Redundancy Configuration Manager – Configuration and Administration Guide, Release 2021.01

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Overview

The Redundancy Configuration Manager (RCM) is a Cisco proprietary node/network function (NF) that provides redundancy of StarOS-based UP/UPFs. The RCM provides N:M redundancy of UP/UPFs wherein "N" is number of Active UP/UPFs and is less than 10, and "M" is the number of Standby UP/UPF in the redundancy group.

The RCM is developed using the Subscriber Microservices Infrastructure (SMI), a Cloud Native (CN) application. The RCM is delivered both as VM-based and CN-based image. For 4G, the RCM VM image is collocated with UPs and deployed as a VM. For 5G, the RCM is deployed as CN application leveraging the SMI Cluster Manager.

For details about RCM integration with SMI Cluster Manager, refer the RCM and SMI Cluster Manager Integration chapter.

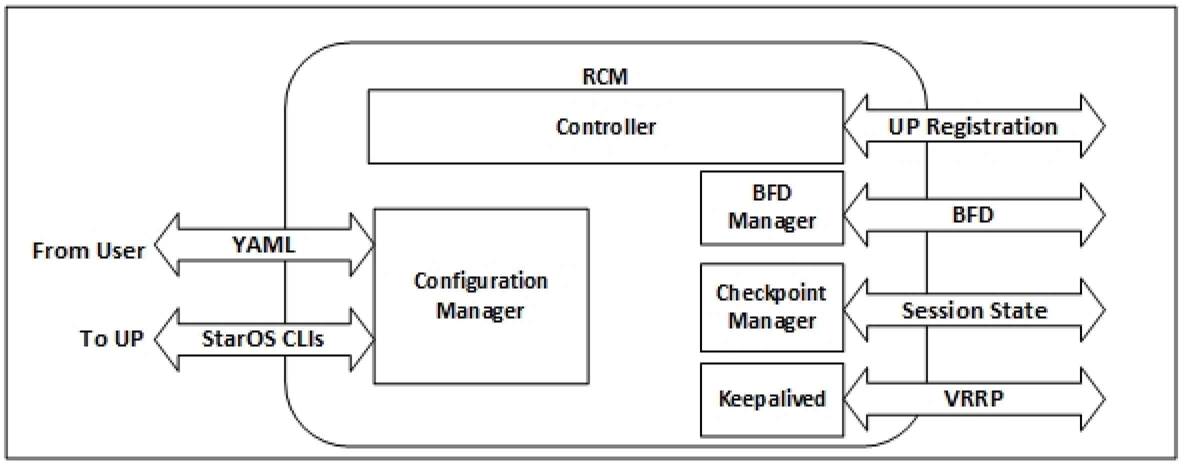
The RCM supports the following functions:

- **Redundancy Management**
  - Monitors the health of each active UP/UPF
  - Selects a standby UP/UPF to become active when an active UP/UPF becomes unreachable
  - Stores session checkpoint information from active UPs/UPFs
  - Sends session checkpoints to new active UP/UPF during switchover
- **Configuration Management**
  - Decides the role of a UP/UPF; Active or Standby
  - Stores the configuration data that is sent to a UP/UPF
  - Provides the configuration data to a new UP/UPF (includes Day-0 to Day-N):
    - **Day-0**: Configuration required on UP/UPF with local context, management IP, and other static configurations other than ECS, APN and host-specific configurations (for example, bulkstats, thresholds, and so on.)
    - **Day-0.5** (RCM Context configurations): Configuration required to connect to UP/UPF.

    Note: Day-0 and Day-0.5 configuration is outside the scope of RCM and must be configured in UP/UPF using ESC/CM/NSO/CFP. Contact your Cisco Account representative for more details.
  - Determines the Control Planes (CPs)/Session Management Functions (SMFs) that register with the UPs/UPFs.

Components

The following diagram illustrates the components of RCM.



The RCM comprises of the following components which runs as pods in the RCM VM:

- **Controller**: It communicates event-specific decisions with all the other pods in RCM.
- **BFD Manager** (**BFDMgr**): It uses the BFD protocol to identify the state of data plane.
- **Configuration Manager** (**ConfigMgr**): It loads the requested configuration to the UPs.
- **Redundancy Manager** (**RedMgr**): It is also called the Checkpoint Manager; it stores and sends the checkpoint data to a standby UP.
- **Keepalived**: It communicates between Active and Standby RCM using VRRP.

Minimum Requirements

Its recommended that the RCM, which runs as a Kubernetes cluster on a VM, meets the minimum hardware and software requirements provided in the following tables.

For sizing parameters and recommendations for typical deployment setup, see Appendix A: Deployment Parameters.

Hardware Requirements

Node Type	CPU Cores	RAM	Storage
RCM	(2 + No. of SessMgrs in one UP) x 2.60 GHz	8GB + 4GB for each active UP	40GB HDD

Software Requirements

VIM	RCM Component Operating System
VMware - ESXI 5.5 or later OpenStack 13 or later	Ubuntu 18.04

NOTE: The above VM recommendation is validated for a single User Plane group of 12 (10:2) UPs.

Deploying the RCM

For 5G deployments, see the RCM and SMI Cluster Manager Integration chapter.

For 4G CUPS deployments, the RCM is deployed as VNF in a single VM. The following VM image types are available for deployment.

Image	Description
rcm-vm-airgap.<release>.ova.SPA.tgz	The RCM software image that is used to on-board the software directly into VMware.
rcm-vm-airgap.<release>.qcow2.SPA.tgz	The RCM software image in a format that can be loaded directly with KVM using an XML definition file, or with OpenStack.
rcm-vm-airgap.<release>.vmdk.SPA.tgz	The RCM virtual machine disk image software for use with VMware deployments.

To deploy the RCM:

1. Download the RCM image tar file that corresponds to your VIM type.
2. Unpack the RCM image from the tarfile related to your VIM.
3. Onboard the RCM image into your VIM per the instructions for your VIM.
4. Create a VM flavor based on the information in Hardware Requirements section.
5. Create cloud-init configuration per your VIM requirements. See RCM VM Deployment Procedure section.
6. Deploy the RCM image to the compute per the instructions for your VIM.
7. Proceed to “Configuring the RCM”.

RCM VM Deployment Procedure

The following steps describes the procedure to deploy the RCM VM:

1. Initialize the RCM VM instance using the cloud-init file.

   Following is a sample configuration from cloud-init file (user_data.yaml):

```
#cloud-config
users:
  - default
  # password generated via: mkpasswd --method=SHA-512 --rounds=4096
  - name: luser
    gecos: luser
    primary_group: luser
    groups: [admin, adm, audio, cdrom, dialout, docker, floppy, luser,
video, plugdev, dip, netdev]

    lock_passwd: false

    passwd:
$6$rounds=4096$Zl7FnVp7dYlT0bw$CFqAVNA8M1wxaEXwAVYlKfekSrTXbGUne1ihJ11xdNk
29bfCk2AURQG4XV.LnFNX6MmsW9OPvFxDZpeapXkYG.

    shell: /bin/bash

    home: /home/luser

ntp:

    servers:

     - 10.84.96.130

     - 10.84.98.2

     - 10.81.254.131

manage_etc_hosts: localhost


ssh_pwauth: yes
```

2. Create the cloud-locald rcm-seed image from the user_data file using the following command. The coomand can be executed from any local server or a jump server from where the deployment is carried out:

   `cloud-localds -H rcm rcm-seed.img user_data.yaml`

   Where:

   - **`cloud-localds`**: Creates a disk for cloud-init to utilize nocloud.
   - **`-H`**: Specifies the host name.

   Usage/Syntax:

   `cloud-localds [ options ] output user-data [ meta-data ]`

3. Attach the rcm-seed.img as CDROM to the VM.
4. After the VM is up:

   a. Ensure the hostname of RCM VM is added to */etc/hosts*

      For example: **`127.0.1.1 rcm`** *`rcm`*

      Where *`rcm`* is the hostname.

   b. Ensure that the kubeadm_init, kubelet, calico_init, helm, and init_cluster services are running. You can verify by executing the following command:

      `systemctl status kubelet/helm/init_cluster/calico_init`

NOTE: Allow additional time (approximately 15 minutes) for Ops Center to come up on first boot. The extra time is required for the system startup to run certain hardening scripts that makes the system more secure.

You can check the following system service status. Excluding kubelet and helm, for which the status will display as Active (Running), status for all other services will display as Active (Exited):

- **`systemctl status kubelet`**

- **`systemctl status kubeadm_init`**
- **`systemctl status calico_init`**
- **`systemctl status hardening`**
- **`systemctl status helm`**
- **`systemctl status init_cluster`**

The Ops Center pods comes up after the status of all the services are Active.

c. For kubectl commands to work for a non-root user, please execute the following (this example assumes the user is called "luser"):

```
mkdir ~luser/.kube
sudo cp /etc/kubernetes/admin.conf ~luser/.kube/config
sudo chown luser:luser ~luser/.kube/config
```

d. Setup the helm using:

```
helm init --client-only --kubeconfig /etc/kubernetes/admin.conf --
stable-repo-url http://10.42.1.1:9000
```

NOTE: The “http://10.42.1.1” is the location of docker images for RCM which is used by Helm. It is a local URL inside the VM.

e. RCM ops-center pods can be seen in the RCM namespace:

```
kubectl get pods -n rcm
```

f. Configure the UP username and password, in Ops Center, that are passed to ConfigMgr. For details, see Configuring UPF Credentials section.

NOTE: Without configuring the UPF credentials, the ConfigMgr pod will not be in running state.

5. Configure the Ops Center to bring up the RCM component pods:

a. Get ops-center pod name by executing below command

```
kubectl get pods -n rcm_namespace | grep ops-center
```

b. Reset the password of the Ops Center using the following command:

```
kubectl exec -ti ops_center_pod reset-admin -n rcm
```

For example: *kubectl exec -ti ops-center-rcm-ops-center-d6d9cf976-jmght reset-admin -n rcm*

c. Access the Ops Center using the password created in Step 5b.

d. Access the Ops Center CLI using ops-center service IP:

```
kubectl get svc -n rcm
ssh -p 2024 admin@svc_ip
```

For example: `ops-center-rcm-ops-center ClusterIP 10.43.213.124<none> 8008/TCP,8080/TCP,2024/TCP,2022/TCP,7681/TCP 39h`

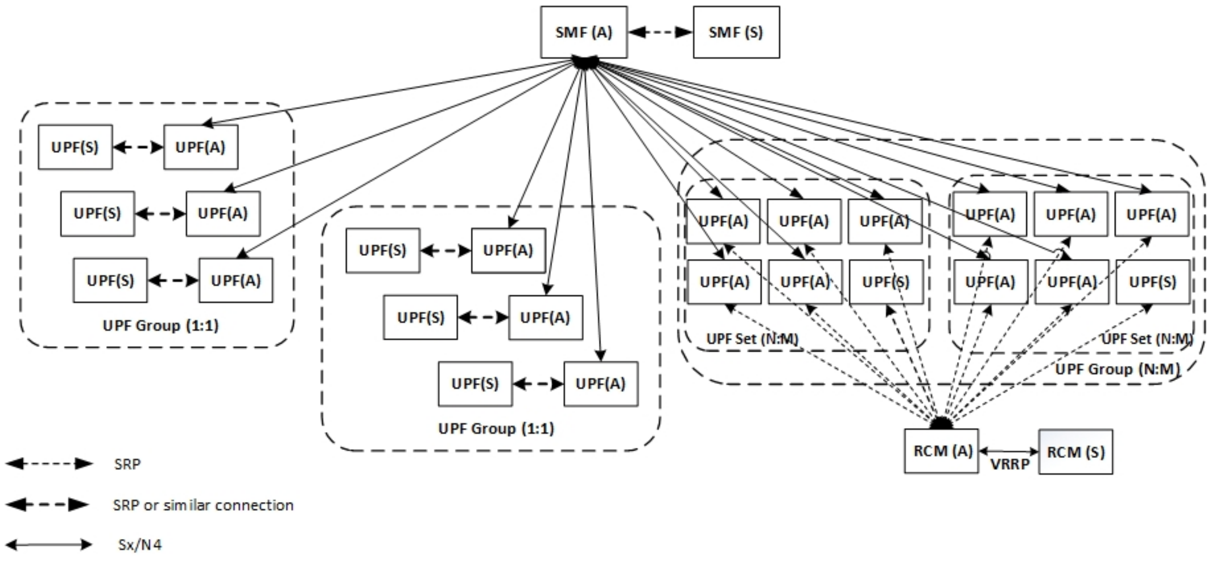
6. After Ops Center CLI is configured, run RCM components using the following command in Global Configuration mode:

```
system mode running
```

To remove RCM components: **`system mode shutdown`**

RCM Deployment Architecture

The following diagram illustrates a typical RCM deployment model.



- It is co-located with all the UPs it manages; RCM can manage multiple independent UP groups.

  Note that the UP groups in 1:1 redundancy mode is through ICSR and are not controlled by RCM.
- It has a high-performance network between itself and its UPs (SR-IOV or equivalent). Same is the case with Keepalive (VRRP) network between RCM HA instances.
- It monitors its UPs for failures and initiates failover to a standby UP.
- It quickly detects a UP failure using the multi-hop BFD protocol.
- It pre-configures (excluding CP and UPs Day-0 and Day-0.5 configuration as they are part of RCM) standby UPs with all the active host-specific configuration.
- Its user interface (UI) displays the state or health of a UP, stats, historical events (logs), and triggers a manual failover. In addition to monitoring, the UI supports the addition and removal of UPs and/or UP groups.
- If an RCM is configured without a redundant RCM, then the UPs under its control continue to run and provide services (not redundantly).
- If RCM restarts and connects to UPs, then the RCM re-learns or audit state from the existing UPs without disrupting services.

How it Works

This section describes how the RCM functions work:

- Redundancy Management
- Configuration Management

Redundancy Management

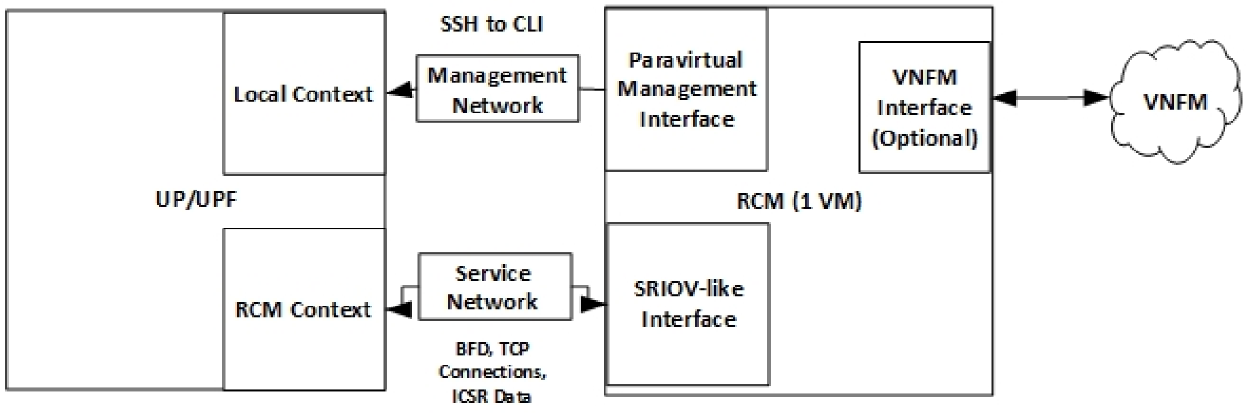
N:M redundancy using RCM, where N > 1 and M is at least 1, is a mechanism that is required to store all the required information at a common location. This common information is properly segregated based on "N" User Planes (UPs)/User Plane Functions (UPFs), and each UP/UPF contains "x" Session Managers (SessMgrs). On a switchover trigger, one of the "M" UPs/UPFs available as standby is selected to receive the appropriate data from the common location. This functionality is achieved through RCM.

To support N:M UP redundancy, the RCM provides the following functionality:

- Procedure to acquire the dynamic configuration based on the configuration changes. The Configuration Manager performs this procedure and pushes the configuration according to the state of the UP (active or standby).
- Method to store and retrieve the checkpoint data. It stores the checkpoint data because the exact standby for each active UP is not pre-allocated. When an active UP fail, the Redundancy Manager (RedMgr) pods send the stored checkpoint data to the newly selected UP from the available pool of standby UPs.
- Mechanism to detect the failure of a UP. A Bidirectional Forwarding Detection (BFD) Manager (BFDMgr) pod monitors the UP/UPFs and detects failures.
- Enables the RCM Controller pod to take decisions and instruct the other pods depending on the UP discovery or failure. Based on number of events, the Controller also controls the actions of the three managers: Configuration Manager, Redundancy Manager, and BFD Manager.
- Maintain information about the IP pool.

Architecture

The following diagram illustrates the logical network layout for a single VM RCM.



The RCM node is built on Subscriber Management Infrastructure (SMI). SMI provides the Kubernetes (K8s) infrastructure, which is used to bring all the required pods to support the redundancy for UPs.

The Ubuntu cloud image supports cloud-init based configuration (https://cloud-init.io). You must use cloud-init to configure local user accounts (ssh key or password-based) and network configuration.

RCM services (rcm-controller, ConfigMgr, RedMgr) are prepopulated in the disk image. An RCM-specific Ops Center provides the user interface to RCM. The RCM services are started on bootup and monitored via K8s liveliness.

In RCM, the VM requires multiple network interfaces. One interface for "management" connectivity (Ubuntu SSH daemon and Ops Center access), and another interface is for "service" connectivity (session state over this interface). The "management" interface has low throughput requirement and so, paravirtual NICs can be used. The "service" interface needs to be high speed and so, a SRIOV type interface is required. One optional "VNFM" interface can be used as pingable interface for ESC. Cloud-init is used to configure these NICs. Cloud-init configuration and NIC naming can vary depending on the environment

For deployment information, refer RCM Deployment section.

Redundancy with Cloud Native

The N:M redundancy with Cloud Native support involves:

- A procedure to acquire the dynamic configuration based on the configuration changes.

  This is performed by the ConfigMgr. It pushes the configuration according to the state of the UP (Active or Standby).
- A way to store and retrieve the checkpoint data. It stores the data as the exact Standby for each Active is not pre-allocated. On Active failure, the checkpoint data is pushed to the newly-selected Active from the available pool of Standby.

  This is performed by the RedMgr (CheckPointMgr) pods.
- A mechanism to detect the failure of UP. A BFDMgr pod monitors all the UPs and detects failure.
- A Controller pod determines and instructs action mechanism to other pods based on UP discovery and failure. Controller also controls the actions of all the three managers on several events.

