IP Address Management

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	Enabled – Always-on
Related Changes in this Release	Not Applicable
Related Documentation	Not Applicable

Revision History

Table 2: Revision History

Revision Details	Release
First introduced.	Pre-2020.02.0

Feature Description

IP Address Management (IPAM) is a method of tracking and managing IP addresses of a network. IPAM is one of the core components of the subscriber management system. Traditional IPAM functionalities are insufficient in Cloud-Native network deployments. Hence, IPAM requires additional functionalities to work with the Cloud-Native subscriber management system. The Cloud-Native IPAM system is used in various network functions, such as SMF and PCF.

The IPAM system includes the following functionalities to serve the Cloud Native and Control and User Plane Separation (CUPS) architecture:

- **Centralized IP resource management** —Based on the needs of the Internet Service Provider (ISP), the Control Plane (CP) is deployed either on a single (centralized) cluster or multiple (distributed) clusters. For multiple cluster deployments, the IPAM automatically manages the single IP address space across the multiple CPs that are deployed in the distributed environment.
- **IP address-range reservation per user-plane**—For subscribers connecting to the Internet core, the User Plane (UP) provides the physical connectivity. The UP uses the summary-routes to advertise subscriber routes to the Internet core. For CPs that are managing multiple UPs, the CP reserves a converged IP subnet to the UPs. In such a scenario, the IPAM splits the available address space into smaller address-ranges and assigns it to different UPs.
- **IP address assignment from pre-reserved address-ranges**—When subscribers request for an IP address, the IPAM assigns addresses from the pre-reserved address range of their respective UP.

How it Works

IPAM uses the following sub-modules for the Cloud-Native subscriber management system:

- IPAM Server—This module manages the complete list of pools and address-space configurations. The IPAM server splits the configured address ranges into smaller address-ranges statically or dynamically to distribute them to IPAM cache modules. The IPAM server is deployed as a centralized entity to serve group of Cloud-Native clusters or can be an integrated entity within a single cluster.
- IPAM Cache—This module receives the free address-ranges from the IPAM server and allocates the individual IP addresses to the IPAM clients. Usually, the IPAM cache is deployed in a distributed mode running within each cluster to communicate with the co-located or remotely-located IPAM server. The IPAM cache also handles address-range reservation per UP and pool threshold monitoring. The IPAM server and cache modules can run as an integrated mode.
- IPAM Client—This module handles the request and release of an individual IP address from the IPAM cache for each IP managed end-device. The IPAM client is tightly coupled with a respective network-function.

IPAM Integration in SMF

Feature Description

The IP Address Management (IPAM) is a technique for tracking and managing the IP address space of a network. A core component of the subscriber management system, the IPAM provides all the functionalities necessary for working with the Cloud-Native subscriber management system. Also, the IPAM acts as a generic IP address management system for the different network functions such as the SMF, Policy Control Function (PCF), and so on.

The IPAM is integrated with the SMF in the Application Services layer.

Architecture

This section describes the IPAM integration in the SMF architecture.

IPAM Integration in SMF

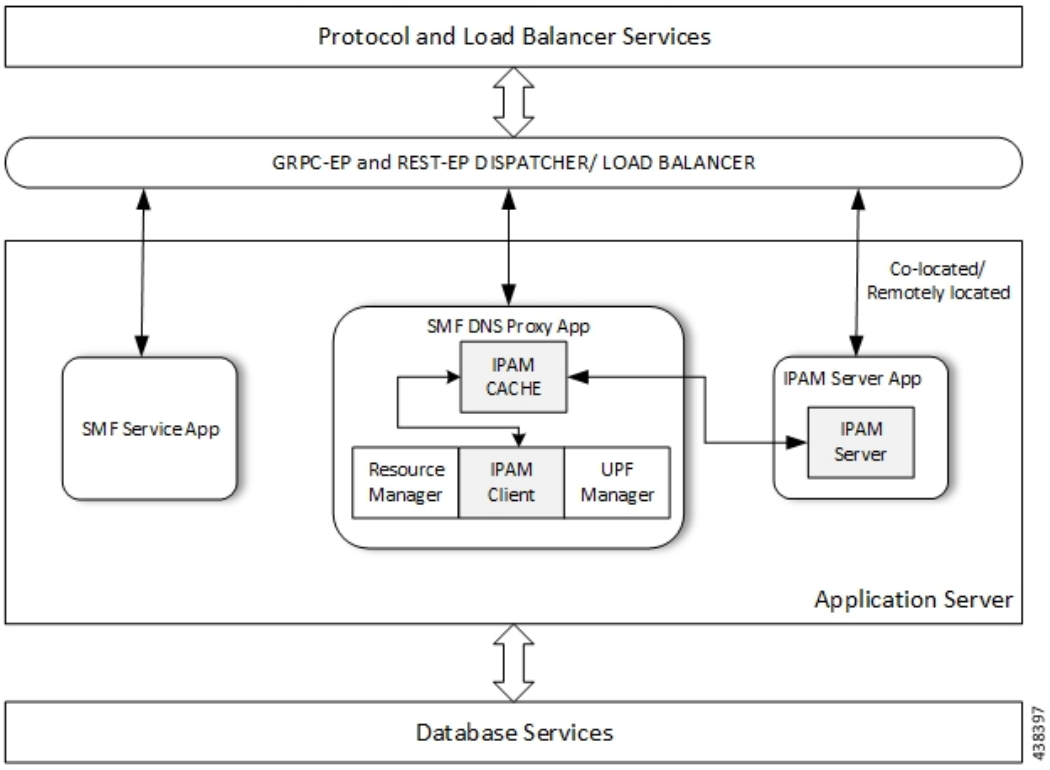
The SMF comprises of loosely coupled microservices that enables the SMF to perform session management (session establishment, modification, and release) and other associated functions. The decomposition of these microservices is based on the following three-layered architecture:

1. Layer 1: Protocol and Load Balancer Services (Stateless)
2. Layer 2: Application services (Stateless)
3. Layer 3: Database Services (Stateful)

The IPAM and SMF integration happens in the Application Services layer.

The following describes the SMF and IPAM integration architecture in the Application Services layer.

