# IP Pool Management

This chapter includes the following topics:



## Revision History

**Note** Revision history details are not provided for features introduced before release 21.24.

| Revision Details | Release |
|---|---|
| Support of maximum chunk-size value for IPv6 pools is increased to 65536. | 21.27 |
| Support of UP selection based on the availability of IP pool chunks. | 21.26 |
| With this release, the VPN limitation of 100 UPs per context has been removed. | 21.25 |
| First introduced | Pre 21.24 |

## Feature Description

When the IP Pool is unused for a large part, it is not an efficient way of utilizing the resources. The User Plane (UP), which are short of IP resources, can benefit if the unused resources are available to them in a dynamic way.

In the CUPS architecture, there is a centralized Control Plane (CP), large number of UPs, and an automatic and efficient way of managing IP Pool across UPs for the following deployments:

- Co-Located CUPS

- Remote CUPS

This feature enables the configuration of maximum chunk size value of 65536 for IPv6 pools for minimum IP subnet /48 size for dynamic discovery and IP pool assignment to UP.

# How It Works

In CUPS architecture, the PDN/IP context at CP distributes the IP chunk resources among multiple registered UPs in a dynamic way. Following sections describes the overall solution.

## Handling UP De-Registration

UP de-registration is triggered in the following scenarios:

- Graceful de-registration from UP—In this scenario, Control-Plane-Group association is removed with User-Plane-Service CLI. The IP addresses are released at sessmgr level on CP.
- UP connection failure from CP—This scenario occurs either because of miss of heartbeat from UP to CP, or because UP restarts and CP is communicated about it. When UP restarts, it implies that the reception of a new Restart-Counter at CP of the specified UP.

After the UP de-registration is triggered, the VPNMGR task on CP validates the identity and address of UP with the information available in the VPNMGR database. In case of mismatch, VPNMGR shows the failure message. In case of match, the validation is successful. On successful validation, VPNMGR takes all the assigned and unassigned chunks from both IPv4 and IPv6 pools from the specified UP.

Whether the UP has some used or all unused IPs, VPNMGR starts a 2-minutes timer before carrying out forceful de-registration of the UP. During forceful de-registration, all IP addresses are deleted from VPNMGR database locally, session entries are removed, and all the chunks are placed to the main address pools at CP.

## Hold Timer

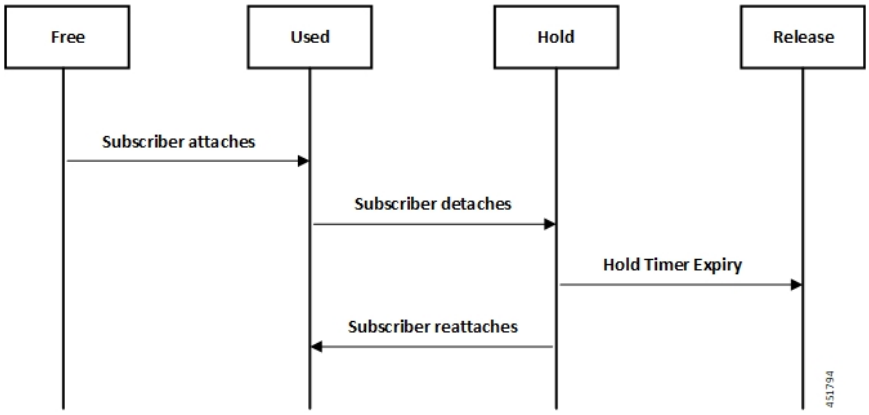
Hold Timer is configured per pool for IPv4 dynamic pools. Static pools and IPv6 pools aren't considered. If Hold Timer isn't configured, an IP address moves from Free to Used state when allocated, and back to Free state when the session is released. With the Hold Timer configured in the pool, a released IP address is moved to Hold state. For the configured Hold Timer duration, the IP address is kept in Hold state and can be reused when the same subscriber attaches again. Since it's in Hold state, the IP address isn't assigned to any other subscriber. After the Hold Timer expiry, the IP address moves to Release state and it's reused when all the free IP addresses are exhausted.

In case of UP deregistration, all IP addresses in Hold state are moved to Free state since the UP details (UP ID and the memory that holds details of UP) aren't preserved at the CP. This might result in the IP address being reused for a different subscriber. Also, VPNMgr recovery and ICSR are supported for Hold addresses.

