K-ONE Technical Document #28

The Study of architecture for supporting Advanced VNF High Availability in OpenStack Tacker

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Summary

Network function virtualization (NFV) provides flexible and scalable network services by leveraging software-based network appliances. In an NFV architecture, the virtual network function manager (VNFM) has a critical role in provisioning, configuring, and operating virtual network functions (VNFs). In addition, the VNF manager should provide other functions to guarantee high availability of network services, such as fault management, monitoring and auto scaling. Currently, many open source projects aim to implement these functions, but there is no standard method of monitoring and detecting failure of VNFs. Therefore, we review current research of High availability and describe what we done for HA in OpenStack environment.

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1. Review of High Availability

1.1. Introduction

For a high availability system, failure detection, isolation and recovery should be automatic and reliable. NFV can provide support for a range of HA mechanisms, such as redundancy, heartbeats, data synchronization, clustering and periodic snapshots or lock-step shadow copies to provide stateful service recovery. The OSS/BSS may already have some level of HA designed into their provisioning of the VNFs and services. In initial stages as operators move NFs to NFV, they may leave these existing mechanisms in place, and use the NFV opaquely for abstraction of resource pool. However, as they design NFV-aware services, they can leverage HA mechanisms offered by NFV. To support HA Mechanism, ETSI also defined HA Definition and OPNFV also implement the part of the HA function in NFV architecture. To check the current status of HA research, we review the document that is related to HA, and review the implementation in OPNFV.
Finally, we explained our result of HA in this document.

1.2. ETSI GS NFV-Reliability

The document ETSI GS NFV REL 3 presents some VNF protection schemes, with which the reliability of NFs is realized. VNF protection schemes investigated include traditional Active-Standby method, Active-Active method and load balancing method with state transfer among VNFs[1][2].

1. **Active-Standby method**

The Active-Standby method is one of the popular redundancy methods adopted in many high availability systems. This configuration is depicted in Figure 1. Note that the Active-Standby method is referred to as one of the 2N redundancy model (N=1) in "Service Availability Forum Application Interface Specification (SA Forum AIS)".

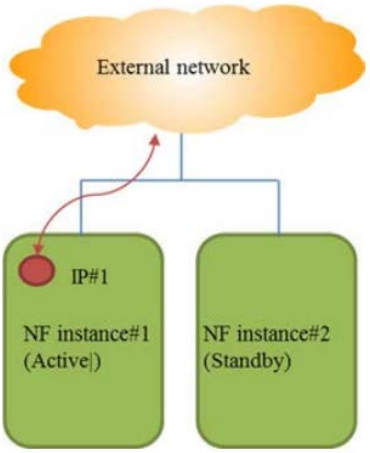


Figure 1 An active-standby configuration of NFs

State protection

Some NFs, such as stateful SIP proxies, use session state information for their operation. In this case, the active NF shares the state information with its standby NF to enable service continuity after a switch-over. The same principle applies for VNF Active-Standby protection schemes. There are two methods to store state information. The state information can be externalized or stored_at/shared_among peer mates. Restoration mechanisms with externalised state data have been described in ETSI GS NFV-REL 001. Hence, this clause focuses on the latter case where state information is stored at peer mates. Since shared state information needs to be kept consistent within the system, checkpointing or other methods will be used as described in ETSI GS NFV-REL 002[3].

Recovery and remediation phase

When an active NF instance fails, the standby NF instance takes over the active role so that the availability of the system is maintained. The possible main steps are as follows:

1) Failure detection of the active NF instance.

2) Failover from the former active NF instance to the former standby NF instance. The former standby instance becomes the new active instance.

3) Replacement of the failed NF instance with a new one which becomes the new standby NF instance.

4) Start of the state information replication to the new standby NF instance.

Transparent failover in traditional deployments is enabled by assigning one logical IP address that the clients use to communicate with the system. In addition, each instance has its own fixed IP address used for designating each NF instance distinctively. During normal operation, the active NF instance serves the logical IP address. If the active NF instance fails and the failure is detected, the former standby NF instance will become active, and starts serving packets destined to the logical IP address. Hence, the system can continue providing the service.