Figure 1: IPAM Integration in SMF



- **SMF Node-Manager Application** – The SMF Node-Manager application takes care of the UPF, ID resource, and IP address management. Therefore, the SMF Node-Manager application integrates IPAM Cache and IPAM client modules. The UPF Manager uses the IPAM Client module for address-range-reservation per UPF.
- **SMF Service Application** – The SMF Service application provides PDU session services. During session establishment and termination, the IP addresses are requested and released back. The SMF Service application invokes the IPC to RMGR in Node Manager, which receives (free) the IP from the IPAM module.
- **IPAM Server Application** – Based on the deployment model, the IPAM Server application can run as an independent microservice, as a part of the same cluster, or in a remote-cluster. For standalone deployments, the IPAM Servers are an integral part of the IPAM cache.

Components

This section describes the different components of the IPAM system.

IPAM Sub-Modules

The IPAM system includes the following sub-modules:

- **IPAM Server** – The IPAM Server module manages the complete list of pools and address-space configuration. It splits the configured address-ranges into smaller address-ranges (statically and dynamically) and distributes it to the IPAM Cache modules. You can deploy the IPAM Server either as

a centralized entity to serve a group of cloud native clusters or as an integrated entity within a single cluster.

- **IPAM Cache** – The IPAM Cache acquires free address-ranges from the IPAM Server and allocates individual IP addresses to the IPAM clients. Deployed in a distributed mode running within each cluster, the IPAM Cache communicates with co-located and remotely located IPAM Servers. Additionally, the IPAM Cache takes care of the address-range reservation per Data-Plane and pool threshold monitoring.
- **IPAM Client** – The IPAM Client module handles the request and release of the individual IP addresses from the IPAM Cache for each IP managed end-device. Based on the use cases, the IPAM Client module caters the needs of specific network functions (such as SMF, PCF, and so on).

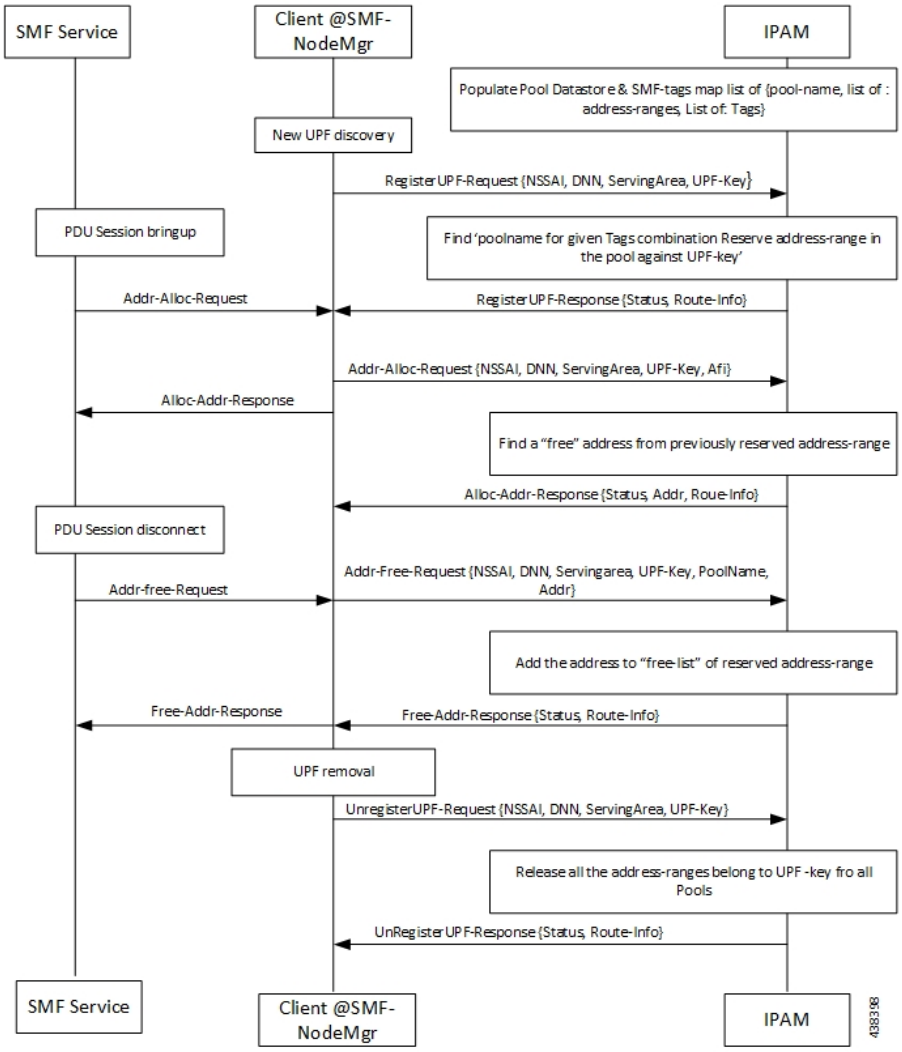
How it Works

This section describes the call flows pertaining to the integration of the IPAM in the SMF.

Call Flows

The following call flow depicts the integration of the IPAM in the SMF.

Figure 2: Integration of IPAM in SMF Call Flow



Configuring the IPAM Feature

This section describes how to configure the IPAM in the SMF.

Configuring the IPAM in the SMF involves the following steps:

1. Configuring IPv4 address ranges.
2. Configuring IPv6 address ranges.
3. Configuring IPv6 prefix ranges.
4. Configuring SMF tags.
5. Configuring IPv4 threshold.
6. Configuring IPv6 address range threshold.

7. Configuring IPv6 prefix range threshold.
8. Configuring IPv4 address range split.
9. Configuring IPv6 address and prefix address range split.
10. Configuring global threshold.
11. Configuring IPAM source.