### Address State Change

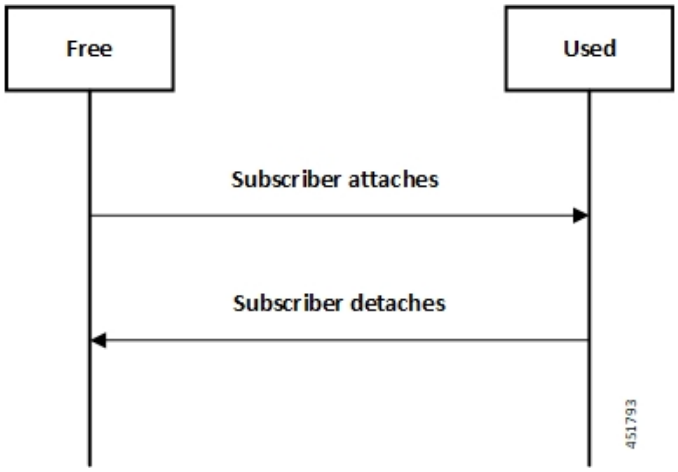
Following call flow describes the address state change with Hold Timer configured.

*Figure 1: Address State Change with Hold Timer*




Following call flow describes the address state change without Hold Timer configuration.

*Figure 2: Address State Change without Hold Timer*




### Configuring Hold Timer

Use the following configuration to enable Hold Timer feature in CUPS.

```
configure
  context context_name
    ip pool pool_name address-hold-timer seconds
    end
```

**NOTES**:

- *pool_name*: Specifies the logical name of the IP address pool. *pool_name* must be an alphanumeric string of 1 through 31 characters.
- When the feature is enabled, and an active subscriber is disconnected, the IP address is held or considered still in use, and isn't returned to the free state until the address-hold-timer expires. This enables subscribers who reconnect within the length of time specified (in seconds) to obtain the same IP address from the IP pool. *seconds* is the time in seconds and must be an integer from 0 through 31556926.

Use the **show ip pool address pool-name** *pool_name* CLI command to check the status of all IP addresses in a pool. It also shows the remaining hold time for the held addresses.

# IP Pools per Context

You can configure 600 IP pools per UP group in a single context at CP. Also, 2000 IPv4 and 256 IPv6 pools can be configured per context in CP which can be distributed among various UP groups with upper limit of 600 pools per UP. The functionality includes:

- UP group can have a maximum of 600 IP pools for all possible combinations of pool type.
- Pools can be either static, dynamic, or combination of both.
- Pools can be all IPv4, IPv6, or combination of both.
- Out of 600, a UP group can have a maximum of 256 IPv6 pool (context level limitation that is same as ASR5500). All 600 pools can be IPv4.
- If more than 600 IP pools are configured in a UP group, then it can't be determined as to which 600 pool/pool chunks will be allocated to a UP.
- The CP maintains count of routes that are installed at UP. If it exceeds 6000 pool routes (context level limitation that is same as ASR5500), then no new chunk is allocated to UP even if it reaches the threshold for overuse. Similarly, if new IP pool is dynamically allocated and 6000 pool routes are already installed, then no new chunk is allocated from that pool even if pool count is less than 600 for that UP.

As part of this feature, the dynamic IPv4 and IPv6 pool count is replaced with total IPv4 and IPv6 pool count in the **show ip user-plane verbose** CLI command. Also, the output of the CLI command is enhanced to display Total Pool Kernel Routes and Max Pool Kernel Routes fields.

# IP Resource Management

In CUPS architecture, the CP has all the IP Pool configurations in PDN/IP context. In compliance with 3GPP standards, the UP registers with CP by Sx Association Request/Response procedure.

During the registration process, the CP finds out all the APNs which are being served by the particular UP, and the associated Pool configuration in each APN. The CP allocates some of the IP chunk resources to a particular UP and sends over the Sx Association Update Request/Response procedure. This information is sent to PDN/IP context instance at UP.

After UP registration is successful, the PDN/IP instance initiates sending of IP chunk resource information to the UP from the Pool. This IP chunk resource information is sent to the UP on Proprietary/Custom IE on Sx Association Update Request/Response message. The PDN/IP instance at UP announces the BGP routes, on per chunk basis, which is received from the CP.

Each UP, which is registered with the CP, is identified using "Peer Id" and the Node ID.

# IP Resource Replenishment/Withdrawal Procedure

For efficient utilization of IP resources, the CP allocates IP resources to UP on need basis. And so, it supports replenishment and withdrawal procedures for IP chunk resources.

