs, requiring authentication and accounting with the enterprise AAA servers. As the AAA servers belong to different mobile virtual network operators (MVNOs), it's possible that their address ranges overlap. The SMF uses VRF to allow the overlapping AAA server addresses in PAPN or MVNO.

Important Currently SMF doesn't support the overlapping addresses for the AAA client.

SMF uses VRF to also remove the Dynamic and Static routes based on UDP interfaces that are optimized by using the default route of VRF. This action replaces the policies with one default route per interface to improve the operational performance.

SMF enables configuration of VRF in the IP pool. The SMF sends IP address details along with the configured VRF name to UPF. UPF maps the IP address to VRF configured within UPF.

SMF supports up to 129 VRFs with a scale of 2K TPS for private APNs and DNNs.

SMF supports the client-side VRF for the Diameter Gx and Gy interfaces. The profile Diameter endpoint refers to the VRF name and interface name that you configure from the Diameter endpoint. The Diameter endpoint uses the VRF name to create a TCP connection from the Diameter client.

Note This implementation is backward compatible if you haven't configured a VRF. In such a case, the creation of a TCP socket towards the Diameter server is applicable with no VRF name configuration.

How it Works

This section describes how the SMF uses the VRF technology for the following use cases:

- PAPN
- Static and dynamic policy removal

VRF Creation

To create the VRF, perform the following steps:

1. Create VRF with gateway through CLI configuration.

   VRF gets created with a default route in the VRF routing table.

2. For the PAPN use case, each PAPN is associated with its own VRF having the default route. Each PAPN VRF must be defined on SMF and leaf switch.

3. For the Static and Dynamic policy removal use case, VRF with default route is created on SMF to handle outbound routes through the default route added by VRF.

   SMF continues to use global VRF for L3 VIP advertisement toward leaf switch. Hence, on leaf, no specific VRF is required for this use case.

VRF Modification

To modify the device or gateway on the existing VRF, use the following steps:

1. Disassociate the VRF to be modified from endpoint and router.
2. Delete the VRF and apply the configuration changes.

Important Make sure you delete the VRF in running system only.

3. Create VRF with modified device or gateway.
4. Associate newly created VRF with modified device or gateway with the endpoint and router. Apply the configuration changes.

VRF Deletion

To delete the device or gateway on the existing VRF, use the following steps:

1. Disassociate the VRF to be deleted from the endpoint and router.
2. Delete the VRF and apply the configuration changes.

Important Make sure you delete the VRF in running system only.

3. If the VRF is shared across logical SMFs, delete the VRF from all logical SMFs to completely remove the VRF configuration from the interface. This is applicable only for static and dynamic use case.

Limitations

This feature has the following limitations:

- NAS-IP for authentication and accounting requests must be the same as the interface CoA-NAS VIP-IP in the RADIUS endpoint CoA-NAS interface configuration.
- The VRFs configured under RADIUS server-group and RADIUS endpoint must be the same.

- For the Disconnect Message (DM) request, the client VRF and the server VRF (CoA-NAS VIP VRF) must match. If there is a mismatch, the DM request is discarded.

Configuring Virtual Routing and Forwarding

VRF Configuration

The VRF configuration is applicable for both PAPN, and Static and Dynamic use cases.

To configure the VRFs in global configuration mode, use the following sample configuration:

```
config
   vrf name vrf_name gateway gateway_ipv4_address gatewayIpv6 gateway_ipv6_address
device interface_name linkDevice linked_device_name
   end
```

Important VRF creation and deletion operations are supported. To modify the existing VRF, VRF must be deleted and then added again.

NOTES:

- **vrf name** *vrf_name* —Specify the VRF name. The maximum VRF length supported is 15.
- **gateway** *gateway_ipv4_address*—Specify the IPv4 address of the gateway.
- **gatewayIpv6** *gateway_ipv6_address*—Specify the IPv6 address of the gateway.
- **device** *interface_name*—Specify the name of the public bonded interface.
- **linkDevice** *linkedDevice_name*—Specify the name of the private bonded interface. This field is applicable only for Static and Dynamic use case.