Configuring IPv4 Address Ranges

Use the following configuration to configure the IPv4 address ranges.

```
configure
   ipam
      address-pool pool_name
         vrf-name string
         ipv4
            address-range start_ipv4_address end_ipv4_address
            commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **vrf-name** *string*: Configures the Virtual routing and forwarding (VRF) name of the pool.
- **ipv4**: Enters the IPv4 mode of the pool.
- **address-range** *start_ipv4_address end_ipv4_address*: Configures the IPv4 range. *start_ipv4_address* specifies the starting IPv4 address. *end_ipv4_address* specifies the ending IPv4 address.

The following is a sample configuration:

```
configure
   ipam
      address-pool p1
         vrf-name one
         ipv4
            address-range 1.1.1.10 1.1.1.255
            address-range 2.2.2.1 2.2.2.255
```

Configuring IPv6 Address Ranges

Use the following configuration to configure the IPv6 address ranges:

```
configure
   ipam
      address-pool pool_name
         vrf-name string
         ipv6
            address-range start_ipv6_address end_ipv6_address
            commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **vrf-name** *string*: Configures the VRF name of the pool.
- **ipv6**: Enters the IPv6 mode of the pool.
- **address-range** *start_ipv6_address end_ipv6_address*: Configures the IPv6 range. *start_ipv6_address* specifies the starting IPv6 address. *end_ipv6_address* specifies the ending IPv6 address.

The following is a sample configuration:

```
configure
   ipam
      address-pool p1
         vrf-name one
         ipv6
            address-range 1::1 1::1000
            address-range 2::1 2::1000
```

Configuring IPv6 Prefix Ranges

Use the following configuration to configure the IPv6 prefix ranges:

```
configure
   ipam
      address-pool pool_name
         vrf-name string
         ipv6
            prefix-ranges
               prefix-range prefix_value prefix-length length
               commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **vrf-name** *string*: Configures the VRF name of the pool.
- **ipv6**: Enters the IPv6 mode of the pool.
- **prefix-ranges**: Enters the prefix ranges mode.
- **prefix-range** *prefix_value* **prefix-length** *length* : Configures the IPv6 prefix range. **prefix-range** *prefix_value* specifies the IPv6 prefix range. **prefix-length** *length* specifies the IPv6 prefix length.

The following is a sample configuration:

```
configure
   ipam
      address-pool p3
         vrf-name three
         ipv6
```

```
prefix-ranges
   prefix-range 1:1:: prefix-length 48
   prefix-range 2:1:: prefix-length 48
```

Configuring SMF Tags

Use the following configuration to configure the SMF tags.

```
configure
   ipam
      address-pool pool_name
         tags
            nssai string
            dnn string
            serving-area string
            commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **tag** : Enters the tag section of the pool.
- **nssai** *string*: Specifies the NSSAI value.
- **dnn** *string* : Specifies the DNN value.
- **serving-area** *string*: Specifies the serving-area value.

The following is a sample configuration:

```
configure
   ipam
      address-pool p1
         tags
            nssai one
            dnn two
            serving-area three
```

Configuring IPv4 Threshold

Use the following configuration to configure the IPv4 threshold:

```
configure
   ipam
      address-pool pool_name
         ipv4
            threshold
               upper-threshold percentage
               commit
```

NOTES:

- **ipam**: Enters the IPAM Configuration mode.

- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **ipv4** : Enters the IPv4 mode of the pool.
- **threshold** : Enters the threshold sub-mode.
- **upper-threshold** *percentage*: Specifies the IPv4 upper threshold value in percentage.

The following is a sample configuration:

```
configure
   ipam
      address-pool p1
         ipv4
            threshold
               upper-threshold 80
```

Configuring IPv6 Address Range Threshold

Use the following configuration to configure the IPv6 address range threshold.

```
configure
   ipam
      address-pool pool_name
         ipv6
            address-ranges
               threshold
                  upper-threshold percentage
                  commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **ipv6** : Enters the IPv6 mode of the pool.
- **address-ranges**: Enters the IPv6 address ranges sub-mode.
- **threshold** : Enters the threshold sub-mode.
- **upper-threshold** *percentage*: Specifies the IPv6 upper-threshold value in percentage.

The following is an example configuration:

```
configure
   ipam
      address-pool p2
         ipv6
            address-ranges
               threshold
                  upper-threshold 75
```

Configuring IPv6 Prefix-Range Threshold

Use the following configuration to configure the IPv6 prefix-range threshold.

```
configure
   ipam
      address-pool pool_name
         ipv6
            prefix-ranges
               threshold
                  upper-threshold percentage
                  commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **ipv6** : Enters the IPv6 mode of the pool.
- **prefix-ranges**: Enters the IPv6 prefix ranges sub-mode.
- **threshold** : Enters the threshold sub-mode.
- **upper-threshold** *percentage*: Specifies the IPv6 upper-threshold value in percentage.

The following is an example configuration:

```
configure
   ipam
      address-pool p3
         ipv6
            prefix-ranges
               threshold
                  upper-threshold 78
```

Configuring IPv4 Address Range Spilt

Use the following configuration to configure the IPv4 address range spilt.

```
configure
   ipam
      address-pool pool_name
         ipv4
            spilt-size per-cache integer
            spilt-size per-dp integer
            commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **ipv4** : Enters the IPv4 mode of the pool.
- **spilt-size per-cache** *integer*: Specifies the size of the IPv4 range to be split for each IPAM cache allocation. The IPAM server consumes this configuration.

- **spilt-size-per-dp** *integer*: Specifies the size of the IPv4 range to be spilt for each Data-Plane (User-Plane) allocation. The IPAM cache consumes this configuration.

The following is a sample configuration:

```
configure
   ipam
      address-pool p1
         ipv4
            split-size per-cache 1024
            split-size per-dp 256
```

Configuring IPv6 Address and Prefix Address-Range-Spilt

Use the following configuration to configure the IPv6 address and prefix address range spilt.

```
configure
   ipam
      address-pool pool_name
         ipv6
            address-ranges
               spilt-size per-cache integer
               spilt-size per-dp integer
               commit
            prefix-ranges
               spilt-size per-cache integer
               spilt-size per-dp integer
               commit
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Configures the address pool configuration. *pool_name* must be the name of the address pool.
- **ipv6** : Enters the IPv6 mode of the pool.
- **address-ranges**: Enters the IPv6 address-ranges sub-mode.
- **spilt-size per-cache** *integer*: Specifies the size of the IPv6 adress-ranges or prefix-ranges to be split for each IPAM cache allocation. The IPAM server consumes this configuration.
- **spilt-size-per-dp** *integer*: Specifies the size of the IPv6 adress-ranges or prefix-ranges to be spilt for each Data-Plane (User-Plane) allocation. The IPAM cache consumes this configuration.
- **prefix-ranges**: Enters the IPv6 prefix ranges sub-mode.