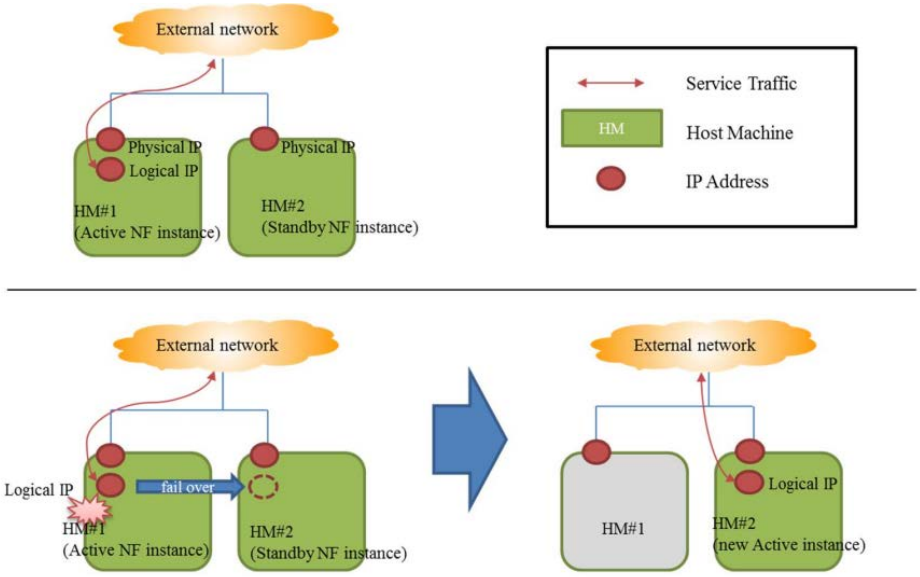


Figure 2 An example of the Active-Standby method in traditional environments

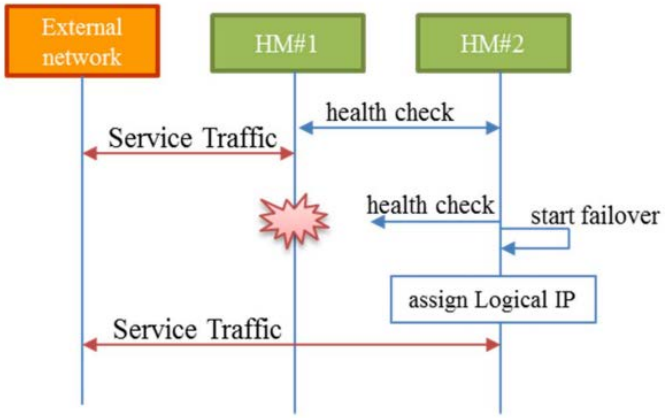


Figure 3 Failover flow for a traditional system with the Active-Standby method

In NFV deployments, the active VNF and clients on the external network are typically connected via NFVI (network infrastructure domain). This makes failover mechanism of virtualised systems different from that of the traditional ones. Since the interconnection between the active VNF and the next NF in the service chain is managed by NFV-MANO, NFV-MANO's availability influences the availability of the NS