Upgrade Process

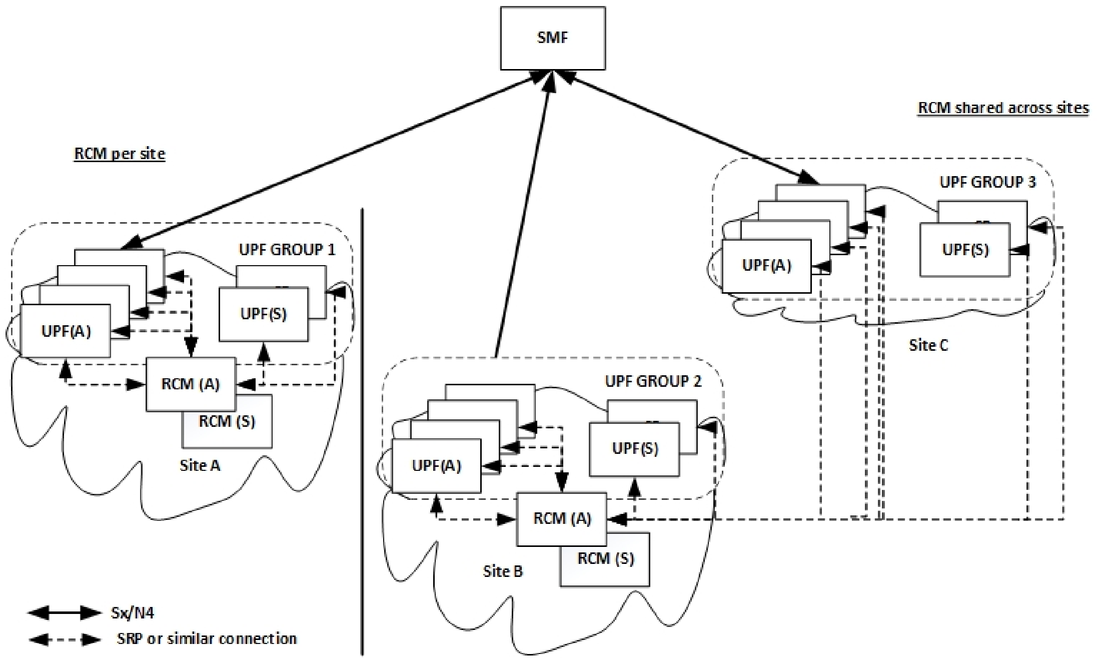
All the required RCM images are bundled as offline tar images and can be downloaded from the software repository. You can perform the rolling upgrades through Common Execution Environment (CEE) Ops Center.

For details, refer the *Upgrading CEE Products* section in the *UCC SMI Common Execution Environment Configuration and Administration Guide.*

For VM-based application, rolling upgrade of components is currently not supported. Any updates to Ubuntu packages or RCM components are delivered through a new disk image. You must delete the current RCM instance, spawn a new RCM instance based on the new disk image, and then configure the new instance.

For upgrade/downgrade of RCM in HA, see RCM Upgrade and Downgrade Procedure in HA.

N:M Redundancy Architecture



In 4G networks, UPs and CPs communicate over the Sx interface. In 5G, the UPFs and SMFs communicate over N4 interface. The UP is user plane which could be a PGW-U, SGW-U, SAEGW-U, or UP(F). A group of UPs that are deployed to support the same configuration are said to be a part of same UP group (UPG). Therefore, for an N:M redundancy configuration, the UP group is comprised of (N+M) UPs that are of the same capacity and capability.

The UP transfers the checkpoint data to Redundancy Manager pods on the RCM. These pods receive the checkpoint data, store them, and segregate them properly so that each checkpoint is retrieved or modified properly. The checkpoint data reuses the same mechanism of Service Redundancy Protocol (SRP) on the UP to transfer the data to achieve the redundancy.

During switchover, the RCM Controller indicates to all the Redundancy Manager pods to push the data of the failed UP to a new UP. First, the Controller pushes the pool-chunk information to the newly selected UP. Secondly, the call records for all the subscribers are pushed to the corresponding Session Managers. Lastly, the Controller itself pushes the route modifier and IP pool information to the new UP. On receiving all the required data, the new UP becomes active and services new calls along with the existing calls.

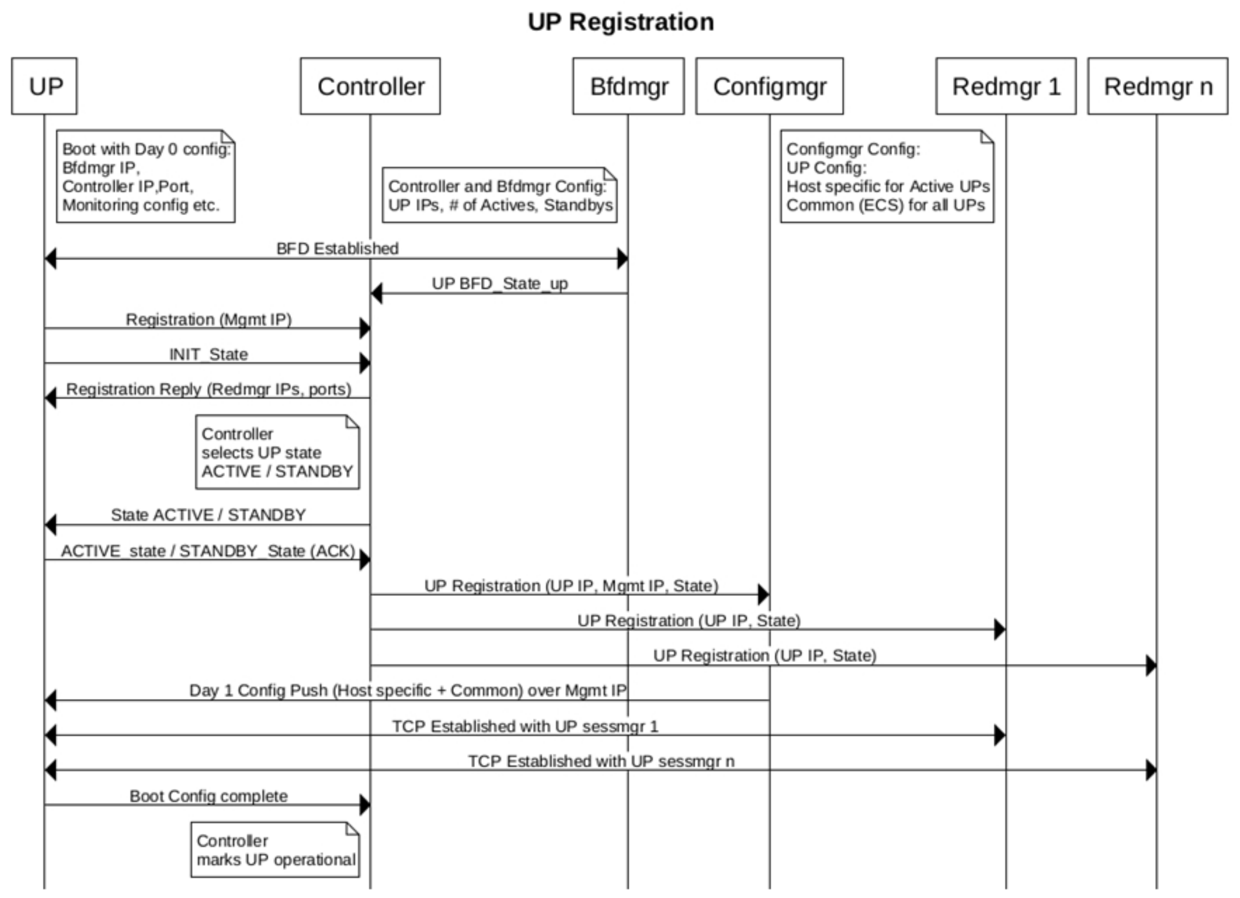
To ensure faster data retrieval, it’s stored in memory. The checkpoint data that the Redundancy Manager receives is stored in the RAM. After careful segregation based on UP, session, and call, the checkpoint data is pushed to the new active UP after a switchover from the RAM.

The BFD Manager detects the failure of a UP and informs the controller about the failure. Then, the Controller selects a new UP from the available pool of ‘m’ standby. The Controller also instructs all the Redundancy Managers to transfer the checkpoint data to the new active UP. It also handles the synchronization of data from various Redundancy Managers to the new UP.

The RCM supports multiple UP groups and segregates based on the UP group. If there is any failure notification, the Controller also identifies the UP. The Session Manager of the UP connects and stores the checkpoint data in the same Redundancy Manager pod. To achieve this result, the Redundancy Manager pod maintains the same IP and port even after a pod reboot.

UP Registration Call Flow

The following call flow illustrates the registration of UP.


UP Registration
UP
Controller
Bfdmgr
Configmgr
Redmgr 1
Redmgr n
Boot with Day 0 config: Bfdmgr IP, Controller IP,Port, Monitoring config etc.
Controller and Bfdmgr Config: UP IPs, # of Actives, Standbys
Configmgr Config: UP Config: Host specific for Active UPs Common (ECS) for all UPs
BFD Established
UP BFD_State_up
Registration (Mgmt IP)
INIT_State
Registration Reply (Redmgr IPs, ports)
Controller selects UP state ACTIVE / STANDBY
State ACTIVE / STANDBY
ACTIVE_state / STANDBY_State (ACK)
UP Registration (UP IP, Mgmt IP, State)
UP Registration (UP IP, State)
UP Registration (UP IP, State)
Day 1 Config Push (Host specific + Common) over Mgmt IP
TCP Established with UP sessmgr 1
TCP Established with UP sessmgr n
Boot Config complete
Controller marks UP operational

Operational Flow

Boot-up Sequence of Pods

On configuring redundancy, the Subscriber Microservices Infrastructure (SMI) brings up the following pods (not in any particular order):

- Configuration Manager Pod
- Redundancy Manager Pods: These are a set of Redundancy Managers based on the UP group and number of Sessions Managers tasks that need support. Ideally this indicates the number of Session Managers tasks in each UP.
- BFD Manager Pod: This is a UP/UPF monitoring pod that monitors all the available UP/UPFs in a redundancy group.
- Controller Pod: This pod also comes up about the same time as all other pods.

Meanwhile, each UP comes up independently. Only the endpoint address of the RCM is configured for each UP.

When each pod comes up, the Controller is notified about the existence of each pod. The Configuration Manager indicates to the Controller about its presence. The Configuration Manager also indicates the readiness to push the configuration, on UP registration. When the Redundancy Manager pods come up, their presence is notified to the Controller. The Controller establishes a communication mechanism with all the Redundancy Manager pods. After the UP starts sending the checkpoint information to each Redundancy Manager, it updates the Controller about the hosting of the checkpoint data and the Session Manager instance. The BFD Manager also establishes the connection with the Controller and exchanges a handshake with the Controller.

UP Bootup Sequence

The following is the UP bootup sequence when the RCM is used:

1. The UP sends Init state to the RCM Controller.
2. The RCM Controller determines to make it Active or Standby and sets the state as PendActive or PendStandby in its data structures (The PendStandby is not available for switchover selection).
3. The RCM Controller sends State (Active or Standby), Host ID (Host string), and Route Modifier to the UP.
4. The UP responds to the RCM Controller acknowledging the State and Host ID.
5. The UP stores or updates its State and Host ID in Shared/System Configuration Task (SCT).

   SCT is a StarOS task for configuring system parameters, retrieving information, and notifying system components of configuration changes.
6. The RCM Controller sends the UP's Endpoint, State, and Host ID notification to its Configuration Manager service.
7. The RCM Controller also sends the UP's Endpoint and State to its Redundancy Manager service.
8. The RCM Configuration Manager pushes the Active or Standby configuration to the UP.
9. The UP stores the "Config Pushed" flag in its SCT (vpnmgr) subsystem.
10. The UP sends a "Config Push Complete" notification to the RCM Controller through vpnmgr.
11. The RCM Controller marks PendActive or PendStandby as full Active or Standby. (The Standby state is now available for switchover).
12. The RCM Controller sends the "Config Push Complete" message its Configuration Manager service for reconfirmation.

UP Switchover Sequence

The following is the UP switchover sequence when the RCM is used:

1. The RCM Controller detects the failure of the UP.
2. The RCM Controller changes the mapping of UP's Endpoint to Host ID, and assigns the failed active UP's Host ID to a new active UP that was selected from the Standby list.
3. The RCM Controller notifies its Configuration Manager service about switchover notification.
4. The RCM Configuration Manager activates the host-config of old active (by negating others), and changes the mapping of Host ID to new active UP.
5. The RCM Controller pushes the IP pool checkpoints to the new Active UP.

6. The RCM Controller notifies the Redundancy Manager service to push all the checkpoint data.
7. The RCM Controller sends State (Active) and Host ID to new Active UP.
8. The new Active UP receives the negate of config and control group association.
9. The new Active UP notifies the RCM Controller about the “Config Push Complete”.
10. The RCM Controller receives the “Config Pushed” flag from new Active and updates its data with State, Host ID, and pushed flag.
11. The RCM Controller notifies the Configuration Manager service about the “Config Push Complete” for validation.

RCM Controller Restart

Upon RCM Controller restart, the UP will detect connection failure and they will reattempt. Once RCM Controller is back, the UP will reconnect. The UPs that are in new state may have to wait for approximately five minutes before successful registration.

VPNMgr Restart

Upon restart of the UP’s VPNMgr, the VPNMgr reconnects with RCM Controller and ensures that both are in sync.

Switchover and Recovery

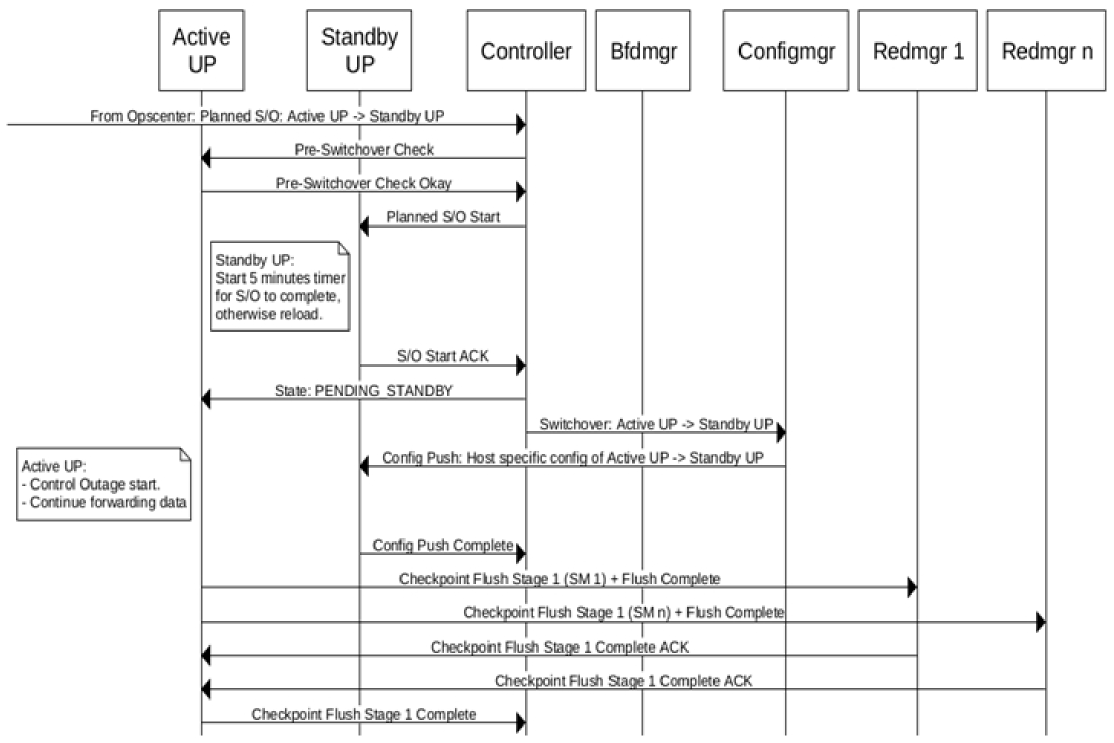
Planned Switchover

Planned switchovers can be done in the following ways:

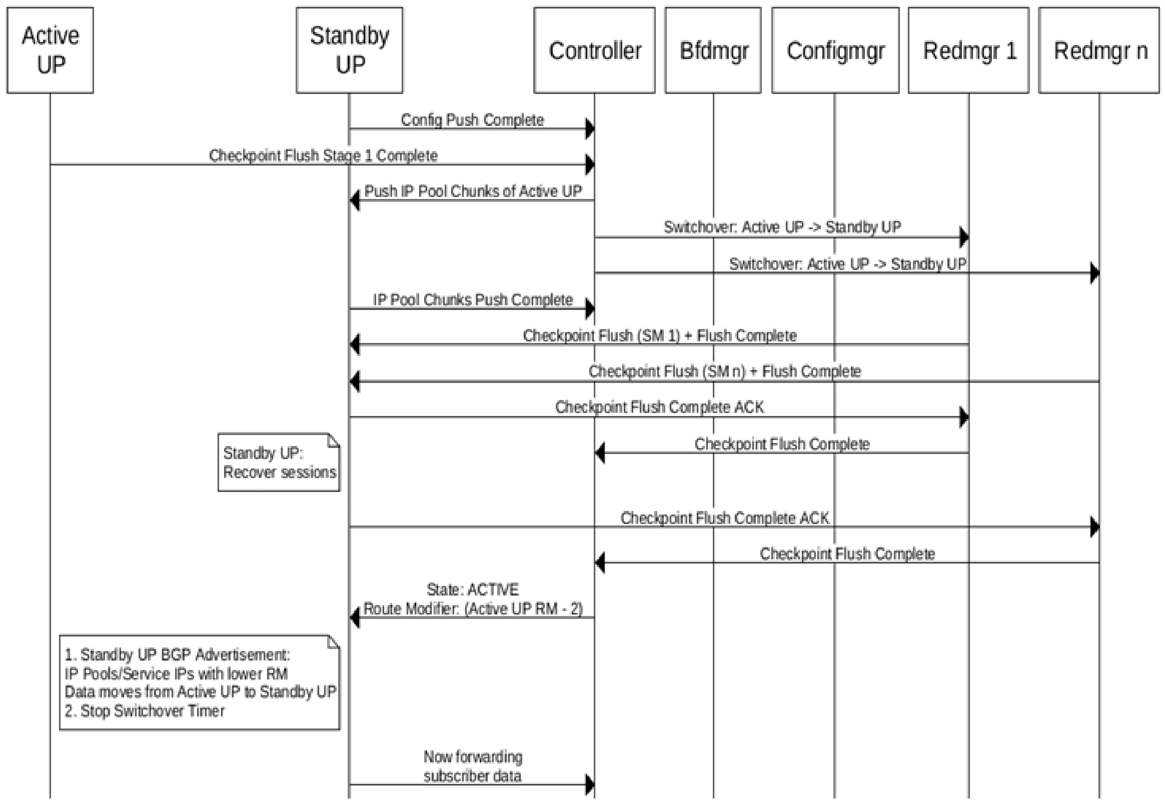
- When a UP is manually rebooted/reloaded during a maintenance window wherein the UP indicates to the RCM about the event of going down.
- When switchover is triggered from the RCM by either the Controller, Configmgr, or BFDMgr using the CLI. For information about the CLI command, refer the Performing Planned Switchover section.

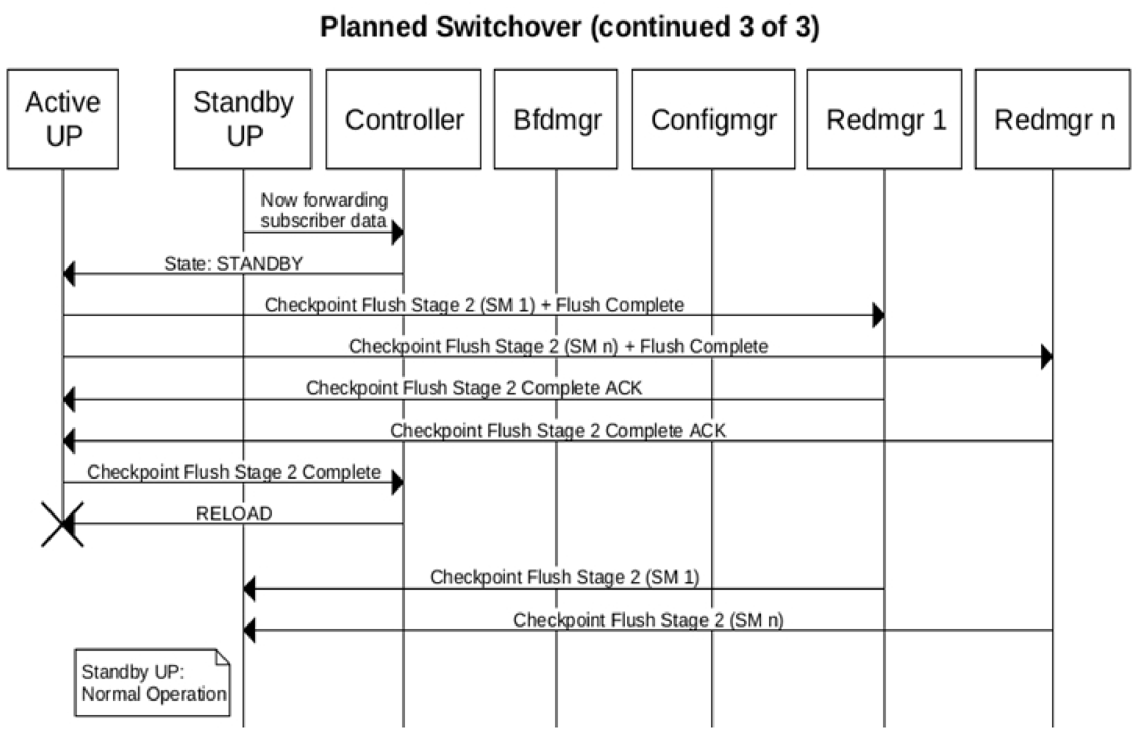
The following images illustrate the call flows for planned switchover.