The following is a sample configuration:

```
configure
   ipam
      address-pool p1
         ipv6
            address-ranges
               split-size per-cache 4096
               split-size per-dp 1024
               !
            prefix-ranges
```

```
split-size per-cache 8192
split-size per-dp 2048
```

Configuring Global Threshold

Use the following configuration to configure the global threshold.

```
configure
   ipam
      threshold
         ipv4-addr percentage
         ipv6-addr percentage
         ipv6-prefix percentage
         commit
```

NOTES:

- **ipam**: Enters the IPAM Configuration mode.
- **threshold**: Enters the threshold sub-mode.
- **ipv4-addr** *percentage* : Specifies the IPv4 threshold value in percentage.
- **ipv6-addr** *percentage* : Specifies the IPv6 threshold value in percentage.
- **ipv6-prefix** *percentage* : Specifies the IPv6 prefix threshold value in percentage.

The following is a sample configuration:

```
configure
   ipam
      threshold
         ipv4-addr 80
         ipv6-addr 75
         ipv6-prefix 70
```

Configuring IPAM Source

Use the following configuration to configure the IPAM source.

```
configure
   ipam
      source local
         source external ipam
            host ip_address
            port integer
            vendor type
            commit
```

NOTES:

- **ipam**: Enters the IPAM Configuration mode.
- **source local**: Enters the local datastore as the pool source.
- **source external ipam** : Enters the external IPAM server as the pool source.
- **host** *ip_address* : Specifies the host name of the external IPAM server.
- **port** *integer* : Specifies the port of the external IPAM server.

- **vendor** *type*: Specifies the vendor type of the external IPAM server.

The following is a sample configuration:

```
ipam
 source external ipam
  host 1.1.1.1
  port 10000
  vendor cisco
```

Verifying the IPAM Integration Configuration

This section describes how to verify the IPAM integration in the SMF feature configuration.

Use the **show ipam pool** command to view the summary of current threshold of each pool.

The following is a sample output of the **show ipam pool** command.

```
show ipam pool
=================================================================
PoolName   Ipv4Threshold  Ipv6AddrThreshold  Ipv6PrefixThreshold
=================================================================
  p1               80%            80%              0%
  p2               75%            0%               70%
=================================================================
```

Use the **show ipam pool** *pool_name* command to view more details of a specific pool name.

The following is a sample output of the **show ipam pool** *pool_name* command.

```
show ipam pool p1
-----------------------------------------------------
Ipv4Addr   [Total/Used/Threshold] = 7680 / 7680 / 80%
Ipv6Addr   [Total/Used/Threshold] = 512 / 512 / 80%
Ipv6Prefix [Total/Used/Threshold] = 0 / 0 / 0%
-----------------------------------------------------
```

Use the **show ipam** *pool_name* **ipv4-addr** command to view the IPv4-address ranges for the given pool-name. Based on the configuration, the address ranges are dynamically split. You can also view whether the address range is free or allocated to a Data Plane (User Plane) using this command.

The following is a sample output of the **show ipam** *pool_name* **ipv4-addr** command.

```
show ipam pool p1 ipv4-addr
=========================================
StartAddress     EndAddress    AllocContext
=========================================
  1.1.1.0        1.1.3.255     Upf-100
  1.1.4.0        1.1.7.255     Upf-200
  1.1.8.0        1.1.10.255    Free
  2.2.1.0        2.2.3.255     Upf-100
  2.2.4.0        2.2.7.255     Upf-300
  2.2.8.0        2.2.10.255    Free
  3.3.1.0        3.3.3.255     Free
  3.3.4.0        3.3.7.255     Free
  3.3.8.0        3.3.10.255    Free
=========================================
```

Use the **show ipam pool** *pool_name* **ipv6-perfix** command to view the prefix-ranges for the given pool-name. Based on the configuration, the address ranges are dynamically split. You can also view whether the address range is free or allocated to a Data Plane (User Plane) using this command.

The following is a sample output of the **show ipam pool** *pool_name* **ipv6-perfix** command.

```
show ipam pool p2 ipv6-prefix
==============================================
Prefix                          AllocContext
==============================================
 aaaa:bbbb:ccc0::/64            Upf-100
 aaaa:bbbb:ccc1::/64            Free
 aaaa:bbbb:dd00::/64            Upf-200
==============================================
```

Use the **show ipam dp** command to view the summary of the current threshold for each Data Plane (User Plane).

The following is a sample output of the **show ipam dp** command.

```
show ipam dp
================================================================
DpName     Ipv4Threshold  Ipv6AddrThreshold  Ipv6PrefixThreshold
================================================================
UPF-100           20%             40%               70%
UPF-200           40%             20%               20%
================================================================
```

Use the **show ipam dp** *dataplane_name* command to view more details of a specific Data Plane (User Plane).

The following is a sample output of the **show ipam dp** *dataplane_name* command.

```
show ipam dp UPF-100
-------------------------------------------------------
Ipv4Addr   [Total/Used/Threshold] = 512 / 100 / 20%
Ipv6Addr   [Total/Used/Threshold] = 512 / 200 / 40%
Ipv6Prefix [Total/Used/Threshold] = 512 / 300 / 70%
-------------------------------------------------------
```

Use the **show ipam dp** *dataplane_name* **ipv4-addr** command to view the IPv4-address ranges assigned to a data plane.

The following is a sample output of the **show ipam dp** *dataplane_name* **ipv4-addr** command.

```
show ipam dp UPF-100 ipv4-addr
=====================================================
StartAddress   EndAddress    AllocContext   Route
=====================================================
1.1.1.1        1.1.1.255      Pool-1        1.1.1.0/24
2.2.1.1        2.2.1.255      Pool-2        2.2.1.0/24
=====================================================
```

Use the **show ipam dp** *dataplane_name* **ipv6-addr** command to view the IPv6-address ranges assigned to a data plane.

The following is a sample output of the **show ipam dp** *dataplane_name* **ipv6-addr** command.

```
show ipam dp UPF-100 ipv6-addr
=======================================================
```

```
StartAddress     EndAddress    AllocContext   Route
=========================================================
100::1           100::100         Pool-1      100::/120
00::1            200::100         Pool-2      200::/120
=========================================================
```

Use the **show ipam dp** *dataplane_name* **ipv6-prefix** command to view the IPv6-address ranges assigned to a data plane.