Configuration Example

The following are example configurations of VRFs with gateway:

```
vrf name papn_vrf_1 gateway 209.165.202.131 device bd2.radius.2161
vrf name papn_vrf_2  gateway 209.165.202.131 device bd2.radius.2162
vrf name vrf_s11 gateway 209.165.202.131 device bd1.s11.1692 linkDevice bd1.s11.1696
```

Endpoint Configuration

To configure the endpoint and associate with the VRF, use the following sample configuration:

```
config
   instance instance-id instance_id
       endpoint { gtp | pfcp | radius | diameter  }
          interface { coa-nas | s5 | s5e | s2b | s11 | n4 | gx | gy  }
            vip-ip ip_address [ vip-interface  interface_name| vip-port vip_port
```

```
 | vrf vrf_name ]
             end
```

NOTES:

- **endpoint { gtp | pfcp | radius | diameter }**—Specify the endpoint name. It can be GTP, PFCP protocol, RADIUS, or Diameter.

  For PAPN support, use the RADIUS endpoint. For the static and dynamic policy removal use case, select the GTP or PFCP protocol.

- **interface { coa-nas | s5 | s5e | s2b | s11 | n4 | gx | gy }**—Specify the interface based on the use case. For PAPN support, select **coa-nas** interface. For the policy removal use case, use any of the other available interfaces. For Diameter endpoint, select **gx** or **gy** interface.

- **vip-ip** *ip_address*—Specify the IPv4 address of the configured endpoint.

- **vip-interface** *interface_name*—Specify the interface name. Note that this is a bonded interface which is associated with VRF.

- **vip-port** *vip_port*—Specify the port number of endpoint.

- **vrf** *vrf_name*—Specify the VRF name defined using global VRF configuration.

Configuration Example

The following are example configurations:

```
instance instance-id 1 endpoint radius interface coa-nas vip-ip 209.165.202.131 vip-port
8112 vip-interface bd2.radius.2161 vrf papn_vrf_1

instance instance-id 1 endpoint radius interface coa-nas vip-ip 209.165.202.133 vip-port
8112 vip-interface bd2.radius.2162 vrf papn_vrf_2

instance instance-id 1 endpoint pfcp interface n4 vip-ip 209.165.202.134 vip-interface
bd2.n4.2105 vrf vrf_n4_ls1

instance instance-id 1 endpoint gtp interface s11 vip-ip 209.165.202.135 vip-interface
bd1.s11.1692 vrf vrf_s11

instance instance-id 1 endpoint diameter interface gx vip-ip 209.165.202.136 vip-interface
 d2.aaa.1212 vrf vrf_signaling
```

VRF Configuration in RADIUS Profile

To configure the VRF in RADIUS server group, use the following sample configuration:

```
config
   profile radius
      server-group group_name
         vrf vrf_name
         server-private { radius_server_ip_address port_number  | [ range ] }
            priority radius_server_priority
            secret radius_server_secret_key
            type { acct | auth }
            end
```

NOTES:

- **server-private {** *radius_server_ip_address port_number* **| [range] }** —Specify the IP address and port number of the private RADIUS servers used for accounting and authentication requests. This server is private to the specific server-group.

  Private servers in the server-group will be given priority over global servers that are associated to the group. If private servers are unreachable or dead, global servers will be selected to send authentication or accounting requests.

- **priority** *radius_server_priority*—Specify the priority of RADIUS server.
- **secret** *radius_server_secret_key*—Specify the RADIUS server shared secret key.

  Must be a string.

- **type { acct | auth }**—Specify the type of private RADIUS server used for accounting and authentication requests.
- **server-private {** *radius_server_ip_address port_number* **[priority** *radius_server_priority* **| secret** *radius_server_secret* **| type { acct | auth }] | [range] }**
- **range**—Specify the IP address range.
- **vrf** *vrf_name*—Specify the VRF name to be configured in AAA server group.