Planned Switchover


Active UP
Standby UP
Controller
Bfdmgr
Configmgr
Redmgr 1
Redmgr n
From Opscenter: Planned S/O: Active UP -> Standby UP
Pre-Switchover Check
Pre-Switchover Check Okay
Planned S/O Start
Standby UP: Start 5 minutes timer for S/O to complete, otherwise reload.
S/O Start ACK
State: PENDING_STANDBY
Switchover: Active UP -> Standby UP
Config Push: Host specific config of Active UP -> Standby UP
Active UP: - Control Outage start. - Continue forwarding data
Config Push Complete
Checkpoint Flush Stage 1 (SM 1) + Flush Complete
Checkpoint Flush Stage 1 (SM n) + Flush Complete
Checkpoint Flush Stage 1 Complete ACK
Checkpoint Flush Stage 1 Complete ACK
Checkpoint Flush Stage 1 Complete

Planned Switchover (continued 2 of 3)

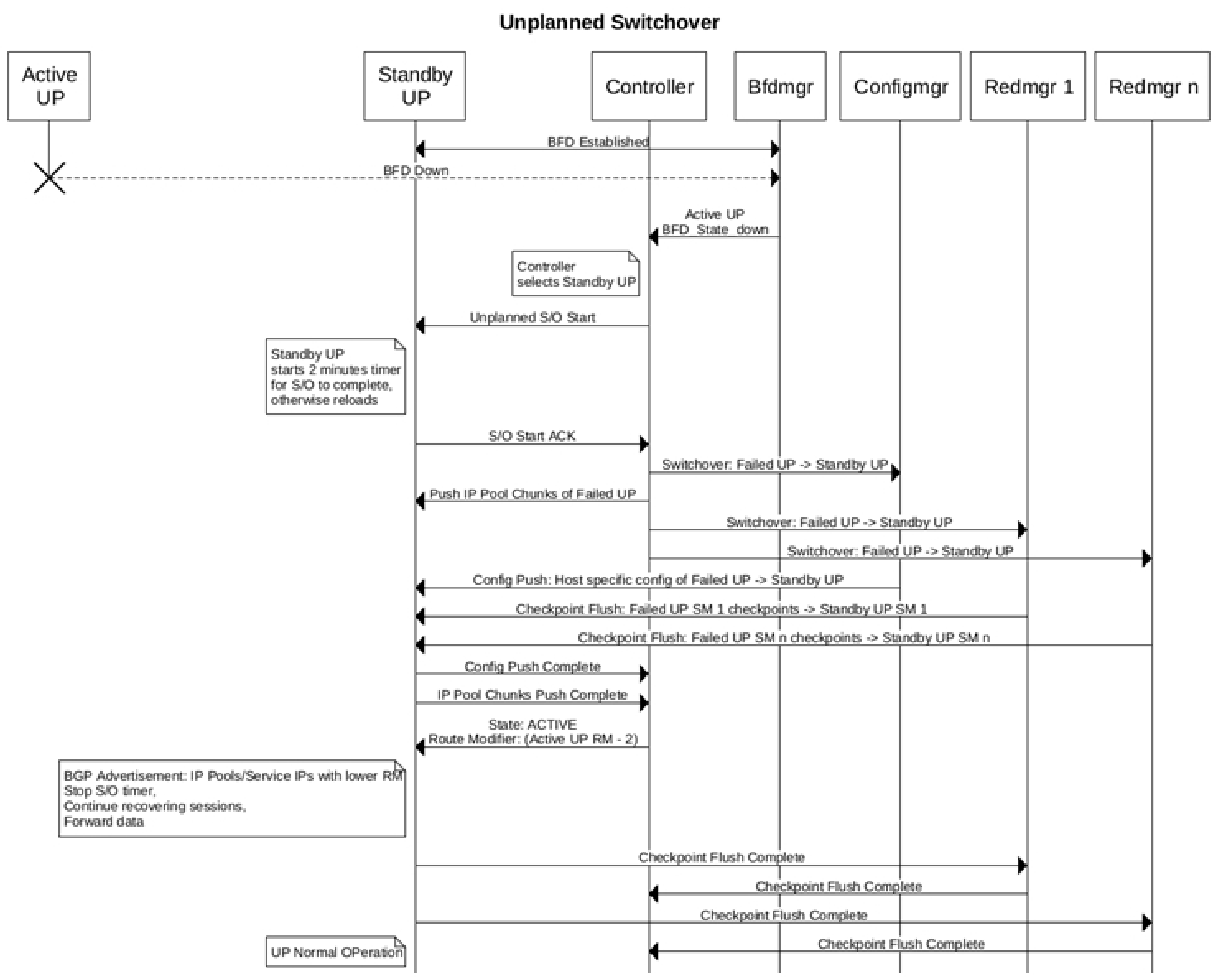

Active UP
Standby UP
Controller
Bfdmgr
Configmgr
Redmgr 1
Redmgr n
Config Push Complete
Checkpoint Flush Stage 1 Complete
Push IP Pool Chunks of Active UP
Switchover: Active UP -> Standby UP
Switchover: Active UP -> Standby UP
IP Pool Chunks Push Complete
Checkpoint Flush (SM 1) + Flush Complete
Checkpoint Flush (SM n) + Flush Complete
Checkpoint Flush Complete ACK
Standby UP: Recover sessions
Checkpoint Flush Complete
Checkpoint Flush Complete ACK
Checkpoint Flush Complete
State: ACTIVE Route Modifier: (Active UP RM - 2)
1. Standby UP BGP Advertisement: IP Pools/Service IPs with lower RM Data moves from Active UP to Standby UP 2. Stop Switchover Timer
Now forwarding subscriber data


Planned Switchover (continued 3 of 3)
Active UP
Standby UP
Controller
Bfdmgr
Configmgr
Redmgr 1
Redmgr n
Now forwarding subscriber data
State: STANDBY
Checkpoint Flush Stage 2 (SM 1) + Flush Complete
Checkpoint Flush Stage 2 (SM n) + Flush Complete
Checkpoint Flush Stage 2 Complete ACK
Checkpoint Flush Stage 2 Complete ACK
Checkpoint Flush Stage 2 Complete
RELOAD
Checkpoint Flush Stage 2 (SM 1)
Checkpoint Flush Stage 2 (SM n)
Standby UP: Normal Operation

Unplanned Switchover

Unplanned switchovers occur due to issues in the UP and it gets rebooted without manual intervention. When unplanned switchover happens, the BFD monitor Pod detects that the UP has gone down and triggers the RCM Controller to start switchover mechanism. The RCM controller chooses a Standby UP and the Redundancy Manager Pods to start pushing configuration and checkpoints to the new UP.

The following image illustrates the call flow for an unplanned switchover.


Unplanned Switchover
Active UP
Standby UP
Controller
Bfdmgr
Configmgr
Redmgr 1
Redmgr n
BFD Established
BFD Down
Active UP BFD State down
Controller selects Standby UP
Unplanned S/O Start
Standby UP starts 2 minutes timer for S/O to complete, otherwise reloads
S/O Start ACK
Switchover: Failed UP -> Standby UP
Push IP Pool Chunks of Failed UP
Switchover: Failed UP -> Standby UP
Switchover: Failed UP -> Standby UP
Config Push: Host specific config of Failed UP -> Standby UP
Checkpoint Flush: Failed UP SM 1 checkpoints -> Standby UP SM 1
Checkpoint Flush: Failed UP SM n checkpoints -> Standby UP SM n
Config Push Complete
IP Pool Chunks Push Complete
State: ACTIVE Route Modifier: (Active UP RM - 2)
BGP Advertisement: IP Pools/Service IPs with lower RM Stop S/O timer, Continue recovering sessions, Forward data
Checkpoint Flush Complete
Checkpoint Flush Complete
Checkpoint Flush Complete
Checkpoint Flush Complete
UP Normal OPeration

Failover Time Optimization for Unplanned Switchover

The minimum time taken by the new UP to become Active and process traffic is determined by the following factors:

- Failure detection of the Active UP
- Configuration/IP Pool Flush from RCM
- Checkpoints Flush from RCM
- Active State transition and Route Convergence

As part of this functionality, a new CLI command (**`switchover allow-checkpoint-processing-active`**) is introduced that allows Active state to be pushed immediately after the "Config Push Complete", and checkpoints are processed even after the chassis moves into Active state. This results in reducing the overall Failover time.

NOTE:

- If the "Config Pushed" time is more than the "Checkpoint Flush" time, this optimization will not yield the expected Failover time reduction.
- Failure Detection time optimization is currently not supported.

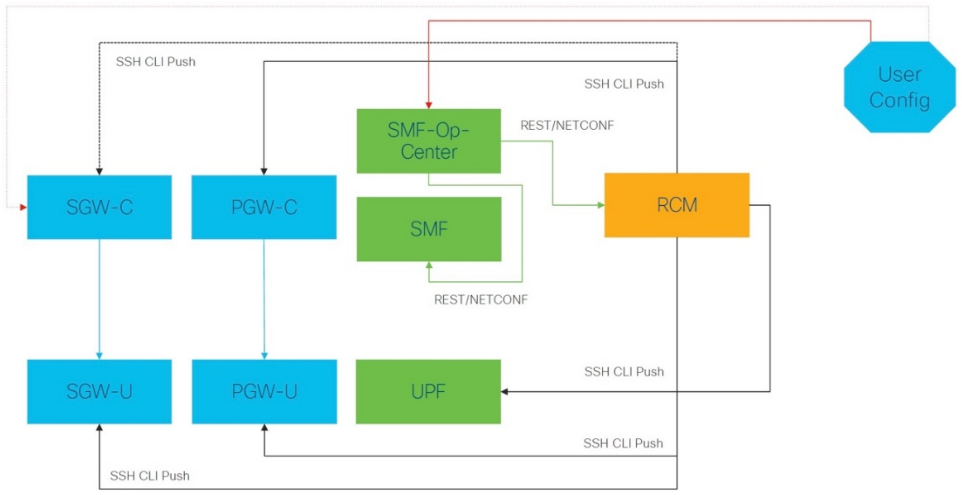
For information about the CLI command, refer the *Configuring Failover Time Optimization for Unplanned Switchover* section.

Configuration Management

Configuration Manager (ConfigMgr) module is required irrespective of whether redundancy is enabled or not. It is responsible to load the requested configuration for UPF. The functionality involves:

- On successful registration of UP with the RCM, the Controller provides the Management IP of the UP. For details, see UP Registration Call Flow.
- ConfigMgr receives the information of all Management IPs from the Controller.
- ConfigMgr pushes the UP Day-1 configuration to UP through SSH connection.
- Configmgr communicates with Controller over the gRPC link and exchanges the information.

The following figure depicts how the configuration works when RCM is used.



The ConfigMgr Pod is used to take the user input (configuration) from the Ops Center CLI and convert it into the corresponding StarOS CLI. The converted CLI is then pushed to the registered UP/UPF over SSH.

NOTE: The ConfigMgr Pod comes up only after the required CLI commands are configured in the Ops Center. Similarly, the UP/UPF node must have the appropriate CLI commands configured for it to connect to the ConfigMgr Pod. In the absence of the CLI commands, the UP/UPF node will not attempt to connect to the ConfigMgr for registration.

The following is the sequence of distributing UP/UPF-specific configuration to all the registered UP/UPFs.

1. The required configuration is applied in the Ops Center to bring up the ConfigMgr Pod. For details, see the Configuring the ConfigMgr Pod section.
2. The policy-charging related configuration is applied to generate the respective configuration maps. This is required for the ConfigMgr Pod to come up.
3. The UP/UPF node is configured with the required CLI commands to start the registration process with the ConfigMgr. For details, see Configuring UP with Day-0 Configuration section.

4. On successful registration, the UP/UPF receives the configured CLIs (configured as part of Step 2) over SSH.

Performing Planned Switchover

Use the following CLI command in Exec mode to perform planned switchover from Active to Standby User Plane.

```
rcm switchover source source_ip_address destination dest_ip_address
```

NOTES:

- The *source_ip_address* and the *dest_ip_address* are the RCM interfaces that you bind under redundancy-configuration-module mode.

Preventing Dual Active Error Scenarios

Use the following CLI configuration in CP to prevent dual Active error scenarios for N:M redundancy.

```
configure
   user-plane-group group_name
      sx-reassociation disabled
      end
```

NOTE:

- **sx-reassociation disabled**: Disables UP Sx reassociation when the association already exists with the CP.

Configuring the RCM

This section describes how to configure the RCM.

Configuring the Controller Pod

Use the following CLI configuration to configure the endpoint to bring up the RCM Controller pod.

```
configure
   endpoint rcm-controller
     vip-ip ip_address
     exit
```

NOTES:

- **vip-ip** *ip_address*: Specifies the host IP address.
- This command is disabled by default.

Configuring the BFD Manager Pod

Use the following CLI configuration to configure the endpoint to bring up the RCM BFD Manager pod.

```
configure
   endpoint rcm-bfdmgr
   vip-ip ip_address
   exit
k8 smf profile rcm-bfd-ep bfd-monitor group group_id
   endpoint ipv4 ip_address
   endpoint ipv4 ip_address
   endpoint ipv4 ip_address
   min-tx-int tx_microseconds
   min-rx-int rx_microseconds
   multiplier count
   standby count
   exit
```

NOTES:

- **k8 smf profile**: Specifies the Kubernetes (k8) SMF configuration with the external IP or port configuration.
- **rcm-bfd-ep**: Specifies the BFD endpoint parameters.
- **bfd-monitor**: Specifies the BFD application configuration.
- **group** *group_id*: Specifies the group ID.
- **standby** *count*: Specifies the number of required Standby UP/UPFs.
- **vip-ip** *ip_address:* Specifies the host IP address.
- This command is disabled by default.

Configuring the ConfigMgr Pod

Use the following CLI configuration to configure the endpoint to bring up the RCM Configuration Manager pod.

```
configure
   endpoint rcm-configmgr
   exit
```

NOTES:

- The UP credentials are passed to Configuration Manager as K8s secret. You must create these credentials before you start the RCM cluster. For details, see Configuring UPF Credentials section.

Configuring UPF Credentials

Use the following CLI commands to configure the credentials for UPF.

```
configure
   k8 smf profile rcm-config-ep upfloginmode { upfcredentialsbased |
upfsshkeysbased }
   exit
```

NOTES:

- **upfloginmode**: Specifies the mode of UP/UPF login.
- **upfcredentialsbased**: Specifies the default or unique credentials per UP/UPF for username/password. This is the default option.
- **upfsshkeysbased**: Specifies the default or unique credentials per UP/UPF for username/SSH-Key.

Sample Configuration for Credential-based UPF Login

```
k8 smf profile rcm-config-ep upfloginmode upfcredentialsbased
k8 smf profile rcm-config-ep rcm-upfinfo group group_name
upf-default-cred username username
upf-default-cred password password
upf mgmt-ip up1_mgmt_ip upfcredentials username username password password
upf mgmt-ip up2_mgmt_ip upfcredentials username username password password
...
...
...
upf mgmt-ip up_n_and_m_mgmt_ip upfcredentials username username password
password
```

NOTE:

- **upf mgmt-ip** *up_n_and_m_mgmt_ip* **upfcredentials username** *username* **password** *password*: These credentials are required only for per-UPF unique-credential scenario.

Sample Configuration for SSH Key-based UPF Login

```
k8 smf profile rcm-config-ep upfloginmode upfsshkeysbased
k8 smf profile rcm-config-ep rcm-upfinfo group group_name
upf-default-sshkeys username username
upf-default-sshkeys private-key private_key
upf mgmt-ip up1_mgmt_ip upfsshinfo username username private-key private_key
upf mgmt-ip up2_mgmt_ip upfsshinfo username username private-key private_key
```

```
...

...

...

upf mgmt-ip up_n_and_m_mgmt_ip upfsshinfo username username private-key
private_key
```

NOTE:

- **upf mgmt-ip** *up_n_and_m_mgmt_ip* **upfsshinfo username** *username* **private-key** *private_key*: These credentials are required only for per-UPF unique-credential scenario.
- After **private-key** keyword, press "Enter" for Multiline mode and then enter the private key.
- You must pass the Management IP of the UPFs for configuration push.

Restricting Configuration Maps Pushed to Configuration Manager

Use the following command to restrict the configuration maps that are pushed to the Configuration Manager by default.

```
configure

   k8 smf profile rcm-config-ep disable-cm { apn | apnprofile |
chargingAction | common | creditCtrl | global | gtpp | gtpuService |
lawfulIntercept | misacs | packetFilter | rulebase | ruledef | sxService |
upSvcs | upfCpg | upfIfc | urrList }

   exit
```

NOTES:

- **{ chargingAction | creditCtrl | global | gtpp | gtpuService | misacs | packetFilter | rulebase | ruledef | sxService | upSvcs | upfCpg | urrList }**: Specifies the Kubernetes (k8) Session Manager function (SMF) configuration with the external IP or port configuration.
- **apn**: Restricts the Access Point Name (APN) map.
- **apnprofile**: Restricts the APN Profile map.
- **chargingAction**: Restricts the charging action map.
- **common**: Restricts the common map.
- **creditCtrl**: Restricts the credit control map.
- **global**: Restricts the content filtering and URI blacklisting map.
- **gtpp**: Restricts the GTPP map.
- **lawfulIntercept**: Restricts the context LI map.
- **gtpuService**: Restricts the GTPU service map.
- **misacs**: Restricts the miscellaneous active charging services (ACS) map.
- **packetFilter**: Restricts the packet filter map.
- **rulebase**: Restricts the rulebase map.

- **`ruledef`**: Restricts the ruledef map.
- **`sxService`**: Restricts the Sx service map.
- **`upSvcs`**: Restricts the User Plane (UP) services map.
- **`upfCpg`**: Restricts the UP function (UP/UPF) Control Plane (CP) group map.
- **`upfIfc`**: Restricts the UP function (UP/UPF) Interface map.
- **`urrList`**: Restricts the usage reporting rule (URR) map.

Configuring the Redundancy Manager Pod

Use the following CLI configuration to configure the endpoint to bring up the RCM Redundancy (Checkpoint) Manager pod.

```
configure
   endpoint rcm-chkptmgr
   replicas count
   vip-ip ip_address
   exit
```

NOTES:

- **`replicas`** *`count`*: Specifies the number of replicas per node.
- **`vip-ip`** *`ip_address`*: Specifies the host IP address.
- This command is disabled by default.

Configuring UP with Day-0 Configuration

This section describes the CLI commands that are required to configure UP with Day-0 configuration. It involves:

- Registering the UP to RCM
- Multi-hop BFD
- Configuring BGP Monitoring
- Configuring BFD Monitoring
- Configuring UP Auto-reboot
- Configuring Failover Time Reduction in RCM

NOTES:

- All UPs have Day-0 configuration with RCM context.
- The physical interfaces and port configurations are part of the Day-0 configuration.