The following is a sample output of the **show ipam dp** *dataplane_name* **ipv6-prefix** command.

```
show ipam dp UPF-100 ipv6-prefix
=============================================================
Prefix                AllocContext      Route
=============================================================
aaaa:bbbb:cccc::/64   Pool-1            aaaa:bbbb:cccc::/48
aaaa:bbbb:dd00::/64   Pool-1            aaaa:bbbb:dd00::/40
=============================================================
```

Static IP Support

Feature Description

IPAM is the core component of the subscriber management system. Traditional IPAM functionalities prove insufficient in the Cloud Native network deployments. Hence, IPAM requires additional functionalities to work with the Cloud Native subscriber management system.

The Static IP Support feature enables the support of static IP on the SMF using IPAM. This feature supports the following functionalities:

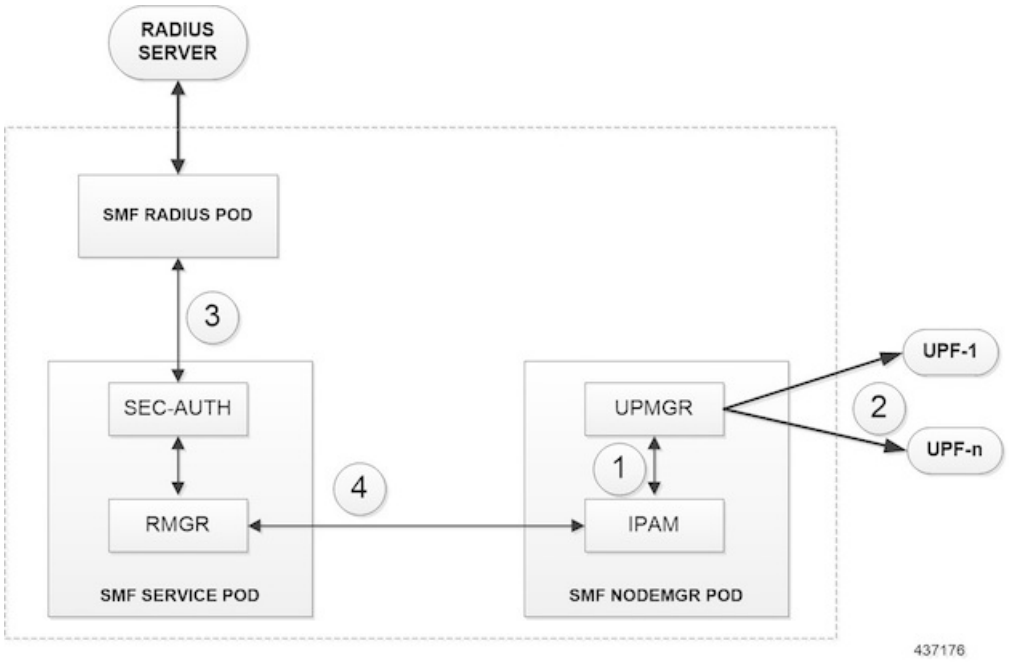
- Supports static pool configuration.
- Splits static address-ranges into smaller chunks and associates them with the configured UPFs.
- Enables program routes according to static address-range reservation during UPF association.
- Enables secondary authentication under the DNN profile.
- Selects UPF based on reserved address-range and Framed-IP received from the Authentication response.

How it Works

This section provides a brief of how the Static IP Support feature feature works.

The SMF receives a framed-IP address of the subscriber from external AAA servers such as RADIUS. While IPAM is not involved in individual IP address management in this scenario, it still handles the route management and UPF management for static address-ranges.

IPAM splits the ‘static’ address-ranges equally according to number of UPFs present in the SMF configuration. Unlike dynamic IP, IPAM splits all static-IP address-ranges and assigns them for all configured UPFs. IPAM involves and selects an UPF when the external AAA server returns the framed-IP of the subscriber. IPAM looks for the route which includes this static-IP and then selects the UPF where the route is already configured.



Procedure

1. IPAM splits the static ranges into equal number of address-ranges based on number of configured UPFs.
2. The UPMGR programs the corresponding static routes on the associated UPFs.
3. Subscribers get static IP from Radius server authorize response.
4. SMF service selects the right UPF based on ADDR ranges and UPF map allocation from the Node Manager.

Address-Range Split

Splitting a given address-range into smaller address-ranges is a key functionality of the IPAM server and IPAM cache. The following guidelines determine address-range split:

1. Size of a split address-range depends upon the ‘configured’ value or the ‘default’ value as per the AFI type.
2. Size of a split address-range must be a ‘power-of-2’ or at least to the closest of it. That is, it should be able to represent the split range in “subnet/mask” notation such that a route can be added in the Data Plane (User Plane) if required.
3. ‘Configured’ or ‘default’ address-range-size must be at the ‘power-of-2’.

The address-range must be split into smaller ranges immediately on configuration or initial start-up. This helps in better sorting of address-ranges based on size and faster allocation during actual address-range-allocation requests. The address-range exchange between modules is always in the mentioned size.

Table 3: Examples of IPv4 Address-Range Split

Address-Range	Split-Size (number of addresses per range)	Split-ranges (* Odd sized ranges)	Route Notation
1.1.1.0 - 1.1.1.255	128	[1] 1.1.1.0 – 1.1.1.127 [2] 1.1.1.128 – 1.1.1.255	[1] 1.1.1.0/25 [2] 1.1.1.128/25
1.1.0.0 – 1.1.10.255	256	[1] 1.1.0.0 – 1.1.0.255 [2] 1.1.1.0 – 1.1.1.255 [3] 1.1.2.0 – 1.1.2.255 ... [n] 1.1.10.0 – 1.1.10.255	[1] 1.1.0.0/24 [2] 1.1.1.0/24 [3] 1.1.2.0/24 ... [n] 1.1.10.0/24
1.1.0.5 – 1.1.2.200	256	[1] 1.1.0.5 – 1.1.0.255 * [2] 1.1.1.0 – 1.1.1.255 [3] 1.1.2.0 – 1.1.2.200 *	[1] 1.1.0.0/24 [2] 1.1.1.0/24 [3] 1.1.2.0/24

Table 4: Examples of IPv6 Address-Range Split

Address-Range	Split-Size (number of addresses per range)	Split-ranges (* Odd sized ranges)	Route Notation
1:: - 1::1000	1024	[1] 1:: – 1::3FF [2] 1::400 – 1::7FF [3] 1::800 – 1::BFF [4] 1::C00 – 1::FFF	[1] 1::/118 [2] 1::400/118 [3] 1::800/118 [4] 1::C00/118
1::3 - 1::1DEF	1024	[1] 1::3 – 1::3FF * [2] 1::400 – 1::7FF [3] 1::800 – 1::BFF … [n] 1::1C00 – 1::1DEF *	[1] 1::/118 [2] 1::400/118 [3] 1::800/118 … [n] 1::1C00/118

Examples of IPv6 Address-Range Split

Prefix split needs two length fields for performing the split.