Based on the threshold logic in CP, it monitors the usage of IP resources in each UP on pool-level basis. If the overall IP chunk usage of the UP crosses certain threshold, the CP sends additional IP chunk resources to the UP.

If certain IP chunks in the UP are not utilised, and idle for certain duration, the CP withdraws those IP chunk resources from respective UPs. For details, see *Configuring Percentage of Chunks Per Pool* section.

# No-chunk-pool for One UP per UP Group

### Feature Description

For static IP address allocation, the SessMgr requests for specific IP address. The VPNMgr searches for that specific IP address. If the chunk is already allocated to a particular UP, then the VPNMgr allocates that address and responds to the UP which serves the call. For static IPv4v6 call, the requested IPv4 and IPv6 address might belong to different UPs and therefore, success of IPv4v6 can't be guaranteed unless there's only one UP per UP Group. So, for successful static IPv4v6 call, only one UP per UP group can be configured. For one UP per UP Group use case, pool chunking isn't recommended as only one UP uses that pool, and the entire pool can be allocated to the UP rather than in chunks. Also, there are certain use cases to contain one APN to one UP. To support both these use cases, an option to not chunk the pool in CUPS architecture is introduced.

Without the no-chunk-pool functionality, if number of usable addresses are less than the chunk size, then minimum of two chunks were configured.

With no-chunk-pool functionality, a pool can be configured without being chunked. The entire pool is allocated to the UP that is first to request for the pool.

**Note** The no-chunk-pool functionality is recommended only for a setup with one UP per UP Group. It's not recommended for multi-UP per UP Group.

### How it Works

The no-chunk-pool functionality includes:

- When a pool is configured as no-chunk-pool, then pool itself is considered as a chunk and the entire pool is allocated to the UP that is first to request for the pool.
- No-chunk-pool can be public, private, or static.
- No-chunk-pool can be configured within VRF.
- For multi-UP per UP Group, the entire dynamic no-chunk-pool is allocated to the UP that is first to do Sx-association.
- For multi-UP per UP Group, the static no-chunk-pool is allocated in round-robin algorithm among currently servicing UP.
- For multi-UP per UP Group, the dynamically added new pool can get allocated to any UP in UP Group and can’t be deterministically known.

### Configuring No-chunk-pool

Use the following configuration to enable no-chunk-pool functionality.

```
configure
   context context_name
      cups enable
         ip pool pool_name ip_address/subnet_mask no-chunk-pool
         ipv6 pool pool_name prefix ip_address/length no-chunk-pool
   exit
```

The no-chunk-pool can be identified from the output of the following CLI commands if the "total-chunks" field displays 1 (one) for that particular pool.

- **show ip pool-chunks pool-all**
- **show ipv6 pool-chunks pool-all**

# Static IP Pool Management

In CUPS architecture, the strategy to manage static IP pools differs from dynamic pool managemnent. Static IP pools are broken down into "static-chunks" similar to how dynamic pools are chunked. However, these static chunks are not distributed to the UPs and remain at the CP until a UE requests for the first static address in a certain Static-IP-Chunk during session creation.

The CP selects the UP using the round-robin algorithm and the entire Static-IP-Chunk, to which the requested static address belongs, is assigned to the selected UP. Therefore, whenever any UE requests static addresses (IPv4 or IPv6) from that chunk, the UE is assigned that UP.

**Note**

- Within dynamic pools, "allow static" is not supported.
- IPv4v6 static PDP is not supported with multiple UPs in a UP Group.
- For the static IPv4v6 PDNs to be successful, both IPv4 and IPv6 addresses must be on the same UP. Only way to ensure this is to have a single UP in the UP group.
- For the multi-PDNs on same APN to be successful, with one PDN as static and the other as dynamic, both addresses must be on same UP. Only way to ensure this is to have a single UP in the UP group.
- In case of static IP pool, address is already decided by UE and so, the benefit of UP selection does not remain.

# UP Selection

In CUPS architecture, during the establishment of sessions, UP selection happens among the registered UP. There are various ways to select UP. In earlier releases, Round-Robin Algorithm based UP selection was supported. Currently, least connection User Plane selection algorithm is supported.