  If VRF is configured in server-group, it is recommended to configure servers using server-private and not associate the global servers.

To define the VRF in RADIUS Dynamic-authorization/COA configuration, use the following sample configuration:

```
config
   profile radius-dynamic-author
      client client_ip_address vrf vrf_name
         nas-identifier nas_identifier_port
         secret secret_key
         end
```

NOTES:

- **client** *client_ip_address*—Specify the RADIUS Dynamic-authorization client configuration.
- **vrf** *vrf_name*—Specify the VRF name to be configured in AAA server group.

  If VRF is configured in server-group, it is recommended to configure servers using server-private and not associate the global servers.

- **nas-identifier** *nas_identifier_port*—Specify the dynamic authorization NAS identifier.
- **secret** *secret_key*—Specify the dynamic authorization server shared secret key.

VRF Association for BGP Peering

To associate VRF with BGP for BGP peering, use the following sample configuration:

```
config
   router bgp bgp_name
       interface interface_name
```

```
vrf  vrf_name
end
```

NOTES:

- **interface** *interface_name*—Specify the local BGP interface.
- **vrf** *`vrf_name*—Specify the VRF details to be associated with BGP.

Configuration Example

The following is an example of BGP peering configuration with no VRF association:

```
interface enp94s0f0.3921
  bondingInterface enp216s0f0
  bondingInterface enp94s0f0
  neighbor 209.165.202.254 remote-as 65141 fail-over bfd
exit
interface enp94s0f1.3922
  bondingInterface enp216s0f1
  bondingInterface enp94s0f1
  neighbor 209.165.202.254 remote-as 65141 fail-over bfd
exit
```

The following is an example of BGP Peering configuration with association with papn_vrf_1.

```
interface enp94s0f0.3923  leaf1
  vrf papn_vrf_1
  bondingInterface enp216s0f0
  bondingInterface enp94s0f0
  neighbor 209.165.202.254 remote-as 65141 fail-over bfd
exit
interface enp94s0f1.3924  leaf2
  vrf papn_vrf_1
  bondingInterface enp216s0f1
  bondingInterface enp94s0f1
  neighbor 209.165.202.254 remote-as 65141 fail-over bfd
exit
```

The following is an example of BGP Peering configuration with association with papn_vrf_2.

```
interface enp94s0f0.3925
  vrf papn_vrf_2
  bondingInterface enp216s0f0
  bondingInterface enp94s0f0
  neighbor 209.165.202.254 remote-as 65141 fail-over bfd
exit
interface enp94s0f1.3926
  vrf papn_vrf_2
  bondingInterface enp216s0f1
  bondingInterface enp94s0f1
  neighbor 209.165.202.254 remote-as 65141 fail-over bfd
exit
```

Configuration Verification

To view the VRF information, use the **show vrf-info all** command.

Following is a sample output of the **show vrf-info all** command.

```
                          GATEWAY                              TABLE
NAME        GATEWAY         IPV6    DEVICE      LINK DEVICE    ID     STATE  POD NAME
-------------------------------------------------------------------------------------
```

```
npapn-vrf12 209.165.200.225      bd2.npv12.756               2516    true  bgpspeaker-pod-1
papn-vrf18  209.165.200.226      bd2.pv18.1236               2621    true  bgpspeaker-pod-1
vrf_s11     209.165.200.227     bd1.s11.1692  bd1.s11.1696   2631    true  bgpspeaker-pod-1
vrf_n4_ls1  209.165.200.228      bd2.n4.2105   bd2.n4.3915    2630    true  bgpspeaker-pod-1
```

To view the VRF route information, use the **show vrf-route-info all** command.