- Network length
- Host length

Prefixes are split between these and a new route is calculated.

Example 1: network-length = 48, prefix-length = 64

Total (64-48) = 16 bits (that is, 65536 prefixes are available for the split)

Example 2: network-length = 32, prefix-length = 56

Total (56-32) = 24 bits (that is, 16 million prefixes available for the split)

Note For Cloud-Native 5G SMF, the host-length is hard-coded as '64'. Only network-length can be configured via the CLI.

Table 5: Examples of IPv6 Address-Range Split

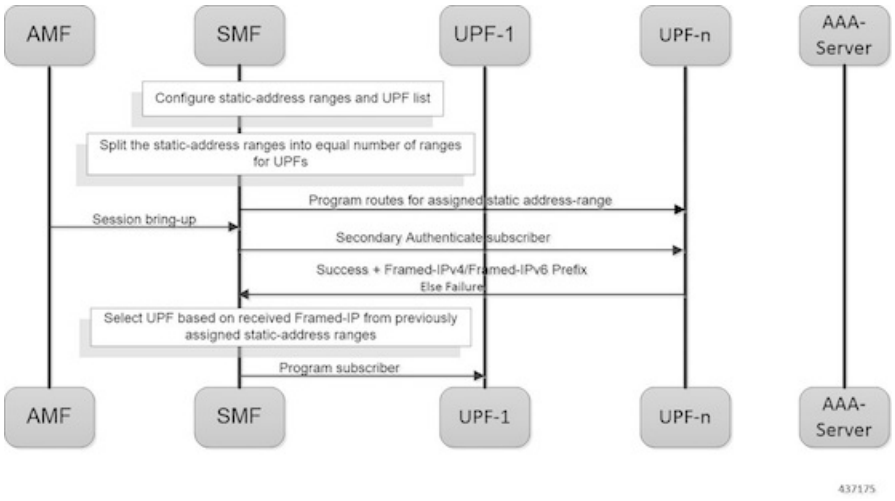
Prefix-Range	Split-Size (number of addresses per range)	Split-ranges (* Odd sized ranges)	Route Notation
1:2:3:: Nw-len = 48 Host-len = 64	8192	[1]1:2:3:: ... 1:2:3:1fff [2]1:2:3:2000:: ... 1:2:3:2fff:: [3]1:2:3:3000:: ... 1:2:3:3fff:: ...	[1]1:2:3::/51 [2]1:2:3:2000/51 [3]1:2:3:3000/51 ...

Call Flows

This section includes the following call flow.

Figure 3: SMF Static IP Call Flow

Figure 4:



Step	Description
1	Configures the static-address ranges and UPF list.
2	Splits the static-address ranges into equal number of ranges for UPFs.

Step	Description
3	Enables program routes for the assigned static address-range.
4	Brings up the session.
5	Enables secondary authentication under the DNN profile.
6	The SMF sends the Authentication Request to the RADIUS server. The RADIUS server sends an Authentication Response with the 'static-ip' of the subscriber. The SMF selects the UPF based on the 'static-ip' and continues with the programming.
7	Completes the subscriber programming.

Limitations

The Static IP Support feature has the following limitations:

- Change of a pool from dynamic to static and vice-versa is not supported when in system-running mode.
- Addition or removal of UPF is not supported when in system-running mode.
- The address-range split must be optimal based on the number of UPFs and number of addresses in the ranges.

  For example:

  - If there are 2 UPFs and 1024 addresses specified in the range, then specify the per-dp-split-size as 512.
  - If there are 3 UPFs and 1024 addresses, then specify the per-dp-split-size as 256.

Configuring Static IP Support

Use the following commands to configure the Static IP Support feature.

```
configure
  ipam
    address-pool pool_name
      static
      end
```

NOTES:

- **ipam**: Enters the IPAM configuration mode.
- **address-pool** *pool_name*: Specifies the name of the address pool to enter the pool configuration. *pool_name* must be the name of the address pool.
- **static**: Enables the static IP mode.

Dual-Stack Static IP Support Through IPAM

Feature Description

The SMF supports dual-stack static IP using IPAM. For dual-stack sessions, the AAA server sends both the IPv4 and IPv6 address prefixes as part of the Access-Accept message. In the SMF-IPAM configuration, both the IPv4 and IPv6 address prefixes are added in the same pool. The IPAM assigns both the IPv4 and IPv6 routes to a single UPF.

During the UPF selection, the Node Manager application uses the UPF for both the IPv4 and IPv6 addresses from the IPAM to handle them accordingly.

How it Works

The SMF supports dual-stack static IP through IPAM in the following ways:

- Pool to UPF mapping—Based on the number of UPFs available, the IPv4 address-ranges and IPv6 prefix-ranges are split into smaller chunks. Then, the pair (chunk) is configured into the same IPAM pool.

  IPAM assigns all the addresses and prefixes that are configured in one dual-stack pool to a UPF in the manner they are received. The AAA server returns the dual-stack addresses from the same pair. From these addresses, SMF selects one UPF for dual-stack programming.

  The load-balancing of number of addresses and prefixes are managed. IPAM performs only the dual-stack static-pool to UPF mapping.

- Address-range no-split configuration—IPAM uses the "no-split" configuration to prevent splitting the address-ranges into smaller chunks. This configuration helps to prevent having multiple routes programming for a specific range.