## UP Selection based on IP Pool Chunk Availability

Prior to 21.26 release, the CP selects an UP based on least session usage or Round-Robin algorithm. If chunks are exhausted in a selected UP, it results in rejection of Session Establishment request by the CP until new IP pools are added for the impacted APNs. This result in wastage of IP resources in an UP, which still has some chunks with free IP addresses.

In 21.26 and later releases, this feature is enhanced to allow UP selection based on the availability of IP pool chunks. When chunks are exhausted in some UPs, and if the CP receives an attach request, the CP selects randomly any UP that has IP addresses available. Also, it ignores any other UP selection algorithm that is configured.

### Limitations

- UP selection for Pure-S calls isn't supported.
- Only non-DNS based UP selection is considered for IP address-based validation.
- UP selection is overridden if the selected UP has no IP address to allocate for the session.
- During Sx association, if one of the contexts don't have sufficient chunks for all UPs, then only UPs which get chunks are maintained in VPN.
- As the VPN overrides UP selection when chunks aren't available in certain UPs, you must follow proper IP pool planning guidelines to minimize uneven load distribution across UPs.

  For IP pool planning guidelines, see IP Pool Planning Guidelines.

# Supported Functionality

The following functionalities are supported as part of the IP Pool Management feature.

- IPv4, IPv6 Public, and private pool-based IP address allocation.
- IPv4 static type address allocation.
- Session Manager recovery and VPN Manager recovery for active calls types.
- CP to CP Interchassis Session Recovery (ICSR) support.
- Hold-timer for IPv4 pools.
- Busy-out (basic functionality) for IPv4 and IPv6 pools.

# Limitations

Following are the known limitations and restrictions of this feature for this release:

- The "allow-static" type pool configuration isn't supported.
- Configure the **cups enabled** CLI before you add a pool in IP context to enable IP Pool Management functionality in CUPS mode.
- IPv4v6 static PDP isn't supported with multiple UPs in a UP Group.
- The output of the following CLI commands displays all pools with maximum of 2048 chunks per pool:

- **show ipv6 pool-chunks up-id** *up_id*
- **show ipv6 pool-chunks pool-name** *ipv6_pool_name*
- **show ip pool-chunks up-id** *up_id*
- **show ip pool-chunks pool-name** *ipv4_pool_name*

- Following are not supported in the CUPS architecture:
  - IPv6 – address hold timer is not supported.
  - PDN v4v6 – address hold timer is not supported.
- Upon UE reattach, CP needs to select the same UP session (as IP address is already advertised by that UP in the earlier session). Hence there is no UP load based selection or location based UP Selection possible.
- Hold timer value of 0 is not supported.
- Recovery of Hold timer is supported for up to 1000 address per session manager.
- Reload chassis results in the standby chassis losing the hold timer information.
- Any change to the Hold timer value also requires a Sx re-establishment like it happens for any other pool configuration.

### Pool System Limits

Currently CP DI-Large model supports the scaling numbers for parameters that are as listed in the table below. These limits remain constant irrespective of the chunk size value used and are the maximum limit value of any given parameter. The limits of the parameter which have reached their maximum value restricted the subsequent parameter's upper limit value.

**Note** Small and medium model will have lower limits than the rest.

| Parameters | Limits |
|---|---|
| IPv4 pools per context | 2000 |
| IPv6 pools per context | 256 |
| IP pools per chassis | 5000 (including both v4 and v6) |
| Dynamic pool addresses | 16 Million per context<br>32 Million per chassis |
| Static pool addresses | 32 Million per context<br>96 Million per chassis |
| Number of VRFs | 300 per context<br>2048 per chassis |

| | |
|---|---|
| Max IP Pool size | 512k |
| Max IPv6 Pool size | 1 Million |

### Implications of chunk size on UP group:

The pool is the basic unit for chunk allocation and all UPs are allocated chunks from the relevant pools. Maximum UPs which can get chunks with chunk size value of 65536 are 1 million/65536 = 16. Due to which only 16 UPs are supported in each UP group for the chunk size value being 65536.

### Implications of chunk size on APN:

For a single UP group used in APN configuration, the limits are same as the UP group limit values.

For multiple UP groups used in APN configuration, refer to the *Multiple UP Groups with Group Specific IP Pool* chapter.The maximum UP groups of 16 UPs that are supported are 16 million addresses per context or 1 million address pool allowing a total of 16 UP groups of 16 UP APN.