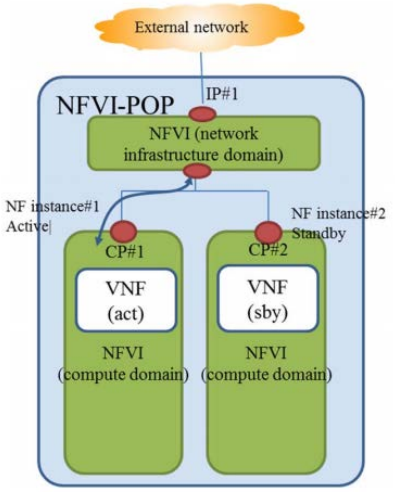


Figure 4 A typical Active-Standby configuration of VNFs in the NFV architecture

In this configuration, the assumption is that the active VNF and the standby VNF are deployed in a location-disjoint mode. For this, NFV-MANO need to support anti-affinity rules for deploying VNFs so that each VNF instance is installed on a different compute domain. Each VNF instance has an internal connection point (CP), with an associated IP address. The two internal connection points are aggregated to a single connection point that is visible to systems on the external network. For example, a virtual router connects the IP address assigned to the external CP with the internal CP of the active VNF. Thereby, the active VNF can communicate with clients on the external network and can provide services. Like in traditional systems with Active-Standby protection, the standby VNF periodically checks the operational status of the active VNF, e.g. using a heartbeat mechanism, which enables failure detection of the active system within the required time for the service. Though NFV-MANO may also perform health check of the VNFs, it increases dependency on NFV-MANO to propagate information concerning the failure of an active VNF to the standby VNF via NFV-MANO. In case the active VNF fails, the standby VNF will initiate the fail-over procedure. It is realised by reassigning the external CP to the internal CP of the former standby VNF.