  The following table lists the errors or exceptions and how to handle them:

Table 6: Error and Exception Handling

Error or Exception	Exception Handling
IPv4 UPF and IPv6 UPF are configured incorrectly	**1.** Select an active UPF. In case both the UPFs are active, select the UPF with the IPv4 address. **2.** Reset the IP information of the other stack and update the PDU session type accordingly.
IPv4 address is invalid or null	Select the UPF with IPv4 address and update the PDU session type accordingly.
IPv6 prefix is invalid or null	Select the UPF with IPv6 address and update the PDU session-type accordingly.
IPv4 address and IPv6 prefix are invalid	Both the IPv4 address and IPv6 prefix are rejected.

Limitations

The dual-stack static IP support using IPAM feature has the following limitation:

When the system is in running mode, the change in ‘no-split' configuration is not supported.

Configuring Dual-Stack Static IP Support Using IPAM Feature

This section describes how to configure the dual-stack static IP support using IPAM.

Configuring IPAM No-Split

This section describes how to configure the IPAM no-split.

```
configure
   ipam
      address-pool pool_name
      ipv4
         split-size no-split
         exit
      ipv6 prefix_ranges
         split-size no-split
         exit
      exit
```

NOTES:

- **split-size no-split**—Prevents the IPv4 address-ranges or IPv6 prefix-ranges from splitting into smaller chunks.

IPAM Offline Mode Support

Feature Description

The SMF supports the addition of a dynamic pool, IPv4, or IPv6 address-range to a dynamic pool by default. The new chunks are added to the respective tags, such as DNN, and are assigned from the same pool.

To delete a dynamic pool or an IPv4 or IPv6 address-range from a dynamic pool:

1. Configure the pool or address-range as offline. The IPAM then stops assigning addresses from the respective pool or address-range.
2. Use the following **clear-subscriber** CLI commands to delete the subscribers based on respective pool or address range that are configured to offline mode:
   - **clear subscriber ipv4-pool** *pool_name*
   - **clear subscriber ipv4-range** *pool_name/start_of_range*
   - **clear subscriber ipv6-pool** *pool_name*
   - **clear subscriber ipv6-range** *pool_name/start_of_range*

3. Use the following **cdl show-sub** CLI commands and wait until all the subscribers are deleted:
   - **cdl show sessions count summary filter { key ipv4-pool:** *pool_name* **condition match }**
   - **cdl show sessions count summary filter { key ipv4-range:** *pool_name/start_of_range* **condition match }**
   - **cdl show sessions count summary filter { key ipv6-pool:** *pool_name* **condition match }**
   - **cdl show sessions count summary filter { key ipv6-range:** *pool_name/start_of_range* **condition match }**
4. After all the subscribers are deleted, delete the pool or address-range from the IPAM configuration.

Configuring the IPAM Offline Mode

This section describes how to configure the IPAM offline feature for pool, IPv4 address-range, and IPv6 prefix-ranges.

Configuring Pool to Offline Mode

Use the following command to configure the entire pool to offline mode.

```
configure
   ipam
      address-pool pool_name
         offline
         ...
         exit
      exit
```

NOTES:

- **address-pool** *pool_name*—Specifies the name of the pool to enter the pool configuration. *pool_name* must be the name of the address pool.
- **offline**—Configures the pool to offline mode.

Configuring IPv4 Address-Range to Offline Mode

Use the following command to configure the IPv4 address-range to offline mode.

```
configure
   ipam
      address-pool pool_name
      vrf-name vrf_name_value
         ip4
            address-range start_ipv4_address end_ipv4_address offline
            address-range start_ipv4_address end_ipv4_address
         !
       !
     !
```

NOTES:

- **address-pool** *pool_name*—Specifies the name of the pool to enter the pool configuration. *pool_name* must be the name of the address pool.
- **ipv4**—Enters the IPv4 mode.
- **address-range** *start_ipv4_address end_ipv4_address*—Specifies the IP addresses for the start and end IPv4 address-range.
- **offline**—Configures the selected address-range to offline mode.

Configuring IPv6 Prefix-Ranges to Offline Mode

Use the following commands to configure IPv6 prefix-range to offline mode.

```
configure
   ipam
      address-pool pool_name
      vrf-name vrf_name_value
        ipv6
              prefix-ranges
               prefix-rangeprefix_value length length_valueoffline
                  prefix-rangeprefix_value length length_value
            !
         !
      !
   !
```

NOTES:

- **address-pool** *pool_name*—Specifies the name of the pool to enter the pool configuration. *pool_name* must be the name of the address pool.
- **ipv6**—Enters the IPv6 mode.
- **prefix-ranges**—Enters the prefix-ranges mode.
- **prefix-range** *prefix_value* **length** *length_value*—Specifies the prefix-range and prefix-length of the IPv6 prefix-range.
- **offline**—Configures the selected address-range to offline mode.

IPAM Redundancy Support Per UPF

Feature Description

The SMF supports IPAM redundancy and load-balancing for each UPF. The IPAM running in the Node Manager microservice has two IPAM instances that are associated to each UPF. When one IPAM instance is inactive, the other IPAM instance manages the address allocation requests for the UPF.

The IPAM redundancy support per UPF feature supports the following functionality:

How it Works

This section provides a brief of how the IPAM redundancy support per UPF feature works.

- Peer Selection—The Node Manager peer is selected during the UPF association.
- UPF Registration with Peer IPAM—IPAM is notified with the instance ID of the peer for the UPF during the registration of the UPF call. IPAM allocates routers from the local data for the specific DNN and checks if the peer IPAM instance is in active or inactive state.

  If the peer IPAM instance is active, a REST call is sent to it to register to the same UPF in the local instance and to receive the routes as response.

  If the peer IPAM instance is inactive, the local instance takes over the IPAM context of the remote instance. Then, the local instance registers to the UPF, receives the routes, and keeps the data back in the cache-pod. After the peer instance is active, it restores the same data from the cache-pod.

  Routes from both the instances are sent to UPF for load-balanced address allocations from both the instances.
- Address Allocation in Load-Balanced Model—As one UPF is registered to two IPAM servers, SMF sends the address allocation requests to any peer that is load-balanced. Respective IPAM instances assign new addresses from their local address bitmap. If one peer instance is inactive, the other peer instance handles all the requests.
- Address-Release Request Handling—In IPAM, the Address Release request is sent to the instance that had allocated the IP the first time. If that peer is inactive, the Address Release request is sent to the peer IPAM.