Following is a sample output of the **show vrf-route-info all** command.

```
Vrf TableId Route
papn-vrf11 2614 default via 209.165.200.225 dev bd2.pv11.1229 proto 217 metric 217
papn-vrf11 2614 broadcast 209.165.200.226 dev bd2.pv11.1229 proto kernel scope link src
209.165.200.225
papn-vrf11 2614 209.165.200.227/29 dev bd2.pv11.1229 proto kernel scope link src
209.165.200.225
papn-vrf11 2614 local 209.165.200.225 dev bd2.pv11.1229 proto kernel scope host src
209.165.200.225
papn-vrf11 2614 broadcast 209.165.200.227 dev bd2.pv11.1229 proto kernel scope link src
209.165.200.225
papn-vrf11 2614 anycast fe80:: dev bd2.pv11.1229 proto kernel
papn-vrf11 2614 local fe80::42a6:b7ff:fe37:38 dev bd2.pv11.1229 proto kernel
papn-vrf11 2614 fe80::/64 dev bd2.pv11.1229 proto kernel metric 256
papn-vrf11 2614 ff00::/8 dev bd2.pv11.1229 proto 3 metric 256

Vrf TableId Route
vrf_s5 2633 default via 209.165.200.225 dev bd1.s5.1691 proto 217 metric 217
vrf_s5 2633 local 209.165.200.226 dev bd1.s5.1691 proto kernel scope host src 209.165.200.225
vrf_s5 2633 broadcast 209.165.200.226 dev bd1.s5.1691 proto kernel scope link src
209.165.200.225
vrf_s5 2633 local 209.165.200.226 dev bd1.s5.1691 proto kernel scope host src 209.165.200.225
vrf_s5 2633 broadcast 209.165.200.226 dev bd1.s5.1691 proto kernel scope link src
209.165.200.225
vrf_s5 2633 broadcast 209.165.200.226 dev bd1.s5.1691 proto kernel scope link src
209.165.200.225
vrf_s5 2633 209.165.200.226/24 dev bd1.s5.1691 proto kernel scope link src 209.165.200.225
vrf_s5 2633 local 209.165.200.225 dev bd1.s5.1691 proto kernel scope host src 209.165.200.225
vrf_s5 2633 broadcast 209.165.200.226 dev bd1.s5.1691 proto kernel scope link src
209.165.200.225
vrf_s5 2633 broadcast 209.165.200.226 dev bd1.s5.1691 proto kernel scope link src
209.165.200.225
vrf_s5 2633 209.165.200.226/24 dev bd1.s5.1691 proto kernel scope link src 209.165.200.225
vrf_s5 2633 local 209.165.200.226 dev bd1.s5.1691 proto kernel scope host src 209.165.200.225
vrf_s5 2633 broadcast 209.165.200.226 dev bd1.s5.1691 proto kernel scope link src
209.165.200.225
vrf_s5 2633 anycast fe80:: dev bd1.s5.1691 proto kernel
vrf_s5 2633 anycast fe80:: dev bd1.s5.1691 proto kernel
vrf_s5 2633 local fe80::42a6:b7ff:fe37:39 dev bd1.s5.1691 proto kernel
vrf_s5 2633 local fe80::42a6:b7ff:fe37:39 dev bd1.s5.1691 proto kernel
vrf_s5 2633 fe80::/64 dev bd1.s5.1691 proto kernel metric 256
vrf_s5 2633 fe80::/64 dev bd1.s5.1691 proto kernel metric 256
vrf_s5 2633 ff00::/8 dev bd1.s5.1691 proto 3 metric 256
vrf_s5 2633 ff00::/8 dev bd1.s5.1691 proto 3 metric 256
```

OAM Support

Bulk Statistics Support

The following statistics are updated to support the VRF feature.

- bgp_outgoing_routerequest_total - This statistics includes "vrf" label to indicate the total count of successful BGP outgoing routes per VRF.
- bgp_outgoing_failedrouterequest_total - This statistics includes "vrf" label to indicate the total count of failed BGP outgoing routes per VRF.
- bgp_speaker_bfd_peer_status - This statistics includes "vrf" label to indicate the BFD peer status.