A new context **`rcm`** is created in UP. The VPNMgr in UP is used to communicate with the RCM.

If RCM Redundancy is configured, use the following command to configure UP.

```
configure
   context context_name
      bfd-protocol
         bfd multihop-peer bfd_manager_ip_address interval tx_interval min_rx
rx_interval multiplier number_of_rx_timeouts
         exit
      redundancy-configuration-module rcm_name
         bind address local_bind_ip_address
         rcm controller-endpoint dest-ip-addr control_ep port port_number
         up-mgmt-ip-addr up_mgmt_addr node-name node_name
         monitor bfd peer bfd_peer_ip_address
         monitor bgp context context_name peer-ip [ group group_number ]
         [ default | no ] rcm-unreachable triggers-reload delay
reload_interval_seconds
         [ default | no ] switchover allow-early-active-transition store-
checkpoint { enable | disable }
         exit
   ip route static multihop bfd bfd_name local_bind_ip_address
bfd_peer_ip_address
   switchover allow-checkpoint-processing-active { true | false }
   end
```

NOTES:

- **redundancy-configuration-module**: Configures the Redundancy Configuration Module (RCM) and enters the RCM mode.
- **rcm**: Specifies the CUPS-related options in this context.
- **controller-endpoint**: Enables the registration of the UP at the Controller Manager endpoint.
- **dest-ip-addr** *control_ep*: Specifies the destination IP address. *control_ep* is the IP address of the Controller endpoint.
- **port** *port_number*: Specifies the TCP port value. *port_number* must be 9200.
- **up-mgmt-ip-addr** *up_mgmt_addr*: Specifies the management IP of the UP, which the Configuration Manager uses to securely connect. *up_mgmt_addr* is the IP address of the UP.

- **node-name** *node_name*: Specifies the node name of the UP to send the Configuration Manager endpoint. *node_name* is the UP node name.
- **peer** *bfd_peer_ip_address*: The *bfd_peer_ip_address* must already be configured as a multihop BFD peer session with RCM BFD Manager pod in the context *context_name*. *bfd_peer_ip_address* IP address can be different from the RCM Controller Pod IP address.
- **group** *group_number*: [Optional] Configure to track multiple BGP peers under same monitor group. *group_number* must be in the range of 1 through 10.

  If group is not specified, monitor will act as an individual monitor.

  If previously configured, use **no monitor bgp context** *context_name peer-ip* CLI command to remove the BGP monitor in RCM.

  UP/UPF informs RCM to trigger UP/UPF switchover under following scenarios:

  - When a monitor, configured without group number, fails.
  - When all the monitors, configured under single group number, fails.
- **peer** *bfd_ip_address*: The *bfd_ip_address* should already be configured as a multi-hop BFD peer session with RCM Bfdmgr pod in **context** *context_name*. This IP address can be different than the RCM Controller Pod IP address.

  If previously configured, use **no monitor bfd peer** *bfd_ip_address* CLI command to remove the BFD monitor in RCM.

  Configuring BFD monitor in RCM provide the following functionality:

  - Switchover Scenario 1: The UP/UPF tears down TCP connection with RCM controller if BFD monitor goes down. It waits for both BFD monitor with RCM BFDMgr and TCP connection with RCM Controller to come up per configured CLI.
  - Switchover Scenario 2: If UP/UPF is not in Init state and receives Init state from Controller, the UP/UPF reboots itself.

  At initial boot time, UP/UPF does not initiate TCP connection with RCM Controller if BFD monitor is down.
- **switchover allow-early-active-transition**: Allows early transition to active during switchover. Traffic is processed along with the pre-allocation of other calls.
- **store-checkpoint { enable | disable }**: Enable or disable storing of checkpoints until the end of checkpoint flushing from RCM.
- **enable**: Enable storing of checkpoints and defer call pre-allocation until end of flushing.
- **disable**: Disable storing of checkpoints and allow call pre-allocation during flushing.
- **bfd multihop-peer**: Specifies the time interval within which RCM must detect failure by using a protocol such as multi-hop BFD.
- *reload_interval_seconds*: Specifies the time interval, zero (0) seconds to 30 days (in seconds), for chassis reload after BFD with RCM goes down. Default is no reload.
- **switchover allow-checkpoint-processing-active { true | false }**:
  - When set to **true**, RCM does not wait for the completion of checkpoint flush before sending Active state and lower Route Modifier to new Active UP.
  - When set to **false**, RCM waits for the completion of checkpoint flush before sending Active state and lower Route Modifier to new Active UP.
  - By default, the CLI command is set to **false**.

Configuring Failover Time Optimization for Unplanned Switchover

Use the following configuration to allow checkpoint processing in Active state, for a brief period, during unplanned switchover.

```
configure
   context context_name
      redundancy-configuration-module rcm_name
         [ no ] switchover allow-checkpoint-processing-active
         end
```

NOTES:

- By default, the configuration is disabled.
- When this CLI command is configured under RCM context in UP, it accepts and processes checkpoints in Active state. This is done only for the Unplanned switchover initiated by the RCM. The checkpoints are accepted only till the checkpoint flush is completed from RCM. Any checkpoint that comes after flush is complete, is dropped.
- Use the **`show config context`** *`context_name`* CLI command to verify if **`switchover allow-checkpoint-processing-active`** CLI command is enabled.

For sample configurations, refer Appendix B: Sample Common and Host-specific Configurations

Monitoring and Troubleshooting RCM

This section provides information about monitoring and/or troubleshooting the RCM.

Show Commands and/or Outputs

The following table lists the show CLI commands that can be used to gather RCM statistics.

Statistics/Information	Show CLI commands	Node (where CLI should be executed)
Information on the status of chassis, session, RCM controller, and so on.	**`show rcm info`**	UP
Information on the status of BGP and BFD monitor.	**`show rcm monitor { bfd | bgp | all }`**	UP
RCM checkpoint details.	**`show rcm checkpoint { info | statistics { active | debug-info | ipsecmgr { all | instance`** *`ipsecmgr_instance_number`* **`} | sessmgr { all | instance`** *`sessmgr_instance_number`* **`} | standby | verbose } }`**	UP
Statistics of RCM Controller pod.	**`rcm show-statistics controller`**	RCM Ops Center

Statistics of RCM ConfigMgr pod.	`rcm show-statistics configmgr`	RCM Ops Center
Statistics of UP BFD status.	`rcm show-statistics bfdmgr`	RCM Ops Center
Statistics of UP sessions	`rcm show-statistics checkpointmgr`	RCM Ops Center
Summary of all RCM show commands	`rcm support-summary`	RCM Ops Center

SNMP Traps

RCM supports event-based SNMP traps to notify important events to an external Network Management System (NMS)/SNMP Manager by using "rcm-snmp-trapper" pod. This pod is based on the snmp-trapper module in smi-apps and supports outbound alerting.

Controller Pod

The following traps are generated by the Controller Pod:

- UPFRegistered
- SwitchoverTriggered
- SwitchoverFailure
- SwitchoverComplete
- BootTimerExpired
- MassUPFailure
- TCPConnect
- TCPDisconnect
- StandbyUPReboot

Configuration Manager Pod

The following traps are generated by the Configuration Manager (ConfigMgr) Pod:

- UPFAdded
- UPFDeleted
- SwitchoverAbortedByController
- SwitchoverFailure
- UPFCfgPushComplete
- UPFCfgPushFailure

Checkpoint Manager Pod

The following traps are generated by the Checkpoint Manager (ChkpointMgr)/Redundancy Manager (RedMgr) Pod:

- ActiveSessmgrConnected
- ActiveSessmgrDisconnected

- StandbySessmgrConnected
- StandbySessmgrDisconnected
- CheckpointAuditStarted
- CheckpointAuditEnded
- CheckpointFlushCompleted

Keepalived Pod

The following traps are generated by the Keepalived Pod:

- PodNotFound
- PodNotRunning
- RCMStateChange

strongSwan Manager Pod

The following traps are generated by the strongSwan Manager pod:

- TunnelsDropped
- TunnelsAdded

Configuring SNMP Traps

Use the following commands to configure SNMP Trap and various parameters.

```
configure

   endpoint rcm-snmp-trapper

   exit

k8 smf profile rcm-snmp-trapper-ep snmp-trapper { enable | v2c-target
ip_address { community public_string [ port port_number ] | port port_number
} | v3-engine-id id_string | v3-target ip_address [ auth { md5 [ auth-key |
port | priv { aes | aes192 | aes256 | des | none } | user-name ] | none | sha
} | port | user-name }
```

NOTES:

- **enable**: Enables SNMP trapper.
- **v2c-target** *ip_address*: Specifies the list of SNMP v2c trap receivers. The *ip_address* specifies the SNMP Trap Receiver hostname or IP address.
- **v3-engine-id** *id_string*: Specifies the source engine ID for v3 traps as hex string, such as 80004f. *id_string* must be a string of minimum five and maximum 32 characters.
- **v3-target**: Specifies the list of SNMP v3 trap receivers.
- **community**: Specifies the SNMP Trap Receiver community.
- **port**: Specifies the SNMP Trap Receiver port.

- **`auth`**: Specifies the authentication protocol to be used.
- **`user-name`**: Specifies the SNMP trap username.
- **`md5`**: Specifies that HMAC-MD5-96 authentication protocol is used.
    - **`none`**: Specifies that no authentication protocol is used.
    - **`sha`**: Specifies that HMAC-SHA-96 authentication protocol is used.
    - **`auth-key`**: Specifies that key to authentication protocol.
    - **`priv`**: Specifies that privacy protocol is used.
        - **`aes`**: Specifies that AES-CFB (128 bits) protocol is used.
        - **`aes192`**: Specifies that AES-CFB (192 bits) protocol is used.
        - **`aes256`**: Specifies that AES-CFB (256 bits) protocol is used.
        - **`des`**: Specifies that CBC-DES protocol is used.
        - **`none`**: Specifies that no privacy protocol is used.

Sample SNMP Trap

The following is a sample SNMP trap:

```
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (43241) 0:07:12.41
SNMPv2-MIB::snmpTrapOID.0 = OID: CISCO-RCM-MIB::rcmFaultActiveNotif
CISCO-RCM-MIB::rcmFaultId = STRING: "SwitchoverTriggered"     CISCO-RCM-
MIB::rcmFaultSource = STRING: "rcm-controller"   CISCO-RCM-
MIB::rcmFaultSeverity = STRING: "Major"       CISCO-RCM-MIB::rcmFaultTime =
STRING: 2572-0-0,0:43:0.0 CISCO-RCM-MIB::rcmFaultType = INT: 3  CISCO-RCM-
MIB::rcmFaultAdditionalInfo = STRING: "Switchover Triggered"        CISCO-
RCM-MIB::rcmFaultClusterName = STRING: "k3scluster"       CISCO-RCM-
MIB::rcmFaultNamespace = STRING: "rcm"        CISCO-RCM-MIB::rcmFaultHostname
= STRING: "host1"       CISCO-RCM-MIB::rcmFaultInstance = STRING: "host1"
CISCO-RCM-MIB::rcmVnfAlias = STRING: "*"
```

For information about MIBs, refer Appendix C: MIBs

RCM High Availability

Feature Description

The Redundancy and Configuration Management (RCM) provides a High Availability (HA) solution for User Planes (UPs). RCM enables support for N:M redundancy which minimizes the number of redundant data UPs required for your deployment. To prevent UP session loss resulting from unplanned RCM outages, the RCM can be deployed in HA mode.

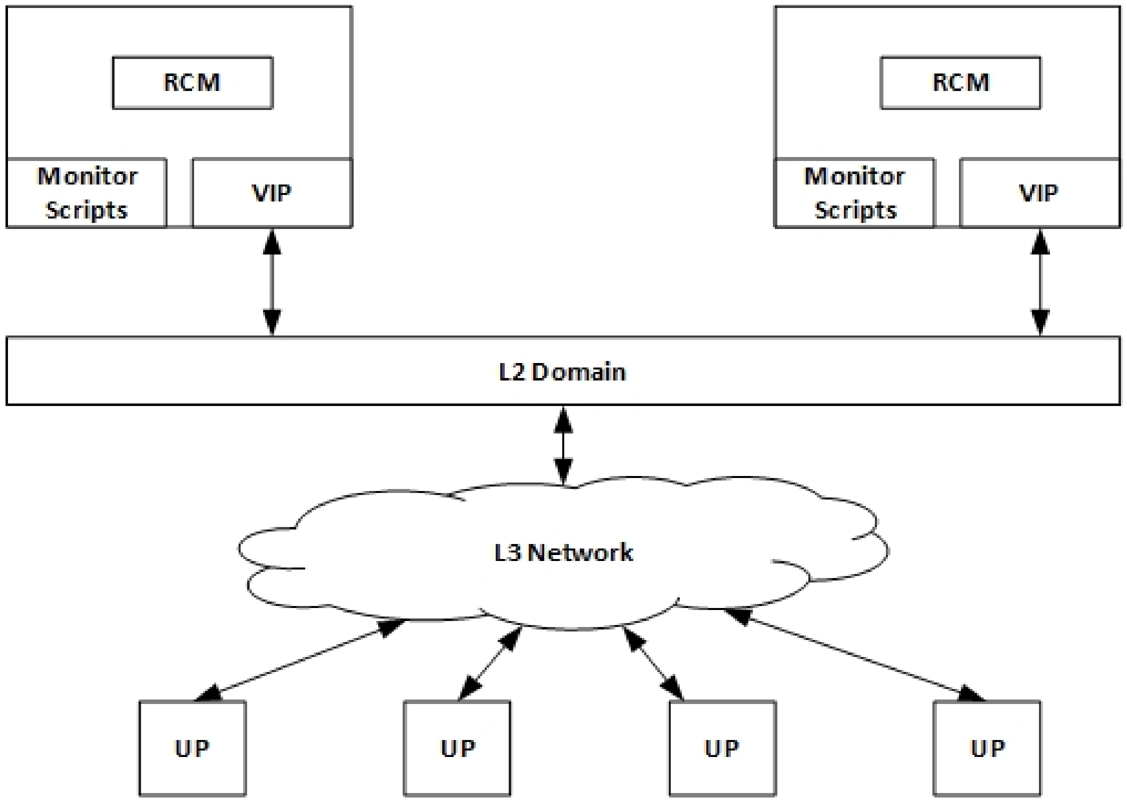
Architecture

RCM HA is achieved by deploying two instances of the RCM. The RCM instances run in active and standby mode. The external IPs for each instance are configured as Virtual IPs (VIP addresses) each running the Virtual Router Redundancy Protocol (VRRP).

Depending on the Primary RCM node (e.g. the Primary VRRP), one of the RCM instances assumes the active role and the other RCM instance assumes the Standby role.

When the active RCM is unavailable, then the VRRP selects the standby RCM as Primary and this instance becomes the new active RCM. The UP automatically connects to the new RCM (as the IP address moves to new RCM). All UPs connected to the previously active RCM experience connection resets and, upon retry, they get connected to the new RCM.

The following image illustrates the RCM HA architecture.



RCM HA deployments require the installation of two RCM instances instead of one. To achieve high-speed communication between the UPs and RCM, and to ensure that the UP switchover time is as minimal as possible, both RCM should be deployed in the same datacenter as the UPs for which they are providing redundancy.

How it Works

RCM HA support is based on VRRP. VRRP dynamically determines which RCM instance serves as the Primary (active) or standby (Backup) based on the assignment of the default route address.

VRRP selects the RCM instance that receives the IP address based on several factors, such as the host priority, first to be active, instance interface state (for example, "Up"), and so on. VRRP provides many options for customizing the rules for determining the Primary and Backup role for the RCM instance.

The RCM architecture is based on UP-to-RCM communication using UDP (BFD) and TCP (Controller, Checkpoint Manager) connections. The UPs are configured with BFD, Controller, and CheckpointMgr IP addresses. The UPs use these IP addresses to communicate with the RCM.

When the RCMs are deployed with HA, BFD, Controller, and Checkpoint IP addresses are configured as one IP address. This IP address, also known as external IP address, is then configured as a VIP in RCM. The VIP is managed by VRRP which determines the RCM that owns the VIP. All UPs use VIP address to communicate with the RCM. The RCM instance which owns the VIP becomes active and the other RCM instance becomes Standby.

When the active RCM reboots or relinquishes its Primary role, the VIP moves to the standby instance resulting in the standby RCM becoming active and the UPs reconnecting to newly active RCM.

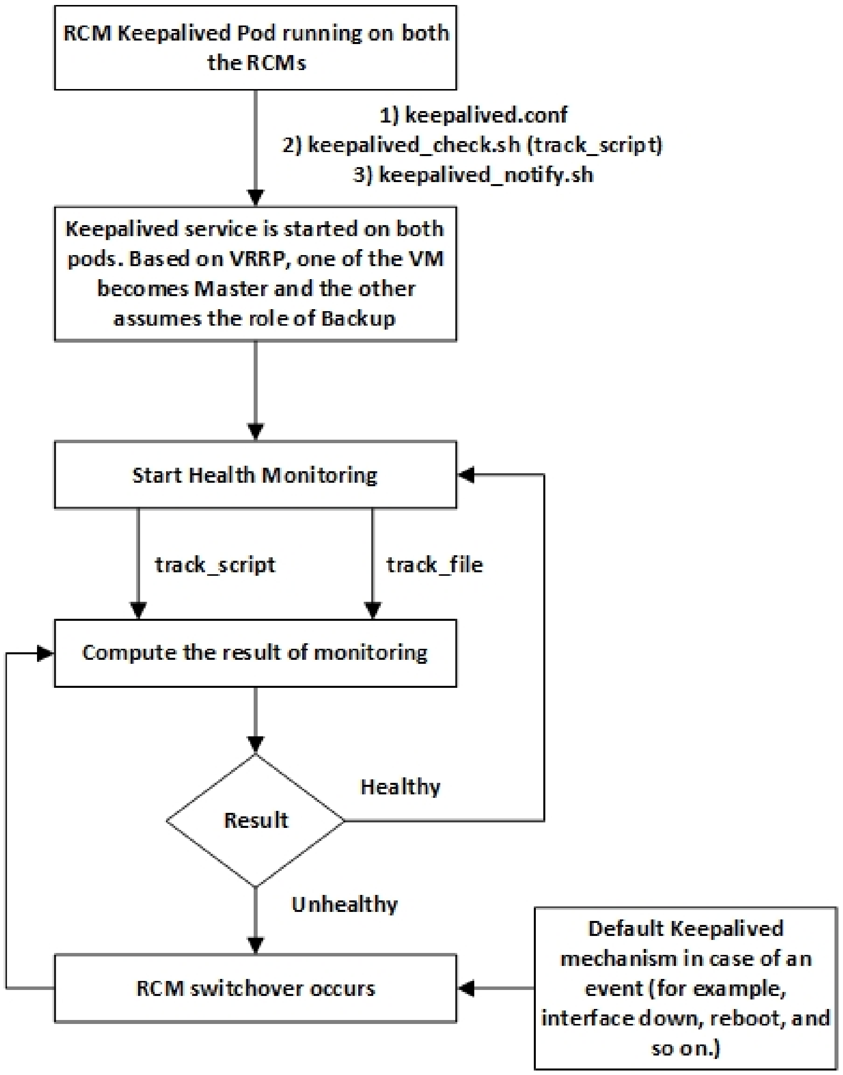
The RCM's Controller Pod learns the state of the UPs and communicates the same to the Configmgr. The Controller Pod ensures consistency of operation and decides when/if to reboot a UP to restore the system to a healthy state. UP reboots are reserved for rare, corner case scenarios.

For double-fault scenarios, (for example, when the switchover process is left in hung state and UP reboots itself after detecting it's in hung state), the Controller sends a START_SWITCHOVER message to the UP and starts the rest of switchover process after getting an Ack from UP.