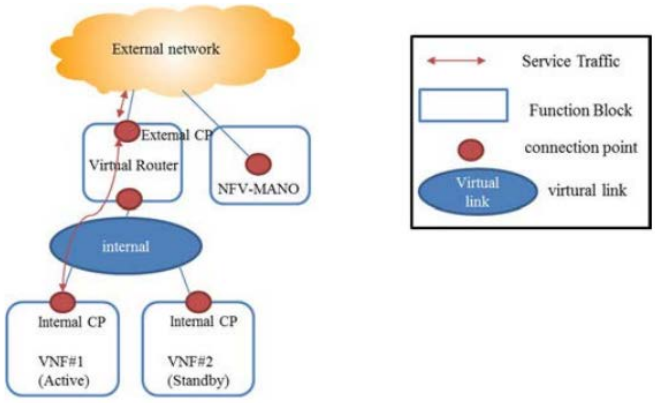


Figure 5 Active-Standby method in the virtualised environment

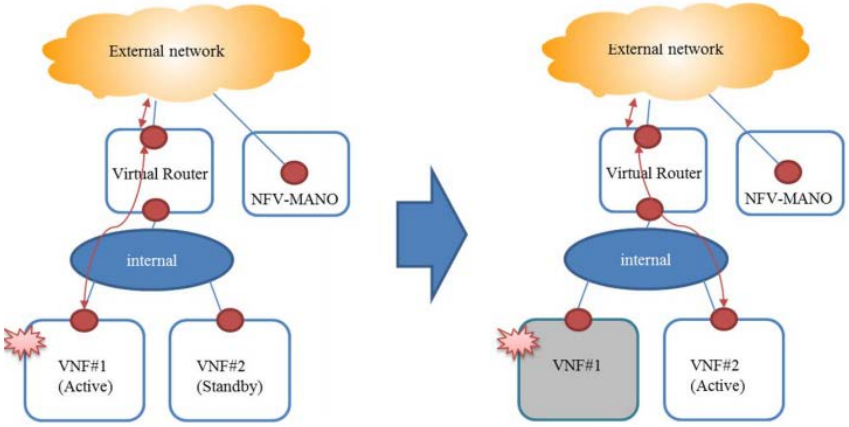


Figure 6 Active-Standby failover in the virtualised environment

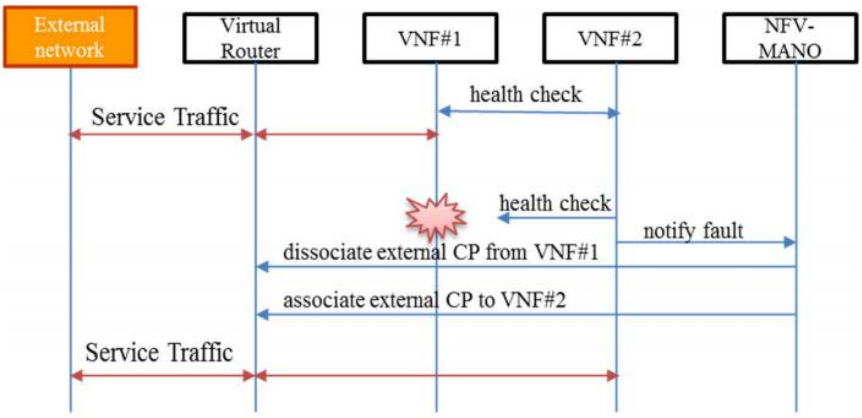


Figure 7 A failover procedure of VNFs in the Active-Standby configuration

In NFV environments, the mapping of the external CP to the internal CP is configured on the virtual router. This mapping cannot be reconfigured without NFV-MANO. Therefore, NFV-MANO should be informed about the failure of the active VNF, and associate the external CP with the internal CP of the former standby VNF instance. Moreover, it is also expected that NFV-MANO instantiates a new standby VNF. Note that the time required for changing the CP mapping affects the availability of the system, since the service is unavailable before reconfiguration, and that the time needed for instantiating a new standby VNF is related to the remediation period's duration. In addition to reconfiguring the CP mapping of the system, further consideration to keep the system's state information consistent is required. Figure 8 shows VNFs configured with the Active-Standby method with state replication between VNFs. The active VNF stores session state information in a storage within itself, and replicates the information to the storage within the standby VNF. Figure 9 shows the restoration procedure for this setup. Since the new active VNF has to check the consistency of the backup state information to judge whether the service can be continued before receiving the subsequent service traffic flow, the route change request sent to NFV-MANO should be triggered by the new active (i.e. the former standby) VNF. For the remainder of this clause, only Active-Standby configurations with state synchronization are described since they are a superset of those configurations without state synchronization.

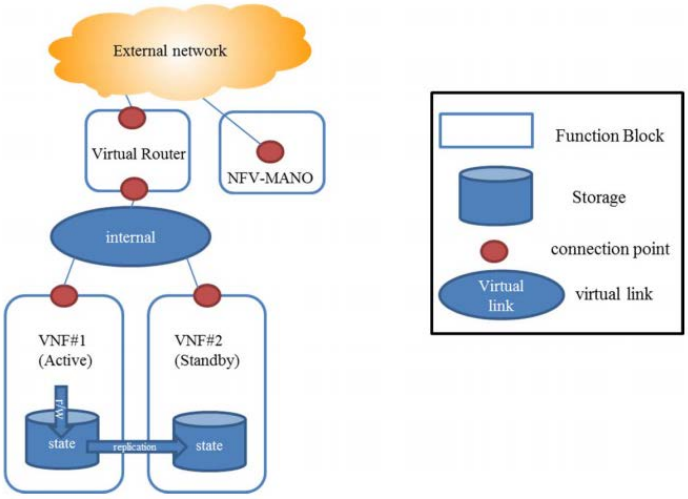


Figure 8 Stateful VNFs with internal storage for states in the Active-Standby configuration

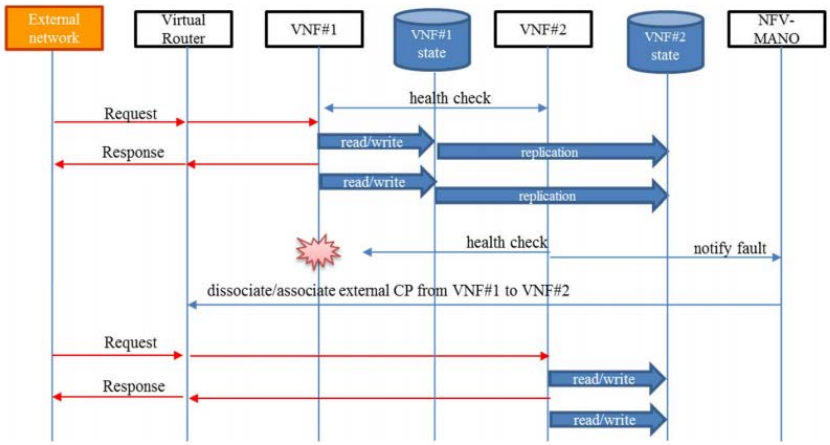


Figure 9 A failover procedure of VNFs synchronizing state information in the Active-Standby configuration

2. Active-Active method

The Active-Active method is a configuration where two NF instances are simultaneously active for the same service (Figure 10). The external network can receive the service by accessing either IP addresses of these NF instances. This configuration is referred to as an Active-Active redundancy configuration (N-way active redundancy model N=2) in the SA Forum AIS document.