Due to the exhaustion of all pool configuration in the v6 pool, the rest of the APN operating in the same VPN context use the same IPv6 pool. The 16 UP groups of 16 UPs is based on the assumption that there are no IPv4 addresses as otherwise the limit is lower than expected. As 32 million dynamic addresses are supported by the system, only 2 SGI contexts are allowed.

# Configuring IP Pool Management

This section provides information about the CLI commands available in support of this feature.

**Important**

- In an earlier release, User Plane profile configuration was required for S-GW and P-GW. With this release, User Plane profile configuration is no longer required in S-GW and P-GW for UP selection. Also, it is not required to be associated with IP pool configuration.
- Same PDN context should be present at both CP and UP.
- IP context name, which is specified in APN configuration, should be same for both CP and UP.

For guidelines around planning IP Pool and User Plane grouping in your network, contact your Cisco Account representative.

# At Control Plane

### Enabling IP Context for IP Pool Management

Use the following CLI commands to enable IP context for IP Pool management.

```
configure
  context context_name
    cups enable
    end
```

### Configuring Custom Threshold Timer

**Important** In 21.9 (mid-July) and later releases, the **cups chunk-allocate-timer** *allocate_timer_seconds* **chunk-release-timer** *release_timer_seconds* CLI command is deprecated, and replaced by **cups chunk-threshold-timer** *threshold_timer_seconds* and **cups min-chunks-threshold-per-pool** *threshold_percent* CLI commands.

There is a threshold timer for chunk redistribution among UPs. By default, for sending chunk into an over utilized UP, check is carried out every 60 seconds, and for removing chunk from an underutilized UP, check is carried out every 300 seconds. For custom threshold timer, use the following CLI commands:

```
configure
  context context_name
    cups chunk-allocate-timer allocate_timer_seconds chunk-release-timer
release_timer_seconds
    end
```

**NOTES**:

- This is an optional configuration. If not configured, then by default the allocate threshold is 60 seconds and the release threshold is 300 seconds.
- Use the **default cups chunk-allocate-timer chunk-release-timer** CLI command to revert back the chunk-allocation and chunk-release timer to 60 and 300 respectively.
- If the release timer is configured to be less than the allocate timer, then it is overwritten with the value that equals to the allocate timer.

### Configuring Chunk Threshold Timer

Use the following CLI commands to configure CUPS IP pool chunk threshold timer for a context.

```
configure
  context context_name
    cups chunk-threshold-timer threshold_timer_seconds
    end
```

**NOTES**:

- *threshold_timer_seconds*: Specifies the chunk threshold timer value in seconds, integer 30 to 300. Default = 60 seconds.
- Use the **default cups chunk-threshold-timer** CLI command to set the default value of 60 seconds.
- In releases prior to 21.9 (mid-July), allocation of new chunks to UP and release of chunks from underutilized UP use to occur based on allocation and release timers, respectively. With 21.9 (mid-July) and later releases, only single threshold timer exists, based on which the allocation and release of chunks occur periodically.

### Configuring Percentage of Chunks Per Pool

Use the following CLI commands to configure minimum percentage of chunks per pool in a context.

```
configure
  context context_name
    cups min-chunks-threshold-per-pool threshold_percent
    end
```

**NOTES**:

- *threshold_percent*: Specifies the minimum chunks in percentage of 0 to 50. Default = 10.
- Use the **default cups min-chunks-threshold-per-pool** CLI command to set the default value of 10 percent.
- Chunks are released periodically only when free chunks with particular pools, at CP, are less than the percentage configured with this CLI command.
  - When minimum chunks equals to, or falls below, the configured percentage, a check is done to ascertain if there is any UP that has less than 50% utilization and has more than 2 free chunks. If there is, then one is taken back from each underutilized UP from that particular pool.
- Warning log is generated for: periodicity = chunk-threshold-timer; till minimum chunks in CP VPNmgr are restored.
- UP lockdown period on registration: For first five (5) minutes of a UP registration, no chunks are taken back from that UP and sent to another UP even if other UPs are in need of chunks.

## Configuring Chunk-size Value

Use this CLI command to specify the size of the chunk for the particular IP pool during pool creation.

```
configure
  context context_name
    ip pool pool_name prefix mask chunk-size chunk_size_value
    end
```

**NOTES**:

- Chunk-size configuration happens only during the configuration of IP pool for the first time along with prefix or mask.
- Chunk-size value must be in powers of 2 and range from 16 through 65536.
- Default Value: 1024

# At User Plane

For IP context in UP, there is no requirement for IP Pool configuration, or to use the **cups enabled** CLI command.