  The IPAM instance that receives the address releases for remote instances, keeps buffering these instances locally and updates the cache-pod periodically. After the remote peers are active, they handle the buffered address-release requests.
- Release of the UPF—When a peer IPAM is active during the release of a UPF, a REST call is sent to clear the data. If the peer IPAM is inactive, the existing IPAM instance takes over the operational data of the remote IPAM, clears the UPF information, and updates the cache-pod.

IPAM Quarantine Timer Support

Feature Description

The IPAM Quarantine Timer Support feature supports the IPAM quarantine timer for the IP pool address. This feature keeps the released IP address busy until the quarantine timer expires to prevent the reuse of that IP address. Each IP pool must be configured with a timer value. This value determines the duration of a recently released address to be in the quarantine state before it is available for allocation. After the timer expires, the IP address is available in the list of free addresses for allocation by the subscriber. A released IP address with no address quarantine timer is considered to be in use for allocation. If a subscriber attempts to reconnect when the address quarantine timer is armed even if it is the same subscriber ID, the subscriber does not receive the same IP address.

Configuring the IPAM Quarantine Timer Support Feature

This section describes how to configure the IPAM quarantine timer support feature.

Configuring IPAM Quarantine Timer

This section describes how to configure the IPAM quarantine timer.

```
configure
   ipam
      address-pool pool_name
         address-quarantine-timer quarantine_timer_value
         vrf-name vrf_name_value
         ip4
            address-range start_ipv4_address end_ipv4_address
            address-range start_ipv4_address end_ipv4_address
         !
       !
     !
```

NOTES:

- **ipam**—Enter the IPAM configuration.
- **address-pool** *pool_name*—Specifies the name of the pool to enter the pool configuration. *pool_name* must be the name of the address pool.
- **address-quarantine-timer** *quarantine_timer_value*—Specifies the value of the quarantine timer in seconds. The default value is 4.
- **vrf-name** *vrf_name_value*—Specifies the name of the VPN routing and forwarding (VRF) for the pool.
- **ipv4**—Enters the IPv4 mode.
- **address-range** *start_ipv4_address end_ipv4_address*—Specifies the IP addresses for start and end IPv4 address-range.

show ipam pool

Field	Description
PoolName	Name of the Address Pool.
Ipv4Utilization	Utilization percentage for IPv4 address for this pool.
Ipv6AddrUtilization	Utilization percentage for IPv6 address for this pool.
Ipv6PrefixUtilization	Utilization percentage for IPv6 prefix address for this pool.

show ipam pool <pool-name>

Field	Description
Ipv4Addr [Total/Used/Utilization]	Total IPv4 address available(configured for this pool) / Number of used address / Utilization percentage for IPv4 address.
Ipv6Addr [Total/Used/Utilization]	Total IPv6 address available(configured for this pool) / Number of used address / Utilization percentage for IPv6 address.
Ipv6Prefix [Total/Used/Utilization]	Total IPv6 prefix address available(configured for this pool) / Number of used address / Utilization percentage for IPv6 prefix

show ipam pool <pool-name> ipv4-addr

Field	Description
StartAddress	Start address of the range.
EndAddress	End address of the range.
AllocContext	Name of data plane to which this address range is allocated.
Flag	Flag Indicate weather pool is Static or if it is offline.

show ipam pool <pool-name> ipv6-addr

Field	Description
StartAddress	Start address of the range.
EndAddress	End address of the range.
AllocContext	Name of data plane to which this address range is allocated.
Flag	Flag Indicate weather pool is Static or if it is offline.

show ipam pool <pool-name> ipv6-prefix

Field	Description
StartAddress	Start address of the range.
EndAddress	End address of the range.

Field	Description
AllocContext	Name of data plane this address range is allocated.
Flag	Flag Indicates whether pool is Static or if it is offline, S(Static) and O(Offline).

show ipam dp

Field	Description
DpName	Name of the data plane which is registered.
Ipv4Utilization	Utilization percentage for IPv4 by this data plane.
Ipv6AddrUtilization	Utilization percentage for Ipv6 address by this data plane.
Ipv6PrefixUtilization	Utilization percentage for Ipv6 prefix by this data plane.

show ipam dp <dataplane-name>

Field	Description
Ipv4Addr [Total/Used/Utilization]	Total IPv4 address available(configured for this data plane) / Number of used address / Utilization percentage for IPv4.
Ipv6Addr [Total/Used/Utilization]	Total IPv6 address available(configured for this data plane) / Number of used address / Utilization percentage for IPv6.
Ipv6Prefix [Total/Used/Utilization]	Total IPv6 prefix address available(configured for this data plane) / Number of used address / Utilization percentage for IPv6 prefix.

show ipam dp <dataplane-name> ipv4-address

Field	Description
StartAddress	Start address of the range.
EndAddress	End address of the range.
Route	Route allocated for this data plane.

Field	Description
N/P	Display the NodeMgr instance IDs from which it received routes Flag Indication S(Static) and O(Offline).

show ipam dp <dataplane-name> ipv6-addr

Field	Description
StartAddress	Start address of the range.
EndAddress	End address of the range.
AllocContext	Name of pool to which this address range belongs.
Route	Route allocated for this data plane.
N/P	Display the NodeMgr instance IDs from which it received routes.
Flag	Flag Indicate whether pool is Static or if it is offline, Flag Indication S(Static) and O(Offline).

show ipam dp <dataplane-name> ipv6-prefix

Field	Description
StartAddress	Start address of the range.
EndAddress	End address of the range.
AllocContext	Name of pool to which this address range belongs.
Route	Route that is allocated for this data plane.
N/P	Displays the NodeMgr instance IDs from which it received routes Indication, N(Native InstId) and P(Peer InstId).
Flag	Flag Indicate weather pool is Static or if it offline Flag Indication, S(Static) and O(Offline).

show ipam

Field	Description
PoolName	Displays Ipv4Utilization, Ipv6AddrUtilization, and Ipv6PrefixUtilization.

Field	Description
DpName	Displays Ipv4Utilization, Ipv6AddrUtlization, and Ipv6PrefixUtlization.