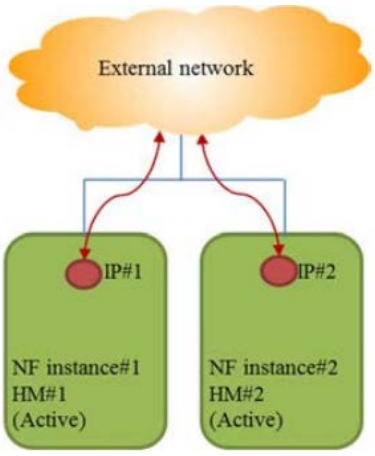


Figure 10 An Active-Active configuration of NFs

State protection

This configuration does not contain a standby system. Therefore, externalisation should be used to maintain the state information for service continuity in case of system failure. The same principle applies for VNF Active-Active protection schemes, and external storages provided by NFVI may be used for the state protection.

Recovery and remediation phase

Figure 11 depicts a configuration change when NF instance#1 fails in a traditional system. External NFs can receive services from NF instance #2 when no answer is received from the NF instance #1, by changing the destination of requests for the NF from IP#1 to IP#2, which is usually done by the DNS in which the NFs are assigned to a primary NF and to a secondary NF. Note that when a load balancer is placed in front of the NF instances, external NFs can get services without knowing the failure of NF instance#1, since the load balancer can deliver all the requests to the NF instance #2 when the NF instance #1 fails

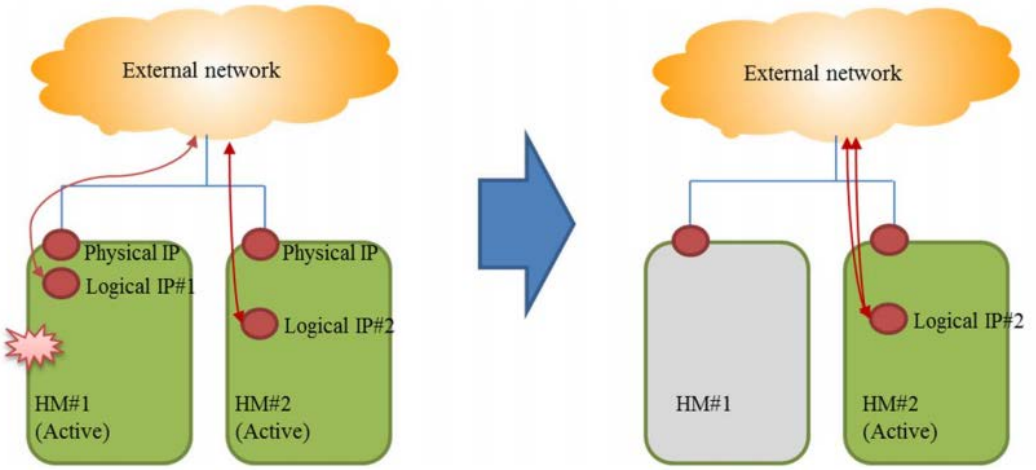


Figure 11 An example of remediation mechanism with Active-Active method in traditional physical environments

In NFV deployment, the active VNF and clients on the external network are connected via NFVI (network infrastructure domain) instead of using a logical IP address assigned to a virtual machine where the VNF is deployed. In this case, two VNFs are deployed on different compute domains according to anti-affinity rules. Two external CPs are assigned to the virtual router in a network infrastructure domain. Each external CP is connected respectively to an internal CP

of each VNF. Figure 12 shows an example of Active-Active configuration in NFV environments. In this figure, NFV-MANO does not have to reconfigure the mapping of external CP and internal CP, since the clients in the external network change the destination of the request message so as to be able to get services from the VNF instance #2