Keepalived

Keepalived is a software implementation of VRRP on Linux that runs as a pod on the RCM VM. VRRP uses the concept of a VIP. One or more hosts (routers, servers, and so on) participates in an election to determine the host that will control the VIP. Only one host (Primary) controls the VIP at a time. If the Primary host fails, the VRRP provides mechanisms for detecting that failure and quickly failing over to a Standby host.

The following flow diagram illustrates how RCM achieves HA using Keepalived.


RCM Keepalived Pod running on both the RCMs
1) keepalived.conf
2) keepalived_check.sh (track_script)
3) keepalived_notify.sh
Keepalived service is started on both pods. Based on VRRP, one of the VM becomes Master and the other assumes the role of Backup
Start Health Monitoring
track_script
track_file
Compute the result of monitoring
Result
Healthy
Unhealthy
RCM switchover occurs
Default Keepalived mechanism in case of an event (for example, interface down, reboot, and so on.)

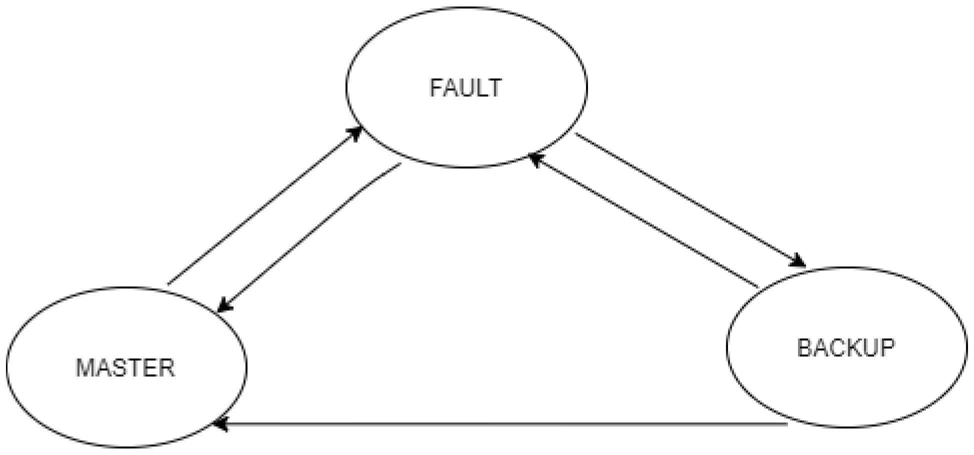
After the Keepalived pod is up and running on both the VMs, one of the RCM VMs comes up as Primary and another as Backup. Keepalived leverages the following files for proper operation:

1. **keeplived.conf**–This is the Keeplalived service configuration file. It contains various Keepalived keywords to tune the service and to track VRRP (using track_file and track_script options) and notify script (keepalived_notify.sh) to run when VRRP instance changes the State. VIP details are part of the configuration applied through the RCM Ops Center.
2. **keepalived_notify.sh**–This is specified using the notify_script keyword mentioned in keepalived.conf file. This script takes actions when the RCM VM changes any state. For example, it specifies what action must be taken when the RCM VM transitions from Primary to a Fault State.

Both keepalived.conf and keepalived_notify.sh are a part of the Keepalived container inside the Keepalived pod. Keepalived also tracks a file using track_file option to keep a check on overall system health. When BFD detects all UPs are down, the RCM controller notifies Keepalived through track_file, the RCM is then deemed unhealthy using keepalived mechanism, and an RCM switchover occurs.

There is a possibility for events other than what is explicitly specified as part of track_file to occur (such as, VM reboot, interface going down, and so on). During such unspecified events, an RCM switchover event is triggered.

The following figure illustrates the States that the VRRP instance in RCM VM can transition to.



After the Keepalived pod is up and running, one of the RCM VM instances comes up as Primary and the other as Backup. When Keepalived health monitoring fails on Primary, it transitions to Fault state first and then to Backup state. At the same time, Backup transitions to Primary role. Whenever the state transitions to Fault state, the VM is rebooted. This action is done by keepalived_notify script.

RCM Upgrade and Downgrade Procedure in HA

In the old RCM VM:

- Take a backup of the running configuration.
- Take a backup of the configuration folders—master, host, svc-type—from `/var/rcm/scripts/config`

In the new RCM VM:

To upgrade the RCM image in case of qcow2, delete the old vol-image, create a new image, and restart the VM.

- Configure the back-up ops-center configuration
- Copy the backed-up contents of master/host/svc-type folders to their respective folders
- Perform system mode running

Prerequisites and Assumptions

RCM HA operation is based on the following prerequisites/assumptions:

- The Operator must reconfigure any delta configurations that was done on one RCM while the other RCM was in rebooting state.
- The Operator must configure both RCM instances in an identical way for updates.
- The Operator need not track which RCM instance is Active and which one is Standby.
- Only one VIP is configured per RCM. This VIP serves as IP for Controller, BFD, and Checkpoint Manager.
- All VRRP requirements, as specified in RFC3768, are needed to implement RCM HA solution. It includes:

  - The interface on which the VIP is defined for both RCM instances are part of same L2 domain.
  - The L2 switch to which the VIP interfaces are connected are multicast enabled.
- The UP is configured with five minutes BFD timeout by default. If the UP does not find RCM within the timeout period, the UP gets rebooted.
- The VRRP protocol ensures that RCM does not end up in active-active state. RCM Backup-Backup state is possible if both VIP interfaces are down.
- A new or rebooted UP may have to wait up to five minutes before getting registered with the RCM. This is expected during initial RCM bring-up and during RCM switchover.
- RCM HA does not support hot-standby wherein checkpoints are synchronized between RCM instances. RCM HA supports cold-standby. That is, upon switchover, new RCM re-learns checkpoints from the UPs.

  RCM HA deployments do not assume the availability of external persistent storage.

Operational Flow

This section describes the scenarios and operation of RCM HA solution.

RCM HA Deployment

The following points describe the operational flow within RCM HA deployments:

1. The Operator brings up the RCM VMs and applies the required configurations (common and host-specific).

   NOTE: The Operator reconfigures the RCM whenever it reboots.
2. One of the RCM VMs becomes active because the VRRP selects that RCM instance as Primary for the following reasons:
   - The RCM instance that comes up first becomes the Primary (provided VIP interface is up) and the other RCM that comes up later becomes Backup, OR
   - If both RCM instances come up simultaneously, then the VRRP uses a tie-breaker algorithm to select one of the RCM instances to be the Primary.
3. The active RCM starts receiving connection requests (e.g. BFD messages, Controller Request, etc.) from the UPs.
4. All UPs start registering with the active RCM.
5. After registration is complete, the active RCM starts assigning active/standby roles to the UPs and configures them based on their role.
6. Active UPs start the checkpoint operation with the active RCM, and the active RCM starts managing the standby UPs.
7. When the active RCM crashes or relinquishes its role as Primary, the Backup RCM becomes active. The old active RCM either reboots or restarts the Controller Pod.

   Should an RCM switchover occur, the UP detects a BFD failure and brings down the TCP connection with the Controller and Checkpoint Manager.

   NOTE: The RCM switchover is triggered by moving the VIP. For UPs, the switchover is merely detected as connection failure and UPs retry the connection.
8. The UPs initiate BFD sessions with the newly active RCM and re-establish the controller TCP connection with it.
9. The UPs share information with the newly active RCM:

   - Their role (for example, Active or Standby)
   - The host-ID allocated to it (in case it was active)
   - Their configuration state (for example, whether a UP received the configuration or not)

10. The newly active RCM builds the state information with the information supplied by the UPs.
11. The newly active RCM resumes operation based on state information:
    - For active UPs, the it starts a full checkpoint operation.
    - For registering UPs, it determines the role and host configuration.
    - For UPs that did not receive the full configuration, it reconfigures the UP and it determines the role for new RCM.

RCM Switchover During UPs Registration/Configuration

While UP registration/Day-1 configuration is in progress, one or more of State, Host ID, and "Config Pushed" flag might not be updated on the UP. As such, the UP publishes the saved State, Host ID, and "Config Pushed" flag to the new Active RCM:

- If the State is Active, the Host ID is not null, and the Pushed flag is true –> The RCM Controller accepts the information and updates the Database. It notifies the Configuration Manager service with this information and the Redundancy Manager about the state.
- If the State is active, the Host ID is not null, and the Pushed flag is false –> The RCM Controller accepts the State of the UP and informs the Configuration Manager to push the configuration again.
- If the State is Active and the Host ID is null –> The RCM Controller informs the UP to reboot.
- If the State is Standby and the Pushed flag is true –> The RCM Controller accepts the information and updates the database. (For Standby, the Host ID is ignored, and the Standby cannot represent an Active host configuration.) It then notifies the Configuration Manager and the Redundancy Manager about the State.
- If the State is Standby and the Pushed flag is false –> The RCM Controller either informs the Configuration Manager to push the configuration to the UP again or reboots the UP.

RCM Switchover During UP Switchover

1. Active UP failure is detected but switchover is not initiated: This is a scenario wherein the Active RCM detects the UP failure, however, before the UP switchover can be initiated, the Active RCM fails. In such scenarios, the new Active RCM receives Init request from the failed UP (after it reboots), and the new Active RCM assigns the appropriate role.

   NOTE: Loss of sessions are expected in this scenario as the failed UP could not be switched over to standby UP.

2. Active UP failure is detected, and switchover is initiated: This is a scenario wherein the Active RCM detects the UP failure and it starts the switchover. However, Active RCM fails before switchover is complete. In such scenarios, the new Active RCM receives Init request from failed UP (after it reboots), and the new Active RCM assigns the appropriate role to the UP. However, the standby UP which received partial checkpoints eventually detects that it's in hung state and so, it reboots. Upon completion of reboot, it registers with new Active RCM and the new Active RCM assigns appropriate role to the UP.

   NOTE: Total loss of sessions is expected for the failed UP as switchover is not completed.

RCM Switchover During Provisioning of UP

Scaling up and scaling down of UPs is not supported for RCM.

RCM Switchover During Decommissioning of UP

Scaling up and scaling down of UPs is not supported for RCM.

Reboot of both RCMs

When both the RCMs are unavailable, the BFD restart timers on the UPs reset to a value such that UPs can continue serving until one of the RCMs is available.

RCM Switchover during Loss of Connectivity to Active UP

The Active UP loses connectivity to the RCM before the RCM switchover, the UP switchover completes, and the old Active UP reconnects to new Active RCM. The new Active UP and old Active UP have the same Host ID. The new Active RCM chooses to keep the UP with lower Route Modifier as Active and reboots the UP with higher Route Modifier.

RCM Switchover during Route Modifier Wraparound

If an Active UP registration is received with lowest Route Modifier, the RCM waits for five minutes (UP self-reboot time):

- If the time period is exceeded, the Route Modifier is wrapped around.
- If within the time period, another Active UP registration is received with same Host ID (but with higher Route Modifier), then the reboot is performed on the UP with the higher Route Modifier. The Route Modifier wraparound procedure is then started for the lowest Route Modifier UP.

Limitations

UP switchover is not supported within five minutes of RCMs switchover. If there is any switchover within this time, it is considered as double-failure and Session Recovery is not possible.

Configuring Ops Center for Keepalived Pod

Use the following parameters to configure the Keepalived pod.

```
configure
   endpoint rcm-keepalived
exit
k8 smf profile rcm-keepalived-ep vrrp-config group group_name
   vrrp interface vrrp_interface
   vrrp routerId router_id
   ipv4-addresses address vip_address
   ipv4-addresses mask address_mask
```

ipv4-addresses broadcast *broadcast_ipaddress*

ipv4-addresses device *device_interface*

host priority *priority*

host hostid *host_id*

exit

NOTES:

- *vrrp_interface*: Specifies the VRRP tracking interface.
- *router_id*: Specifies the VRRP router ID.
- *vip_address*: Specifies the Keepalived VIP IP address which must be same in both RCM VMs.
- *address_mask*: Specifies the VIP IP address mask.
- *broadcast_ipaddress*: Specifies the VIP IP broadcast address.
- *device_interface*: Specifies the interface where VIP IP must be configured.
- *priority*: Specifies the VRRP host priority and must be different for both the RCM VMs.
- *host_id*: Specifies the VRRP host ID.

Setting IPTables Rules for Keepalived

Set the iptables rules for Keepalived using the below command in each VM.

sudo ufw allow in on *interface_name* **from** *peer_vm_address*

For example:

```
sudo ufw allow in on ens6.2299 from 192.168.20.247
```

NOTES:

- *peer_vm_address* must be configured to the same value specified in the keepalived.conf file.

RCM IPSec

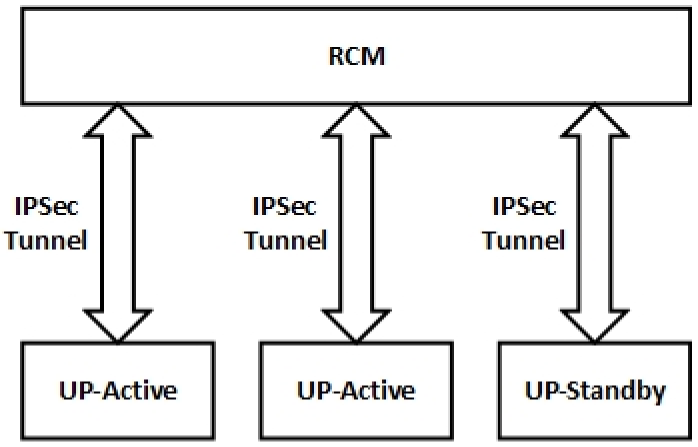
Feature Description

Security is very crucial aspect of any solution that meets vital customer requirements on security-related issues. RCM provides a secure computing environment and is part of a stable solution. RCM addresses both internal and external security aspects by protecting traffic between RCM and UP using IP Security (IPSec).

IPSec is a suite of protocols that interact with one another to provide secure private communications across IP networks. These protocols allow the system to establish and maintain secure tunnels with peer security gateways. IPSec provides confidentiality, data integrity, access control, and data source authentication to IP datagrams.

Architecture

The following diagram depicts the overall architecture of the RCM IPSec solution.



There is one IPSec (L3) tunnel between RCM and each UP. This node-level L3 tunnel between RCM and UP guarantees full protection of information exchanged between RCM and UP.

At a high-level, the RCM IPSec solution provides the following functionality:

- RCM supports multiple IPSec tunnels.
- RCM functions with or without IPSec.
- RCM supports OpsCenter CLI using which IPSec can be enabled and IPSec-related information can be configured.
- Show CLI commands display details of the IPSec tunnel and IPSec data exchanged.
- RCM generates SNMP traps when the tunnel is established, released, re-established, and so on.
- Supports configuration of strongSwan with a static routing table.
- RCM HA supports reestablishment of UP with IPSec tunnel during switchover scenario.

Supported Algorithms

The RCM IPSec supports the Internet Key Exchange version 2 (IKEv2) protocol. The following table provides information about the supported options.

Protocol	**Type**	**Supported Options**
Internet Key Exchange version 2 (IKEv2)	IKEv2 Encryption	AES-CBC-128 AES-CBC-256
	IKEv2 Pseudo-Random Function (PRF)	PRF-HMAC-SHA1 PRF-HMAC-SHA2-256
	IKEv2 Integrity	HMAC-SHA1-96 HMAC-SHA2-256-128 HMAC-SHA2-384-192 HMAC-SHA2-512-256
	IKEv2 Diffie-Hellman (DH) Group	Group 14 (2048-bit) Group 15 (3072-bit) Group 16 (4096-bit)

How it Works

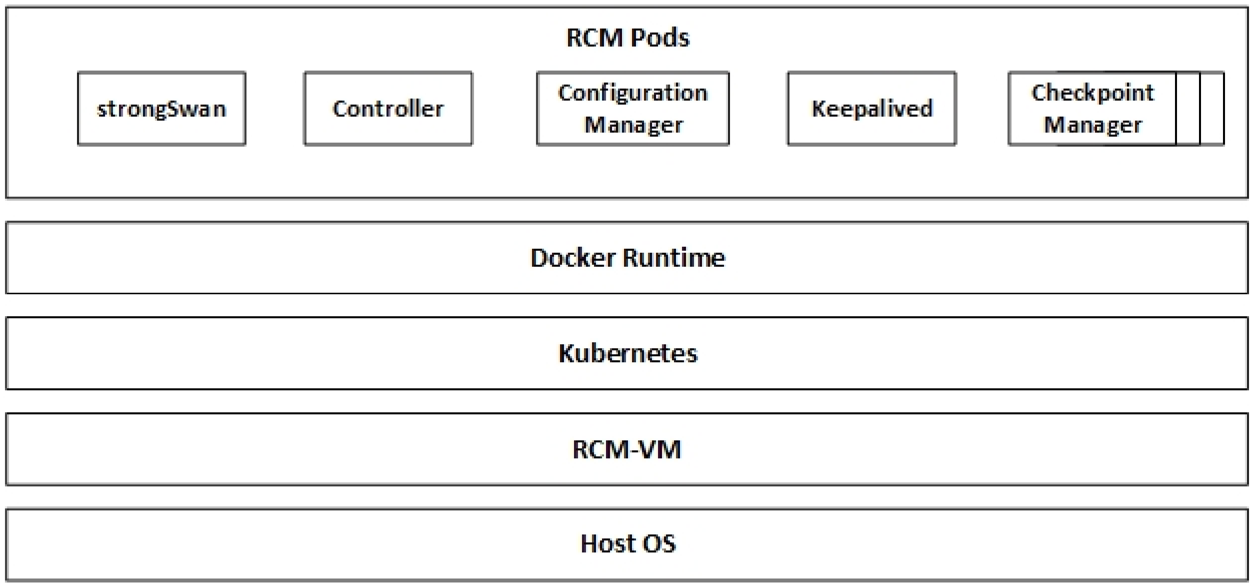
A single IPSec tunnel is established between RCM and UP. This tunnel carries checkpoint traffic, configuration files, VPNMGR traffic towards RCM, and so on. Since configuration from RCM uses SSH, there is no need to use IPSec for SSH traffic.

To support IPSec operation, the following pod is introduced:

- **strongSwan**: Establishes the IPSec tunnel (that is, the Control Plane of IPSec)

The strongSwan runs as a pod with Host mode networking and as a Deamon process. When you enable the IPSec using OpsCenter, then strongSwan pod gets created. IPSec tunnel initiation always happens from UP. The strongSwan handles the IPSec tunnel creation aspect. And, once the IPsec tunnel parameters are determined, it configures the host kernel for the IPSec data plane. The host kernel performs the encryption/decryption of IPSec traffic. When host kernel receives the encrypted packet, it decrypts the packet and punts it to the application listening on specific IPs. The strongSwan maintains the tunnel state between the RCM and the UP.

The following illustration depicts the system architecture of RCM VM.