# Configuring User Planes for a System

Use the following CLI commands to configure maximum number of User Planes expected to be functional in a system.

```
configure
  context context_name
    cups max-user-planes value
    end
```

**NOTES**:

- In releases prior to 21.25:

  **cups max-user-planes** *value*: The default value is 10.

  The maximum number of user-planes supported in a context and UP Group is 100.

- In 21.25 and later releases:

  **cups max-user-planes** *value*: The value is in the range of 1-1000. The default value is 10.

  The maximum number of user-planes supported in a context is increased to 1000.

  This refers to the VPNMGR limits and not the actual number of user-planes that are supported. The actual number of user-planes supported in the system is determined by Sx.

  Use this CLI command to tune the chunks that were initially allocated on Sx-association. It can't be used to restrict the addition of new UPs into a system.

- Use the **default cups max-user-planes** CLI command to revert back the maximum user-planes value to 10.

# Monitoring and Troubleshooting

This section provides information regarding monitoring and troubleshooting the feature.

## Show Command(s) and/or Outputs

This section provides information regarding show commands and/or their outputs in support of this feature at CP.

### show ip pool-chunks pool-name <pool-name>

The output of this command displays all the chunks in the specified IPv4 pool.

- chunk-id
- pool-id
- up-id
- total-addr
- free-addr
- used-addr
- hold-addr
- release-addr

- busyout-free
- busyout-used

## show ip pool-chunks pool all

The output of this command displays the IPv4 pool chunks that are allocated to all the User Planes.

- chunk-id
- pool-id
- up-id
- total-addr
- free-addr
- used-addr
- hold-addr
- release-addr
- busyout-free
- busyout-used

**Note** The above fields are also displayed for the **show ipv6 pool-chunks pool all** CLI command except for the "hold-addr" and "release-addr" fields.

## show ip pool-chunks up-id <up_id> user-plane-group name <grp-name>

The output of this command displays all the IPv4 chunks that are allocated to a specific User Plane.

- chunk-id
- pool-id
- up-id
- total-addr
- free-addr
- used-addr
- hold-addr
- release-addr
- busyout-free
- busyout-used

## show ip user-plane chunks

The output of this command displays IPv4 chunks allocated to each User Plane.

- up-id
- total-chunks
- free-chunks
- used-chunks
- full-chunks

**Note** The above fields are also displayed for the **show ipv6 user-plane chunks** CLI command.

## show ip user-plane prefixes

The output of this command displays IPv4 prefixes allocated to each User Plane.

- up-id
- Total
- Free
- Used
- Hold
- Release
- Busyout-Free
- Busyout-Used

**Note** The above fields are also displayed for the **show ipv6 user-plane prefixes** CLI command.

## show ip user-plane verbose

The output of this command displays all the details related to a User Plane.

- User-plane Group Name
- User-plane ID
- User-plane address
- Sxmgr-id
- IPv4 Chunks
  - Total

    - Free
    - Used
    - Full
- IPv4 address
    - Total
    - Free
    - Used
    - Hold
    - Release
    - Busyout-Free
    - Busyout-Used
- IPv6 Chunks
    - Total
    - Free
    - Used
    - Full
- IPv6 prefixes
    - Total
    - Free
    - Used
    - Busyout-Free
    - Busyout-Used
- Total Pool count
    - IPv4
    - IPv6
- Total Pool Kernel Routes
- Max Pool Kernel Routes
- Total VRFs
- apn-without-pool-name-v4
- apn-without-pool-name-v6
- Pool-groups

## show ip user-plane

The output of this command displays the details of all the User Planes that are registered with the VPN Manager.

- up-id
- user-plane-address
- user-plane-group-name
- sxmgr-id

**NOTES**:

- Use the **show ip user-plane up-id***up_id***user-plane-group name** *grp-name* to view the details of a specific User Plane belonging to a specific User Plane group.

## show ipv6 pool-chunks pool-name <pool-name>

The output of this CLI command displays all the chunks in the IPv6 pool.

- chunk-id
- pool-id
- up-id
- total-addr
- used-addr
- busyout-free
- busyout-used

## show ipv6 pool-chunks up-id <up_id> user-plane-group name <grp-name>

The output of this command displays all the IPv6 chunks that are allocated to a specific User Plane.

- chunk-id
- pool-id
- up-id
- total-addr
- used-addr
- busyout-free
- busyout-used