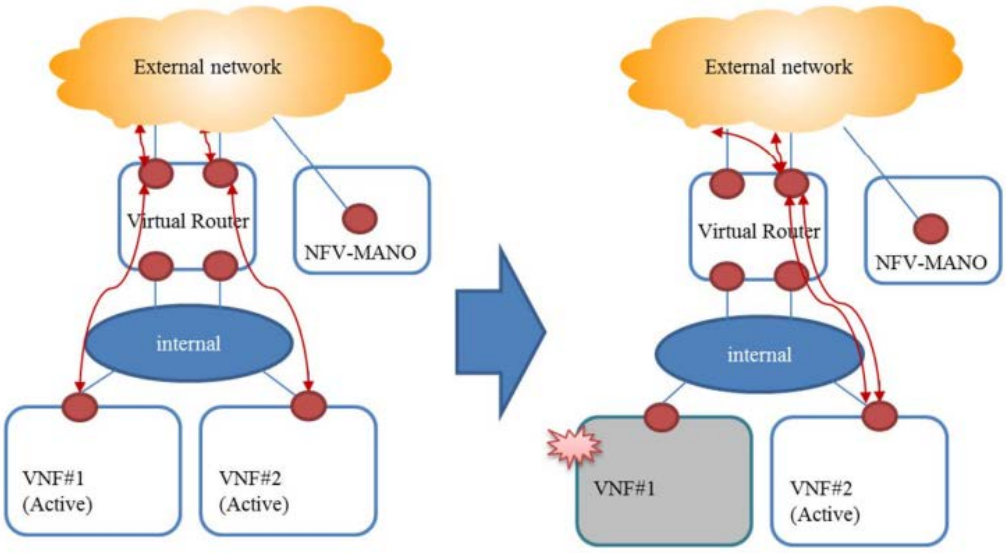


Figure 12 An example of Active-Active method in the NFV environment

3. Load balancing Method

Load balancing is a popular method used for Web servers. In cloud environments, a load balancer is deployed in front of several VNFs. The service traffic goes through the load balancer and is distributed to several VNFs that handle the whole traffic (Figure 13). A load balancing method that corresponds to the N-way redundancy model of the SA Forum AIS document is investigated in this clause.

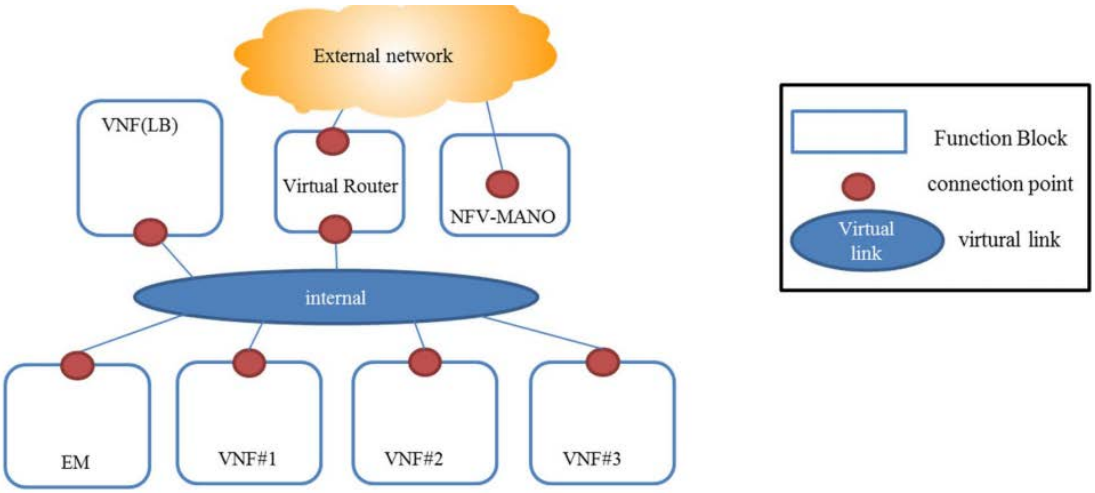


Figure 13 A load balancing model in virtualised environments

State protection

When a VNF is stateful, e.g. SIP proxies, there are two methods to store state information. One method is to externalize the state information. The other is to share the state information among peer mates, which means that the state information of the service instances within VNFs have their standby information in other VNFs as shown in Figure 14. In this figure, the state information of the service instances running on VNF#1 is replicated in VNF#2 as a backup. Similarly, the one of service instances on VNF#2 (resp. #3) is replicated on VNF#3 (resp. #1)