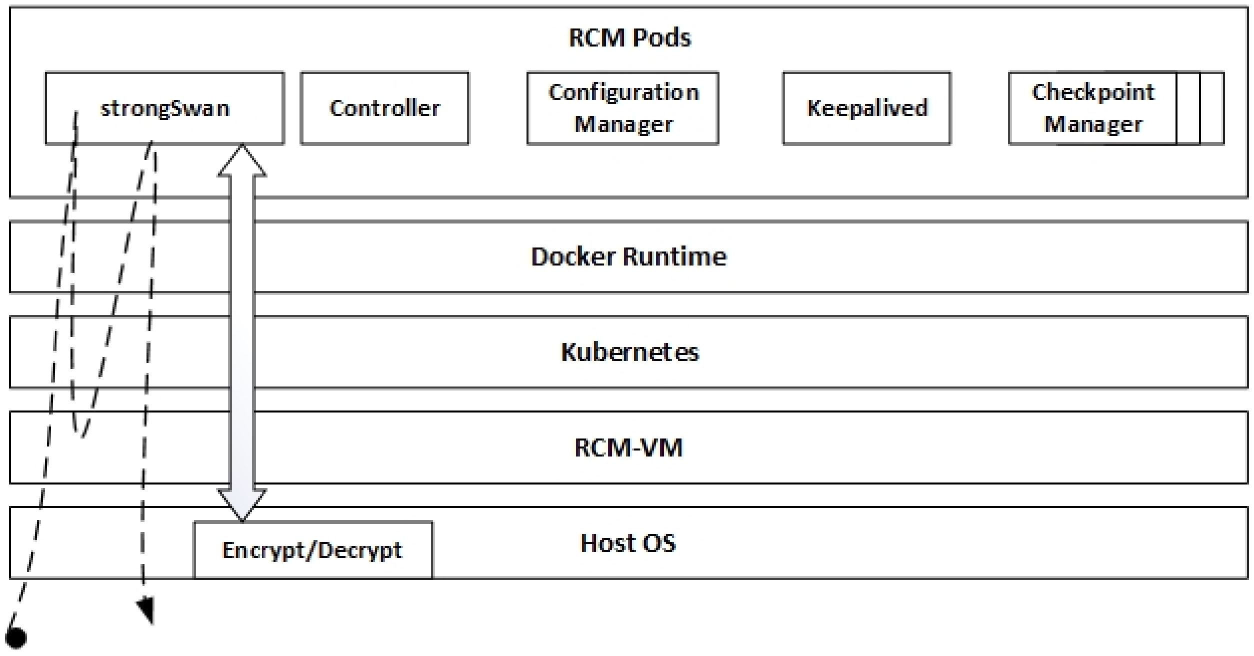


When RCM is deployed on bare metal, the RCM VM layer does not exist, and packet flow involves host kernel.

NOTE: Additional hardware for RCM is required as few cores must be dedicated for strongSwan.

RCM IPSec Tunnel Establishment

The following illustration depicts how IPSec tunnel is established between RCM and UP, and the packet flow.



The following steps explain how IPSec tunnel is established between RCM and UP:

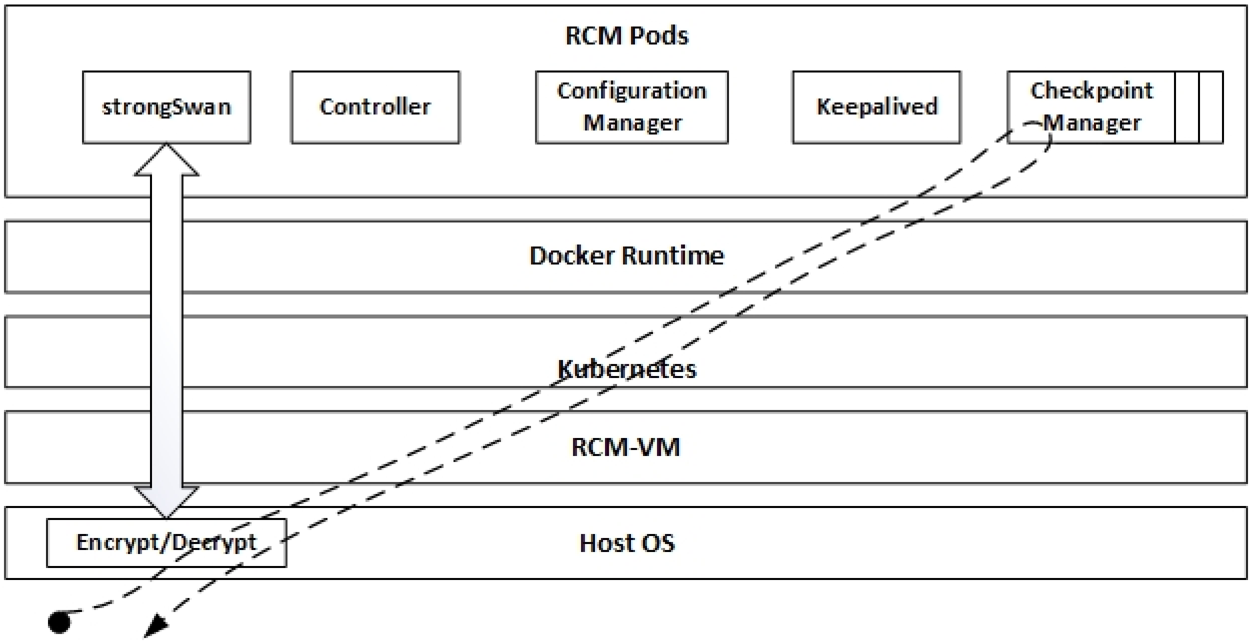
3. UP initiates IPSec tunnel establishment using IPSec control protocol such as IKEV1 or IKEV2. You may opt to choose only IKEV2.
4. Host kernel receives the packet.
5. The host kernel sends the packet to strongSwan.

   The above steps are repeated between UP and RCM till IPSec tunnel establishment concludes.
6. After the tunnel is established, strongSwan configures the host kernel with IPSec data plane parameters.
7. Host kernel is now ready to encrypt/decrypt IPSec packet towards the UP, and strongSwan is ready to maintain the IPSec tunnels between host kernel and UP.

   NOTE: Above sequence of operation is executed whenever UP establishes an IPSec tunnel.

Checkpoint Data Transfer

The following illustration depicts the checkpoint data transfer and packet flow.



The following steps explain the sequence of checkpoint data transfer and packet flow:

8. SessMgr of UP sends checkpoint over IPSec tunnel (note that all packet between RCM and UP uses the same tunnel, and there is one tunnel between UP and RCM).
9. Host kernel receives the packet and decrypts it.
10. The host kernel sends the packet to desired checkpoint manager (essentially, this happens through Kubernetes networking).
11. Checkpoint manager processes the packet and generates a response (for example, TCP ACK).
12. The response packet is sent to the host kernel.
13. Host kernel encrypts and egresses the packet.
14. The strongSwan maintains the tunnel state between RCM and UP and also keeps count of the tunnels idle-state and count of encrypted/decrypted packets.

RCM IPSec during Switchover

During RCM switchover, Standby RCM becomes Active. During this time, UPs try reconnecting with the new RCM. However, the reconnection fails as the new RCM does not have an IPSec tunnel. To resolve this reconnection failure, IPSec keepalive timer must be configured. IPSec keepalive timer expires as new RCM does not send keepalive messages. When this happens, UP triggers the establishment of new IPSec tunnel. After the IPSec tunnel is established, all UP connections toward new RCM becomes operational, and IPSec data is exchanged.

Limitations and Restrictions

The following are the known limitations/restrictions of RCM IPSec feature:

- Dynamic change of IPSec mode is not supported.

  Configuring strongSwan with static routing table is supported. Dynamic routing table update is not supported.

Configuring RCM IPSec

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

Enabling IPSec in RCM

Use the following configuration to enable IPSec in RCM.

```
configure

   rcm-ipsec enable true

   exit
```

NOTE:

- After IPSec is enabled, mandatory parameters like **`left-subnet`** and **`right-subnet`** must be configured.

Disabling IPSec in RCM

Use the following configuration to enable IPSec in RCM.

```
configure

   rcm-ipsec enable false

   exit
```

Configuring IPSec Transform Set

The IPSec Transform Set Configuration mode is used to configure IPSec security parameters. Use the following CLI commands to configure the IPSec Transform Set Configuration mode.

```
configure
```

```
    rcm-ipsec ikev2-ikesa transform-set

    exit
```

Configuring IPSec Parameters

Use the following CLI commands to configure IPSec parameters in RCM.

```
configure

    rcm-ipsec ikev2-ikesa transform-set

        dh-group { 14 | 15 | 16 }

        encryption { aes-cbc-128 | aes-cbc-256 }

        hmac { sha1-96 | sha2-256-128 | sha2-384-192 | sha2-512-256 }

        left-subnet

        prf { sha1 | sha2-256 }

        psk aes_encrypted_string

        right-subnet

        exit

    end
```

NOTES:

- **`dh-group { 14 | 15 | 16 }`**: Specifies Diffie-Hellman group configuration. It configures the appropriate key exchange cryptographic strength and activates Perfect Forward Secrecy by applying a Diffie-Hellman group.
  - Group 14 provides 2048 bits of keying strength. This is the default option.
  - Group 15 provides 3072 bits of keying strength.
  - Group 16 provides 4096 bits of keying strength.
- **`encryption { aes-cbc-128 | aes-cbc-256 }`**: Specifies the encryption algorithm and encryption key length.
  - **`aes-cbc-128`**: An advanced Encryption Standard Cipher Block Chaining with a key length of 128 bits. This is the default setting for this command.
  - **`aes-cbc-256`**: An advanced Encryption Standard Cipher Block Chaining with a key length of 256 bits.
- **`hmac { sha1-96 | sha2-256-128 | sha2-384-192 | sha2-512-256 }`**: Specifies integrity algorithm using a Hash-based Message Authentication Code (HMAC).
  - **`sha1-96`**: Uses a 160-bit secret key and produces a 160-bit authenticator value. This is the default setting for this command.
  - **`sha2-256-128`**: Uses a 256-bit secret key and produces a 128-bit authenticator value.

   - **sha2-384-192**: Uses a 384-bit secret key and produces a 192-bit authenticator value.
   - **sha2-512-256**: Uses a 512-bit secret key and produces a 256-bit authenticator value.
- **left-subnet**: [Mandatory] Specifies the RCM external IP/VIP.
- **prf**: Specifies the Pseudo-Random Function (PRF) algorithm.
- **psk**: Specifies the Pre-Shared Key for peer authentication.
- **right-subnet**: [Mandatory] Specifies the RCM service IP and port for UP.

Configuring strongSwan Endpoint

Use the following CLI commands to configure the strongSwan endpoint to create the pod.

```
configure
   endpoint rcm-strongswan vip-ip ip_address
   end
```

Sample Configuration

The following is a sample configuration for your reference.

```
configure
rcm-ipsec enable true
rcm-ipsec ipsec transform-set
encryption aes-256-gcm-128
 hmac        sha1-96
 dh-group    16
exit
rcm-ipsec ikev2-ikesa timer
 ikelifetime         10000
 retransmit-tries    5
 retransmit-timeout  99
exit
rcm-ipsec ikev2-ikesa transform-set
 encryption aes-cbc-128
 hmac        sha2-256-128
 prf         sha1
 dh-group    14
 psk         test
 left-subnet 192.0.2.1 port 1111 prefix-length 32
 left-subnet 192.0.3.1 port 1111 prefix-length 32
 right-subnet 192.0.4.1 port 2222 prefix-length 24
 right-subnet 192.0.5.1 port 2222 prefix-length 24
exit
```

SNMP Traps

The following traps are generated by the strongSwan Manager pod:

- TunnelsDropped
- TunnelsAdded

For the complete list of SNMP Traps available in RCM and configuration, see SNMP Traps under the Monitoring and Troubleshooting RCM section.

RCM and SMI Cluster Manager Integration

Feature Description

The Subscriber Microservices Infrastructure (SMI) Kubernetes (K8s) Cluster Manager allows you to deploy 5G Network Functions (NFs) which are developed based on SMI. SMI Cluster Manager (SMI CM) can also deploy UPF that is based on StarOS image.

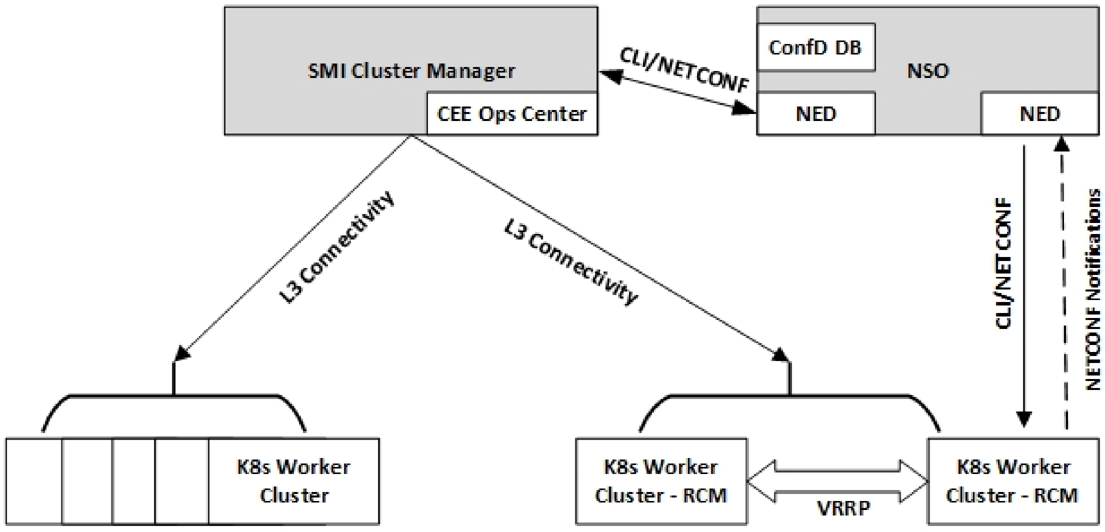
The Network Services Orchestrator (NSO) core function pack (CFP) prepares the configuration that is required to deploy all NFs including RCM, SMF, and UPF.

StarOS Network Element Drivers (NEDs) in the NSO is used to configure the UPF. The NED prepares the StarOS CLI from the configurations that are done through the Network Configuration Protocol (NETCONF) on NSO and pushes them to the UPFs. The RCM is configured using NSO through the NETCONF client on port 2022.

The K8s worker is a cluster of nodes managed by an instance of Kubernetes. However, for RCM, the K8s cluster is a single node.

How it Works

The SMI CM provisions the K8s clusters. Each K8s cluster deploys a particular NF. The RCM, a Cisco proprietary NF for UPFs that provides N:M redundancy, is allocated to one of the K8s worker clusters. The RCM must be a single-node K8s cluster. When RCM HA is used, the SMI CM brings up two RCM K8s clusters in separate nodes. These RCM clusters must be collocated in the same rack as the UPFs. The SMI CM brings up RCM pods like it does for other 5G NF components.



1. Once the SMI CM provisions the RCM pods in a K8s cluster, the rcm-ops-center starts running on that single-node RCM cluster.
2. NSO configures the Day-1 RCM configuration on each of the RCMs (Active and Standby).

   The Day-1 configuration consists:

  - Endpoint information: rcm-controller, rcm-bfdmgr, rcm-configmgr, replicas of rcm-checkppointmgr, rcm-keepalived and, optionally, rcm-snmp-trapper and rcm-ipsec nodes.
  - IP addresses, BFD timers, and other operational parameters for logging levels, and so on.

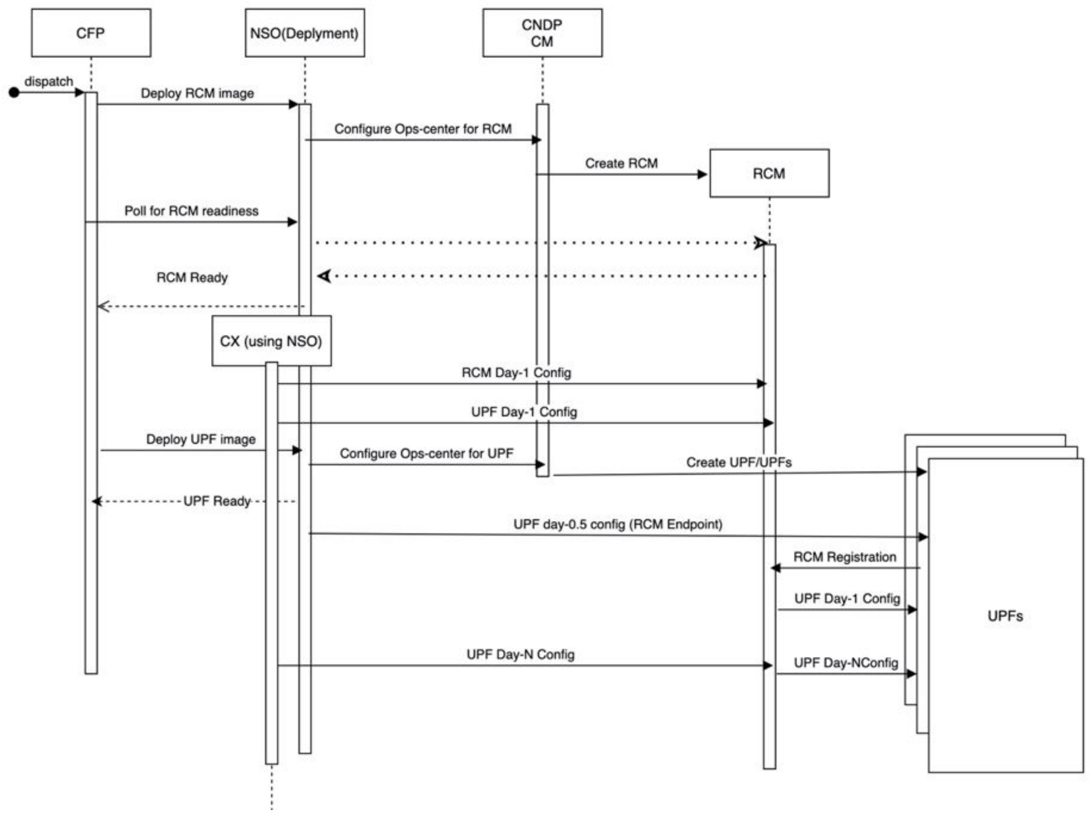
3. When VIP is configured for rcm-keepalived pod on both RCM clusters, VRRP connection on both clusters is established. One of them is selected as master/primary and other as backup.
4. Once the required functional pods of RCM on each cluster is up and running, the NSO configures the required UPs Day-1 configuration on each RCM. For details about configuration, see the Configuring RCM and UPF for Redundancy section.
5. The SMI CM provisions the UPF on a VM. Once the UPF boots, it is configured with RCM context. Using the details on RCM endpoint IP in rcm-context configuration, the UPF establishes connection with the Active RCM.
6. The Day-1 UPF configuration is pushed by RCM/NSO based on the configuration mode.

The cee-ops-center in SMI CM monitors all the K8s clusters. It has pods for collecting various diagnostic information from each cluster, such as Prometheus, alert managers, log retrievers, and so on. The cee-ops-center on the SMI CM collects information from both the cluster of RCMs and displays collective information on its dashboard.

Call Flows

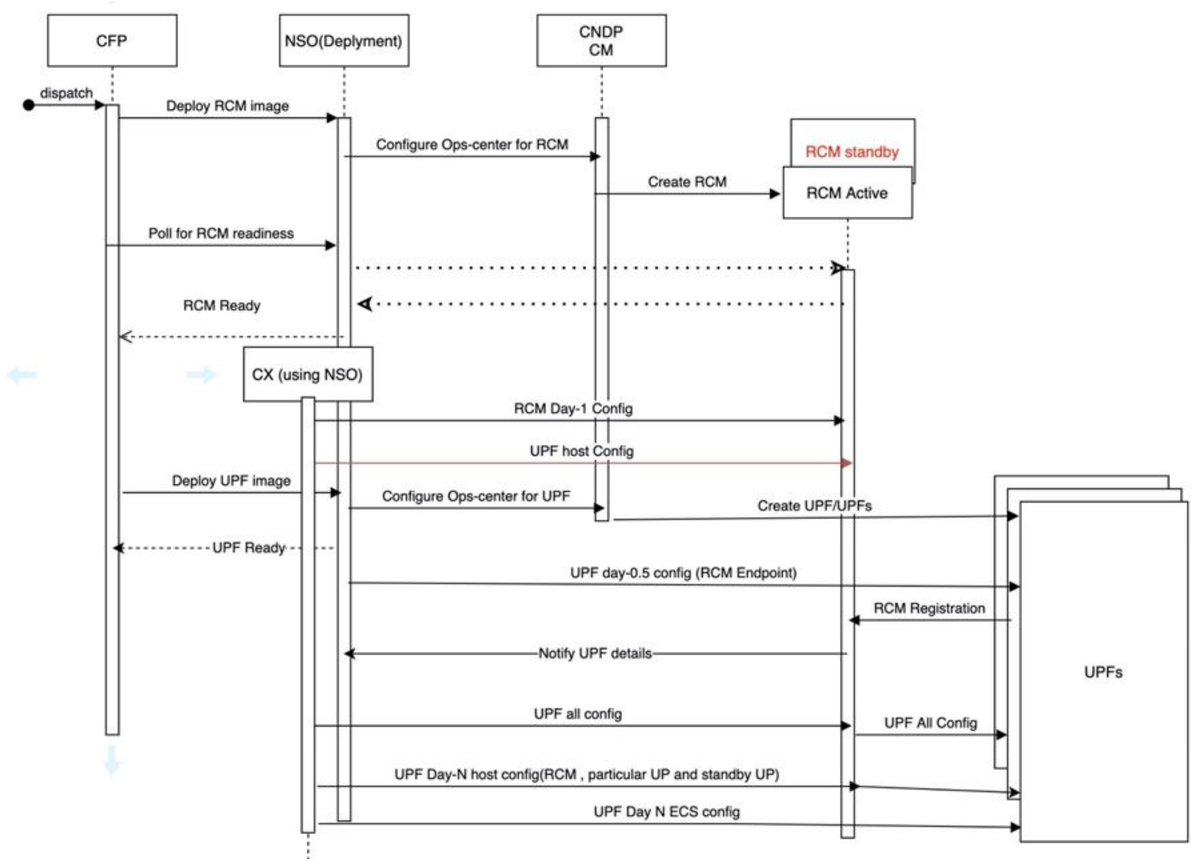
UPFs Configured by RCM

The following call flow illustrates bringing up of RCM using SMI CM and NSO core function pack (CFP) if the RCM configures the UPFs.



UPFs Configured by NSO

The following call flow illustrates bringing up of RCM when NSO configures the UPFs, and RCM needs only the host-specific configuration from NSO where it uses that configuration during switchover.



Provisioning RCM

All the RCM components can be deployed as pods using the helm charts. Each individual pod in RCM is built on SMI application infrastructure like other cloud native NFs. The RCM product is bundled as tar images.

SMI CM can only provision one RCM per single-node K8s cluster. The RCM BFDMgr runs in host networking mode. There is a possibility for port conflict if other running applications use the same port as RCM pods. Since RCM is specifically customized for StarOS UP/UPFs, we recommend isolating the RCM pods from other NFs.

RCM HA in SMI CM

The SMI CM deploys two RCMs as two separate single node K8s clusters. Both the RCMs communicate over VRRP to determine Master/Backup roles. The SMI CM is unaware of the redundancy that is achieved by the two RCM K8s clusters using the rcm-keepalived.

When rcm-keepalived pods come up after configuring with VRRP parameters, they communicate and determine the Master/Primary. The Master/Primary RCM serves all the UPFs to provide redundancy.

The health monitoring script in each RCM cluster runs periodically to check the status of the current cluster. If any issue is detected, the entire namespace must be redeployed. To trigger the RCM namespace reload, a script is provisioned on the node that communicates with the rcm-keepalived. Redeploying only the RCM namespace avoids unnecessary reload of non-RCM NFs if they are deployed in the same cluster.

Configuring RCM and UPF for Redundancy

The NSO is leveraged for configuring various NFs, including RCM. The NSO configures RCM, required to support redundancy, using the NETCONF interface.

When configuration of UPF is done through RCM, the NSO provides the configuration required for UPFs in a format that is interpreted by the RCM.

The common configuration that must be configured by NSO for UPF, through RCM, is in the following syntax:

```
configure
   redundancy-group group_number
      common line_number “staros_cli_string”
      end
```

The host configuration that must be configured by NSO for UPF, through RCM, is in the following syntax:

```
configure
   svc-type { upinterface | sxsvc | upsvc | gtpusvc | cpgrp | li }
      redundancy-group group_number
         host line_number “staros_cli_string”
         end
```

Configuring UPF Credentials in SMI CM

For details about the configuring UPF credentials, see Configuring UPF Credentials. It is also possible to configure the default credentials for each redundancy group, wherein you need not configure the credentials for each UPF. If credentials are not explicitly configured for any UPF, the default credentials are used.

Monitoring and Troubleshooting

This section provides information about the functionality available to monitor and/or troubleshoot RCM in SMI CM.

Log Forwarding and Gather TAC

The SMI CM leverages journalD service—a Linux system service for collecting and storing log data—running on the node and uses the log-forwarder to forward the logs to the configured server on the CEE.

The Gather TAC functionality, developed to fetch the cores and logs, is reused by SMI CM to fetch cores and logs from RCM cluster like any other NFs.

For details, refer the *Log Forwarding* and *Gather TAC* sections in the *UCC SMI Common Execution Environment Configuration and Administration Guide*.

Metrics and Alerts

The metrics for each RCM pod is defined per Prometheus. The metrics are incremented/decremented using the APIs provided by the SMI App-infra.

The metrics from each RCM POD is exposed at port 8081:

```
    prometheus.io/scrape: 'true'
    prometheus.io/port: "8081"
```

The 8081 port is exposed in each pod's service.

```
    - name: metrics
      port: 8081
```

NOTE:

- A label for a metric must be defined in *metrics/metric-labels.go*
- Add the defined label to the SMI App-infra using GetPrometheusLabelss "Add" method.
- Register the added metric using the "RegisterCounter_V1"/"RegisterGauge_V1"

method.

- All available APIs to be used on counters can be found in GIT repository.
- All the Alerts that are part of SMI App-infra of the RCM pods is available at cee-ops-center.
- For details about the counters/metrics that are added for RCM pods, see the Appendix G: RCM Metrics section.

Grafana

Grafana is an open-source data visualization tool used for displaying application metrics in interactive dashboards. A separate dashboard is created to monitor the metrics exposed by the RCM pods.

For details about Grafana, refer the *Grafana* section in the *UCC SMI Common Execution Environment Configuration and Administration Guide.*

Appendix A: Deployment Parameters

CAUTION: This section provides sizing parameters and recommendations based on typical deployment setup, and its solely for your reference.

Typical Deployment

Typical deployment consists of:

- 10 Active UPs per RCM
- One or multiple redundancy group with total of 10 Active UPs across all redundancy groups
- Each UP with 10 SessMgrs
- Total UP capacity with 200k (approx.) sessions and per session size of 38 KB (approx.)
    - Approx. 7.2 GB for 200k sessions (Approx. 1.8 GB with compression)

Parameters

For a typical deployment, consider the following sizing parameters:

- Memory
- CPU
- Network
- Hard Disk

The required resources differ with:

- The number of UPs registered with RCM
- The number of SessMgrs in each UP
- The number of sessions in each SessMgr of an UP
- Call Events Per Second (CEPS)

Memory Sizing

For a Typical Deployment example given above:

- All checkpoints are stored in RAM
- Memory required for checkpoints for each UP is 2 GB (approx.)
- Application garbage collector takes time to free up old checkpoints
- Checkpoints are continuous (Added/Modified/Deleted)
- Based on CEPS
- Typically requires 4 GB for one UP with 200k sessions excluding operational overhead of minimum 10 GB.

To support 10 UPs with 200k sessions each and 500 CEPS, recommended size of RAM is minimum of 50 GB.

CPU Sizing

The following parameters must be considered for CPU sizing:

- The number of Checkpoint Managers (ChkpointMgrs)/Redundancy Managers (RedMgrs) should be equal to the number of SessMgrs in each UP.
- All UP has same number of SessMgrs.
- During switchover, all the ChkpointMgrs work parallelly to flush checkpoints from RCM to new Active UP:
    - To achieve true parallelism, it is recommended to have as many cores as the number of ChkpointMgrs.
    - Additionally, two cores for operations involving other pods.

  Note: You can try with lesser number of cores if the total number of sessions are less.

Network Sizing

The following parameters must be considered for network sizing:

- Requires two interfaces:
    - RCM service interface where checkpoints are transferred
    - Management interface where SSH and SFTP of configurations can be performed

      You can use RCM interface and configure in RCM context of UP. However, its recommended to keep them separate.
- Additionally, operational interface to login to the Ops Center and for NETCONF communication to configure the Ops Center. Operations interface is also used to collect logs, diagnose, alert, and so on. This interface can be same as Management interface.
- For RCM High Availability (HA), an additional L2-level network for VRRP is required.
- Speed:
    - Minimum of 25Gbps link for RCM interface for checkpoints

      (Low latency as BFD runs on this interface.)
    - A basic 1Gbps link for management interface

Hard Disk Sizing

The following parameters must be considered for hard disk sizing:

- Disk space required for logging, docker images, and so on.
- It is recommended to have at least 40 GB of disk space.
- If resource crunch occurs, the pods are evicted.
- Some persistent storage to preserve data across reboots.

The following table is a typical recommendation.

Number of UPs	SessMgrs/UP	Total Sessions/RCM	Recommended Cores	Recommended Memory
5	8	1000K	10	32 GB
6	8	1200K	10	36 GB
8	10	1600K	12	45 GB
10	12	2000K	14	55 GB
10	16	2000K	18	55 GB

Appendix B: Sample Common and Host-specific Configurations

CAUTION: This section provides sample Common and Host-specific configurations based on typical deployment setup, and its solely for your reference.

Common Configuration

The following is a sample Common configuration. All ACS-related configurations are part of Common

configuration.

```
redundancy-group 1
common 0 "sleep 5 "
common 1 "config "
common 2 "active-charging service ACS "
common 3 "idle-timeout udp 60 "
common 4 "statistics-collection ruledef all "
common 5 "exit"
```

NOTE: There should be an "exit" in the Common configuration for each section, such as rulebase, ruledef,

host pool, port map, and so on.

Host-specific Configuration

The following is a sample Host-specific configuration.

```
svc-type upinterface
   redundancy-group 1
   host Active1
   host 1 config
   host 2 " context EPC2"
   host 3 " interface S5_SGW_PGW_loopback_up1 loopback"
   host 4 " ip address 192.168.170.77 255.255.255.255"
   host 5 " #exit"
   host 6 " interface pgw-ingress-ipv6-loopback_up1 loopback"
   host 7 " ipv6 address bbbb:aaaa::14/128"
   host 8 " #exit"
svc-type sxsvc
   redundancy-group 1
   host Active1
   host 1 config
   host 2 " context EPC2"
   host 42 " sx-service sx_up1"
   host 43 " instance-type userplane"
   host 44 " bind ipv4-address 192.168.170.77"
   host 45 " exit"
   host 46 " end"
exit
svc-type upsvc
   redundancy-group 1
   host Active1
   host 1 config
   host 2 " context EPC2"
   host 46 " user-plane-service up_up1"
   host 47 " associate gtpu-service pgw-gtpu_up1 pgw-ingress"
   host 48 " associate gtpu-service sgw-ingress-gtpu_up1 sgw-ingress"
   host 49 " associate gtpu-service sgw-engress-gtpu_up1 sgw-egress"
   host 50 " associate gtpu-service saegw-sxu_up1 cp-tunnel"
   host 51 " associate sx-service sx_up1"
   host 52 " associate fast-path service"
   host 53 " associate control-plane-group g1"
   host 54 " exit"
   host 55 " #exit"
   host 56 end
exit
svc-type gtpusvc
   redundancy-group 1
   host Active1
   host 1 config
   host 2 " context EPC2"
   host 30 " gtpu-service pgw-gtpu_up1"
   host 31 " bind ipv4-address 192.168.170.14"
   host 32 " exit"
   host 33 " gtpu-service saegw-sxu_up1"
   host 34 " bind ipv4-address 192.168.170.31"
   host 35 " exit"
   host 36 " gtpu-service sgw-engress-gtpu_up1"
   host 37 " bind ipv4-address 192.168.170.51"
   host 38 " exit"
   host 39 " gtpu-service sgw-ingress-gtpu_up1"
   host 40 " bind ipv4-address 101.101.102.48"
   host 41 " exit"
   host 42 " end"
exit
svc-type cpgrp
   redundancy-group 1
   host Active1
   host 0 config
   host 1 "control-plane-group g1"
   host 2 "peer-node-id ipv4-address 192.168.196.10"
   host 3 exit
   host 4 end
exit
```

NOTE:

1. If you have 10 active hosts, then you should have 10 active Host-specific configuration present under these services.
2. The Lawful Intercept (LI) configuration must be under “svc-type cpgrp”. There is no specific service for LI.

Appendix C: N:M Configuration Separation Table

CP	RCM	UP
1. URR List must be explicitly configured under Active Charging Service (ACS). 2. The **`sx-pfd-push`** and **`sx-reassociation`** CLI commands under UP group must be disabled.	Common configuration: • ACS • APN • GTPP Group (for URR generation) • AAA Group (for URR generation) Host Configuration: • Service loopback interfaces • Sx Service • GTPU Service • UP Service • CP Group • Lawful Intercept (LI): LI configuration must be under CP group configuration.	Day-0 configuration [All physical interfaces, contexts (including RCM context), routing configurations (including BGP), bulkstats, SNMP, Syslog, and so on.] Day-1 (Common and Host) configuration is pushed from RCM.

Appendix D: MIBs

The following is the information from *CISCO-RCM-MIB.my* file.

```
-- *****************************************************************

-- CISCO-RCM-MIB.my

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-- All rights reserved.

-- *****************************************************************


CISCO-RCM-MIB DEFINITIONS ::= BEGIN


IMPORTS

    MODULE-IDENTITY,

    OBJECT-TYPE,

    NOTIFICATION-TYPE

        FROM SNMPv2-SMI

    MODULE-COMPLIANCE,

    NOTIFICATION-GROUP,

    OBJECT-GROUP

        FROM SNMPv2-CONF

    TEXTUAL-CONVENTION,

    DateAndTime

        FROM SNMPv2-TC

    ciscoMgmt

        FROM CISCO-SMI;



ciscoRcmMIB MODULE-IDENTITY

    LAST-UPDATED    "202008120000Z"

    ORGANIZATION    "Cisco Systems, Inc."

    CONTACT-INFO

            "Cisco Systems


            Customer Service
            Postal: 170 W Tasman Drive
            San Jose, CA  95134
            USA

            Tel: +1 800 553-NETS"
    DESCRIPTION
        "The MIB module for the Cisco Redundancy Configuration Manager (RCM)
platform.

        This MIB only handles notifications from the RCM."
    REVISION        "202008120000Z"
    DESCRIPTION
        "Added rcmFaultClusterName, rcmFaultNamespace, rcmFaultHostname
         and rcmFaultInstance fields to identify the faults."
    REVISION        "201809190000Z"
    DESCRIPTION
        "Initial version of this MIB module."
    ::= { ciscoMgmt 1000}

-- Textual Conventions definition will be defined before this line

ciscoRcmMIBNotifs  OBJECT IDENTIFIER
    ::= { ciscoRcmMIB 0 }

ciscoRcmMIBFaults  OBJECT IDENTIFIER
    ::= { ciscoRcmMIB 1 }

ciscoRcmMIBConform  OBJECT IDENTIFIER
    ::= { ciscoRcmMIB 2 }

rcmFaultId OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..64))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Uniquely identify the fault within a monitored entity."
    ::= { ciscoRcmMIBFaults 1 }

rcmFaultSource OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..128))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Uniquely identify the monitored entity
         It can be a hostname or IP Address or
         human readable identity."
    ::= { ciscoRcmMIBFaults 2 }



rcmFaultSeverity OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..16))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Indicates the level of urgency for operator attention
         Refer 3GPP TS32.111-5 v9.0.0 section 4.3."
    ::= { ciscoRcmMIBFaults 3 }

rcmFaultTime OBJECT-TYPE
    SYNTAX          DateAndTime
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "The date and time when the fault is detected."
    ::= { ciscoRcmMIBFaults 4 }

rcmFaultType OBJECT-TYPE
    SYNTAX INTEGER {
           indeterminate(0),
           host-level(1),
           rcm-internal(2),
           userplane(3),
          pod-business-logic(4)
        }
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Indicates the type of fault"
    ::= { ciscoRcmMIBFaults 5 }

rcmFaultAdditionalInfo OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..2048))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Additional Information about the fault."
    ::= { ciscoRcmMIBFaults 6 }

rcmFaultClusterName OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..128))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "The cluster name associated to the fault."
    ::= { ciscoRcmMIBFaults 7 }
rcmFaultNamespace OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..128))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Identifies the namespace associated to
        the fault.  This field is not always available for
        every fault."
    ::= { ciscoRcmMIBFaults 8 }

rcmFaultHostname OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..128))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Identifies the hostname or ip address associated
        with the fault.  This field is not always available
        for every fault."
    ::= { ciscoRcmMIBFaults 9 }
rcmFaultInstance OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..128))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Identifies the instance associated to
        the fault.  The instance is set by the alert rule
        creator and may not reference a host but could reference
        a process or KPI that is associated to the fault.  This
        field is not always available for every fault"
    ::= { ciscoRcmMIBFaults 10 }

rcmVnfAlias OBJECT-TYPE
    SYNTAX          OCTET STRING (SIZE  (1..128))
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "Alias for the monitored entity"
    ::= { ciscoRcmMIBFaults 11 }

-- Default Notification Type

rcmFaultActiveNotif NOTIFICATION-TYPE
    OBJECTS         {
                        rcmFaultId,
                        rcmFaultSource,
                        rcmFaultSeverity,
                        rcmFaultTime,
                        rcmFaultType,
                        rcmFaultAdditionalInfo,
                        rcmFaultClusterName,
                        rcmFaultNamespace,
                        rcmFaultHostname,
                        rcmFaultInstance,
                        rcmVnfAlias
                    }
    STATUS          current
    DESCRIPTION
        "This notification is generated by RCM
         whenever a fault gets triggered."
   ::= { ciscoRcmMIBNotifs 1 }

rcmFaultClearNotif NOTIFICATION-TYPE
    OBJECTS         {
                        rcmFaultId,
                        rcmFaultSource,
                        rcmFaultSeverity,
                        rcmFaultTime,
                        rcmFaultType,
                        rcmFaultAdditionalInfo,
                        rcmFaultClusterName,
                        rcmFaultNamespace,
                        rcmFaultHostname,
                        rcmFaultInstance,
                        rcmVnfAlias
                    }
    STATUS          current
    DESCRIPTION
        "This notification is generated by RCM
         whenever a fault gets cleared."
   ::= { ciscoRcmMIBNotifs 2 }

ciscoRcmMIBCompliances  OBJECT IDENTIFIER
    ::= { ciscoRcmMIBConform 1 }

ciscoRcmMIBGroups  OBJECT IDENTIFIER
```

```
    ::= { ciscoRcmMIBConform 2 }

rcmMIBCompliance MODULE-COMPLIANCE
    STATUS          current
    DESCRIPTION
        "The compliance statement for entities that support
        the Cisco RCM Managed Objects"
    MODULE          -- this module
    MANDATORY-GROUPS {
                        rcmMIBFaultGroup,
                        rcmMIBNotificationGroup
                    }
    ::= { ciscoRcmMIBCompliances 1 }

-- Units of Conformance

rcmMIBFaultGroup OBJECT-GROUP
    OBJECTS         {
                        rcmFaultId,
                        rcmFaultSource,
                        rcmFaultSeverity,
                        rcmFaultTime,
                        rcmFaultType,
                        rcmFaultAdditionalInfo,
                        rcmFaultClusterName,
                        rcmFaultNamespace,
                        rcmFaultHostname,
                        rcmFaultInstance,
                        rcmVnfAlias
                    }
    STATUS          current
    DESCRIPTION
        "The set of RCM Fault groups defined by this MIB"
    ::= { ciscoRcmMIBGroups 1 }

rcmMIBNotificationGroup NOTIFICATION-GROUP
```

```
   NOTIFICATIONS    { rcmFaultActiveNotif,
                      rcmFaultClearNotif }
    STATUS          current
    DESCRIPTION
        "The set of RCM notifications defined by this MIB"
    ::= { ciscoRcmMIBGroups 2 }

END
```

Appendix E: P2P/ADC Plugin Configuration and Update Procedure

This section provides information about P2P/ADC Plugin configuration and update procedure.

The following steps are required in all the UPs.

3. Copy the patch to `/flash` of all the UPs.
4. To patch the plugin, execute the following CLI command:

   ```
   patch plugin p2p /flash/libp2p-<plugin_filename>
   ```
5. To install the plugin, execute the following CLI command:

   ```
   install plugin p2p patch_libp2p-<plugin_filename>
   ```
6. Configure the P2P module and upgrade it through RCM for all the UPs (Active and Standby in one step):

   ```
   configure
      plugin plugin_name
         module priority number version plugin_version
         end
   update module plugin_name
   ```

To roll back the P2P/ADC plugin in all UPs, execute the following CLI command in Exec mode:

```
rollback module plugin_name
```

NOTES:

- You must load, patch, and install the plugin on all the UPs individually.
- Configurations in Step 4 is loaded in the RCM configuration file using the Modify script. For details, see Modifying Host Configuration section.
- Ensure to save the plugin at CP and UP.

Appendix F: RCM Configuration Generation Utility

This section provides sample Host configurations that is based on typical deployment setup, explanations of the configurations, usage, and script-help.

CAUTION: The information captured in this section is solely for your reference.

Host Configurations

`host Active1` <<<----Name of the host

`svc-type upinterface` <<<<----For interface-specific configuration, we need to use this svc-type

```
config
context EPC2
interface loop1_up1 loopback
ip address 192.0.2.1 255.255.255.0
#exit
interface loop2_up1 loopback
ip address 192.0.2.2 255.255.255.0
#exit
interface loop3_up1 loopback
ip address 192.0.2.3 255.255.255.0
#exit
interface loop4_up1 loopback
ip address 192.0.2.4 255.255.255.0
#exit
interface loop5_up1 loopback
ip address 192.0.2.5 255.255.255.0
#exit
#exit
end
```

`svc-type sxsvc` <<<<----For Sx service-specific configuration, we need to use this svc-type

```
config
context EPC2
sx-service sx_up1
instance-type userplane
bind ipv4-address 192.0.2.5
exit
```

```
#exit
end
svc-type upsvc <<<<----For UP service-specific configuration, we need to use this svc-type
config
context EPC2
user-plane-service up_up1
associate gtpu-service pgw-gtpu_up1 pgw-ingress
associate gtpu-service sgw-ingress-gtpu_up1 sgw-ingress
associate gtpu-service sgw-engress-gtpu_up1 sgw-egress
associate gtpu-service saegw-sxu_up1 cp-tunnel
associate sx-service sx_up1
associate fast-path service
associate control-plane-group g1
exit
#exit
#exit
end
svc-type gtpusvc <<<<----For GTPU service-specific configuration, we need to use this svc-type
config
context EPC2
gtpu-service pgw-gtpu_up1
bind ipv4-address 192.0.2.2
exit
gtpu-service saegw-sxu_up1
bind ipv4-address 192.0.2.3
exit
gtpu-service sgw-engress-gtpu_up1
bind ipv4-address 192.0.2.4
exit
gtpu-service sgw-ingress-gtpu_up1
bind ipv4-address 192.0.2.1
#exit
#exit
end
svc-type cpgrp <<<<----For CP group-specific configuration, we need to use this svc-type
```

```
config
control-plane-group g1
peer-node-id ipv4-address 192.0.3.1
exit
end
exit
```

Script Help-string

`~/Script/script_1302_02$ ./apply_config.sh`

Usage: **`./apply_config.sh -[ g m i h n G] -f filename`**

- -g : redundancy-group name
- -m : Append the starOS common/Host config to ops-center config
- -i : Input Common config file where starOS cli is present.
- -h : Input Host config file where starOS cli is present.
- -n : Input Namespace where ops-center is running.
- -G : Input Generation 4/5
    - For RCM VM version, input the value as 4. For RCM Cloud Native version, input the value as 5.

Applying both Common and Host-specific Configuration

```
~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -i
input/<path_name>/common_master.cli -h
<path_name1>/<path_name2>/host_master.cli
Validating....
Adding Commit Flag
Applying Clean Common Config
admin@10.0.0.1's password:
Commit complete.
Applying Clean Host Config
admin@10.0.0.1's password:
Commit complete.
```

Applying Common Configuration

```
~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -i
<path_name1>/<path_name2>/common_master.cli
Validating....
Adding Commit Flag
```

```
Applying Clean Common Config

admin@10.0.0.1's password:

% No modifications to commit.
```

Applying Host-specific Configuration

```
~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -h
<path_name1>/<path_name2>/host_master.cli

Validating....

Applying Clean Host Config

admin@10.0.0.1's password:

Commit complete.
```

Modifying Common Configuration

```
~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -m -i
<path_name1>/<path_name2>/common_

common_config_mod_2.cli common_config_mod.cli common_master.cli
common_master_mod_2.cli common_master_mod.cli

~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -m -i
<path_name1>/<path_name2>/common_config_mod.cli

Validating....

Applying Modified Common Config

admin@10.0.0.1's password:

Commit complete.

~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -m -i
<path_name1>/<path_name2>/common_config_mod_2.cli

Validating....

Applying Modified Common Config

admin@10.0.0.1's password:

Commit complete.
```

Modifying Host Configuration

```
~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -m -h
<path_name1>/<path_name2>/host_master_mod.cli

Validating....

preparing mod host config

Applying Modified Host Config

admin@10.0.0.1's password:

Commit complete.
```

```
~/Script/script_1302_02$ ./apply_config.sh -g 1 -G 5 -n smf -m -h
<path_name1>/<path_name2>/host_master_mod_2.cli

Validating....

preparing mod host config

Applying Modified Host Config

admin@10.0.0.1's password:

Commit complete.
```

Appendix G: RCM Metrics

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: smf-metrics-{{ .Release.Name }}
  labels:
    documentation-type: metrics
    documentation-group: smf
    documentation-group-version: {{.Chart.Version}}
data:
  documentation.yaml: |-
   metrics:
      entries:
         -  category: RCM Bfdmgr UPF Event Stats
            metric: bfdmgr_upf_event_stats
            description: "Number of events received for each UPF"
            sampleQuery: "bfdmgr_upf_event_stats{service_name=\"bfdmgr\"}"
            labels:
            -  label: endpoint
               description: "endpoint IP of UPF"
               example: "1.1.1.1"
            -  label: groupid
               description: "GroupId of the UPF"
               example: "1"
         -  category: RCM Bfdmgr Controller Event Stats
            metric: bfdmgr_controller_event_stats
            description: "Number of events sent to rcm-controller"
            sampleQuery:
"bfdmgr_controller_event_stats{service_name=\"bfdmgr\"}"
            labels:
            -  label: endpoint
               description: "endpoint IP of UPF"
               example: "1.1.1.1"
            -  label: groupid
```

```
                description: "GroupId of the UPF"
                example: "1"
         -   category: RCM checkpointmgr Current call count
             metric: chkptmgr_total_call_count
             description: "Current Number of calls checkpointed to RCM 
checkpointmgr"
             sampleQuery: "chkptmgr_total_call_count{service_name=\"rcm-
checkpointmgr\"}"
             labels:
             -   label: sessmgr_no
                 description: "Sessmgr Number of UP"
                 example: "1"
             -   label: up_address
                 description: "IP address of UP"
                 example: "1.1.1.1"
         -   category: RCM checkpointmgr Current active VOLTE call count
             metric: chkptmgr_volte_active_call_count
             description: "Current Number of volte active calls checkpointed 
to RCM checkpointmgr"
             sampleQuery: 
"chkptmgr_volte_active_call_count{service_name=\"rcm-checkpointmgr\"}"
             labels:
             -   label: sessmgr_no
                 description: "Sessmgr Number of UP"
                 example: "1"
             -   label: up_address
                 description: "IP address of UP"
                 example: "1.1.1.1"
         -   category: RCM checkpointmgr Current non-prio active call count
             metric: chkptmgr_non_prio_active_call_count
             description: "Current Number of non-prio active calls 
checkpointed to RCM checkpointmgr"
             sampleQuery: 
"chkptmgr_non_prio_active_call_count{service_name=\"rcm-checkpointmgr\"}"
             labels:
             -   label: sessmgr_no
                 description: "Sessmgr Number of UP"
                 example: "1"
```

```
            - label: up_address
              description: "IP address of UP"
              example: "1.1.1.1"
        - category: RCM checkpointmgr Current non-active VOLTE call count
            metric: chkptmgr_volte_non_active_call_count
            description: "Current Number of non-actove VOLTE calls
checkpointed to RCM checkpointmgr"
            sampleQuery:
"chkptmgr_volte_non_active_call_count{service_name=\"rcm-checkpointmgr\"}"
            labels:
            - label: sessmgr_no
              description: "Sessmgr Number of UP"
              example: "1"
            - label: up_address
              description: "IP address of UP"
              example: "1.1.1.1"
        - category: RCM checkpointmgr Current non-prio non-active call
count
            metric: chkptmgr_non_prio_non_active_call_count
            description: "Current Number of non-prio non-active calls
checkpointed to RCM checkpointmgr"
            sampleQuery:
"chkptmgr_non_prio_non_active_call_count{service_name=\"rcm-checkpointmgr\"}"
            labels:
            - label: sessmgr_no
              description: "Sessmgr Number of UP"
              example: "1"
            - label: up_address
              description: "IP address of UP"
              example: "1.1.1.1"
        - category: RCM checkpointmgr Current Emergency call count
            metric: chkptmgr_emergency_call_count
            description: "Current Number of Emergency calls checkpointed to
RCM checkpointmgr"
            sampleQuery: "chkptmgr_emergency_call_count{service_name=\"rcm-
checkpointmgr\"}"
            labels:
            - label: sessmgr_no
```

```
                description: "Sessmgr Number of UP"
                example: "1"
             -  label: up_address
                description: "IP address of UP"
                example: "1.1.1.1"
          -  category: RCM checkpointmgr UP connection count
             metric: chkptmgr_up_connection_count
             description: "Count related to UP connections to RCM
checkpointmgr"
             sampleQuery: "chkptmgr_up_connection_count{service_name=\"rcm-
checkpointmgr\"}"
             labels:
             -  label: sessmgr_no
                description: "Sessmgr Number of UP"
                example: "1"
             -  label: up_address
                description: "IP address of UP"
                example: "1.1.1.1"
             -  label: up_mode
                description: "Mode in which UP is running"
                example: "active/standby"
             -  label: conn_state
                description: "Connection state of UP"
                example: "connected/disconnected"
          -  category: RCM checkpointmgr UP Flush completed count
             metric: chkptmgr_up_flush_completed_count
             description: "Count related to UP flush completed in
checkpointmgr"
             sampleQuery:
"chkptmgr_up_flush_completed_count{service_name=\"rcm-checkpointmgr\"}"
             labels:
             -  label: sessmgr_no
                description: "Sessmgr Number of UP"
                example: "1"
             -  label: up_address
                description: "IP address of UP"
                example: "1.1.1.1"
          -   category: RCM checkpointmgr UP Audit count
             metric: chkptmgr_up_audit_count
             description: "Count related to UP Audits in RCM checkpointmgr"
             sampleQuery: "chkptmgr_up_audit_count{service_name=\"rcm-
checkpointmgr\"}"
             labels:
             -  label: sessmgr_no
                description: "Sessmgr Number of UP"
                example: "1"
             -  label: up_address
                description: "IP address of UP"
                example: "1.1.1.1"
             -  label: state
                description: "Current state"
                example: "start/end"
          -   category: RCM configmgr UP count
             metric: configmgr_upf_count
             description: "Current count of UPs in a particular host group in
 rcm configmgr"
             sampleQuery: "configmgr_upf_count{service_name=\"rcm-
 configmgr\"}"
             labels:
             -  label: host_grp_name
                description: "UP host group name"
                example: "any string"
          -   category: RCM configmgr switchover abort count
             metric: configmgr_swover_abort_count
             description: "Count of switchover aborts in a particular host
 group in rcm configmgr"
             sampleQuery: "configmgr_swover_abort_count{service_name=\"rcm-
 configmgr\"}"
             labels:
             -  label: host_grp_name
                description: "UP host group name"
                example: "any string"
          -   category: RCM configmgr switchover failure count
             metric: configmgr_swover_failure_count
```

```
            description: "Count of switchover failures in a particular host
group in rcm configmgr"
            sampleQuery: "configmgr_swover_failure_count{service_name=\"rcm-
configmgr\"}"
            labels:
            -  label: host_grp_name
               description: "UP host group name"
               example: "any string"
         -  category: RCM configmgr config push failure count
            metric: configmgr_cfg_push_failure_count
            description: "Count of config push failure in a particular host
group in rcm configmgr"
            sampleQuery:
"configmgr_cfg_push_failure_count{service_name=\"rcm-configmgr\"}"
            labels:
            -  label: host_grp_name
               description: "UP host group name"
               example: "any string"
         -  category: RCM configmgr config push complete count
            metric: configmgr_cfg_push_complete_count
            description: "Count of config push complete in a particular group
in rcm configmgr"
            sampleQuery:
"configmgr_cfg_push_complete_count{service_name=\"rcm-configmgr\"}"
            labels:
            -  label: host_grp_name
               description: "UP host group name"
               example: "any string"
         -  category: RCM controller switchover failure count
            metric: controller_switchover_failure_stats
            description: "Count of failed switchover in rcm controller"
            sampleQuery:
"controller_switchover_failure_stats{service_name=\"rcm-controller\"}"
            labels:
            -  label: failure_reason
               description: "Reason string for failure"
               example: "Unknown Destination Endpoint <> , Pre-switchover
Failed, Notification of switchover Trigger to standby UP encountered error
etc"
```

```
        -  category: RCM controller switchover count
           metric: controller_switchover_stats
           description: "Count of total switchover in rcm controller"
           sampleQuery: "controller_switchover_stats{service_name=\"rcm-
controller\"}"
           labels:
           -  label: swover_reason
              description: "Reason string for switchover"
              example: "BFD Failure, Planned Switchover etc"
           -  label: state
              description: "State of switchover"
              example: "started or completed"
        -  category: RCM controller last switchover duration
           metric: controller_last_switchover_seconds_total
           description: "Duration of last switchover completion in rcm
controller"
           sampleQuery:
"controller_last_switchover_seconds_total{service_name=\"rcm-controller\"}"
        -  category: RCM controller UPF registered count
           metric: controller_upf_registered_stats
           description: "Count of total UPF registered in rcm controller"
           sampleQuery: "controller_upf_registered_stats{service_name=\"rcm-
controller\"}"
           labels:
           -  label: grpId
              description: "Group ID of UPF"
              example: "any valid string"
           -  label: endpoint
              description: "Endpoint address of UPF"
              example: "any ip address string"
        -  category: RCM controller mass UPF failure count
           metric: controller_mass_upf_failure_stats
           description: "Count of mass UPF failures in rcm controller"
           sampleQuery:
"controller_mass_upf_failure_stats{service_name=\"rcm-controller\"}"
        -  category: RCM controller UPF boot timer expiry count
           metric: controller_upf_boot_timer_expiry_stats
```

```
            description: "Count of total UPF boot timer expiry in rcm
controller"
            sampleQuery:
"controller_upf_boot_timer_expiry_stats{service_name=\"rcm-controller\"}"
            labels:
            -  label: endpoint
               description: "Endpoint address of UPF"
               example: "any ip address string"
         -  category: RCM controller IPC sent count
            metric: controller_ipc_sent_stats
            description: "Count of total IPC message sent from rcm
controller"
            sampleQuery: "controller_ipc_sent_stats{service_name=\"rcm-
controller\"}"
            labels:
            -  label: pod_name
               description: "Name of pod with which controller is
communicating"
               example: "rcm-configmgr or rcm-chkptmgr"
         -  category: RCM controller IPC sent error count
            metric: controller_ipc_sent_error_stats
            description: "Count of total IPC message sent error for rcm
controller"
            sampleQuery: "controller_ipc_sent_error_stats{service_name=\"rcm-
controller\"}"
            labels:
            -  label: pod_name
               description: "Name of pod with which controller is
communicating"
               example: "rcm-configmgr or rcm-chkptmgr"
         -  category: RCM controller IPC received count
            metric: controller_ipc_rcvd_stats
            description: "Count of total IPC message received by rcm
controller"
            sampleQuery: "controller_ipc_rcvd_stats{service_name=\"rcm-
controller\"}"
            labels:
            -  label: pod_name
               description: "Name of pod with which controller is
communicating"
```

```
                  example: "rcm-configmgr or rcm-chkptmgr"
          -   category: RCM controller UPF msg sent count
              metric: controller_upf_msg_sent_stats
              description: "Count of total message sent to UPF by rcm
controller"
              sampleQuery: "controller_upf_msg_sent_stats{service_name=\"rcm-
controller\"}"
              labels:
              -   label: grpId
                  description: "Group ID of UPF"
                  example: "any valid string"
              -   label: endpoint
                  description: "Endpoint address of UPF"
                  example: "any ip address string"
              -   label: msg_type
                  description: "Name of msg sent/recvd"
                  example: "UpfMsgType_Registration, UpfMsgType_HB,
UpfMsgType_State etc"
          -   category: RCM controller UPF msg received count
              metric: controller_upf_msg_rcvd_stats
              description: "Count of total message from UPF received by rcm
controller"
              sampleQuery: "controller_upf_msg_rcvd_stats{service_name=\"rcm-
controller\"}"
              labels:
              -   label: grpId
                  description: "Group ID of UPF"
                  example: "any valid string"
              -   label: endpoint
                  description: "Endpoint address of UPF"
                  example: "any ip address string"
              -   label: msg_type
                  description: "Name of msg sent/recvd"
                  example: "UpfMsgType_Registration, UpfMsgType_HB,
UpfMsgType_State etc"
          -   category: RCM controller UPF BFD event count
              metric: controller_upf_bfd_event_stats
```

```
            description: "Count of total BFD events received by rcm
controller"
            sampleQuery: "controller_upf_bfd_event_stats{service_name=\"rcm-
controller\"}"
            labels:
            -  label: grpId
               description: "Group ID of UPF"
               example: "any valid string"
            -  label: endpoint
               description: "Endpoint address of UPF"
               example: "any ip address string"
            -  label: event
               description: "Name of bfd event"
               example: "bfd_up or bfd_down"
         -  category: RCM controller BFD heartbeat failure count
            metric: controller_bfd_hb_timeout_stats
            description: "Count of total BFD heartbeat timeout received by
rcm controller"
            sampleQuery: "controller_bfd_hb_timeout_stats{service_name=\"rcm-
controller\"}"
         -  category: RCM controller UPF TCP disconnect count
            metric: controller_upf_tcp_disconnect_stats
            description: "Count of total upf tcp disconnects received by rcm
controller"
            sampleQuery:
"controller_upf_tcp_disconnect_stats{service_name=\"rcm-controller\"}"
            labels:
            -  label: grpId
               description: "Group ID of UPF"
               example: "any valid string"
            -  label: endpoint
               description: "Endpoint address of UPF"
               example: "any ip address string"
         -  category: RCM controller UPF TCP connect count
            metric: controller_upf_tcp_connect_stats
            description: "Count of total upf tcp connects received by rcm
controller"
            sampleQuery:
"controller_upf_tcp_connect_stats{service_name=\"rcm-controller\"}"
```

```
labels:
-  label: grpId
   description: "Group ID of UPF"
   example: "any valid string"
-  label: endpoint
   description: "Endpoint address of UPF"
   example: "any ip address string"
```