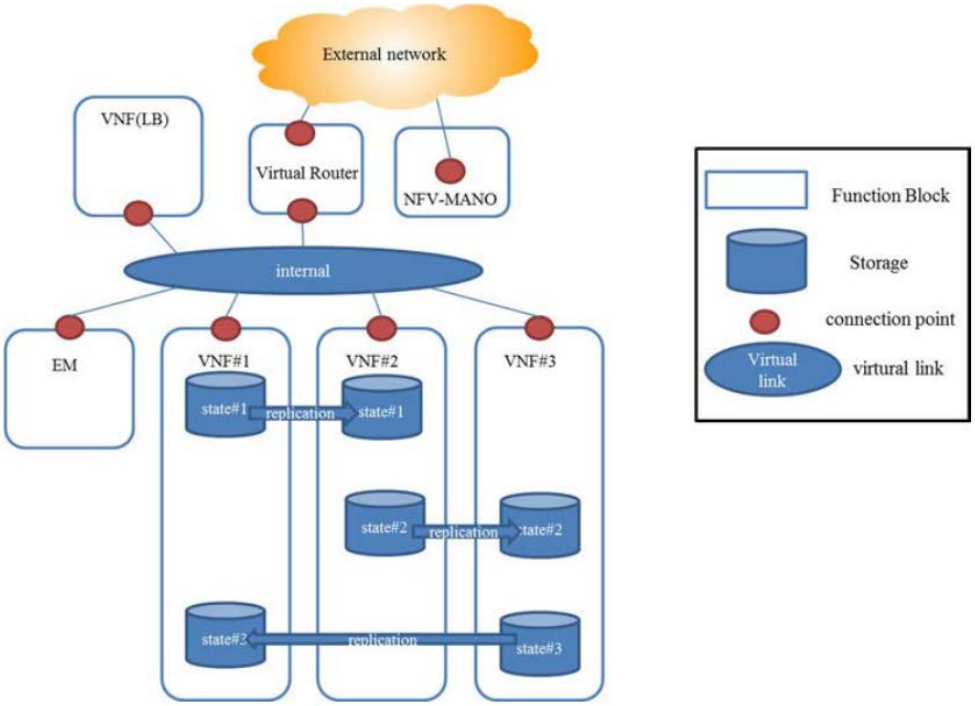


Figure 14 Load balancing model with internal storage

Restoration mechanisms with externalized state data have been described in ETSI GS NFV-REL 001. Hence, this clause mainly focuses on the latter case where state information is stored at peer mates. Since shared state information is to be kept consistent within the system, checkpointing or other methods will be used as described in ETSI GS NFV-REL 002.

Remediation and recovery phases

As an assumption, a load balancer periodically checks the operational status of VNFs to which service traffic is delivered to avoid delivering traffic to the failed VNF. When the load balancer detects the failure of a VNF, it stops providing traffic to the failed VNF and delivers it to other VNFs so that service continuity is maintained (Figure 15). When VNFs are stateful, the traffic to the failed VNF has to be delivered to the VNF that stores the state information of the failed service instances as a backup. The standby service instances of the VNF continue the service with the backup information. In some cases, the standby service instances recognize the failure of the corresponding active service instances so as to take over the ongoing services. A possible way to do this is that VNFs check one another, so that the standby service instances within the VNF are aware of the failure of their corresponding active service instances. Since

the external CP that is visible to clients on the external network is only assigned to the virtual load balancer, NFV-MANO does not have to explicitly change the configuration between the load balancer and VNFs for remediation. For recovery, NFV-MANO should deploy a new VNF that compensates the performance and the availability lost due to the failure.

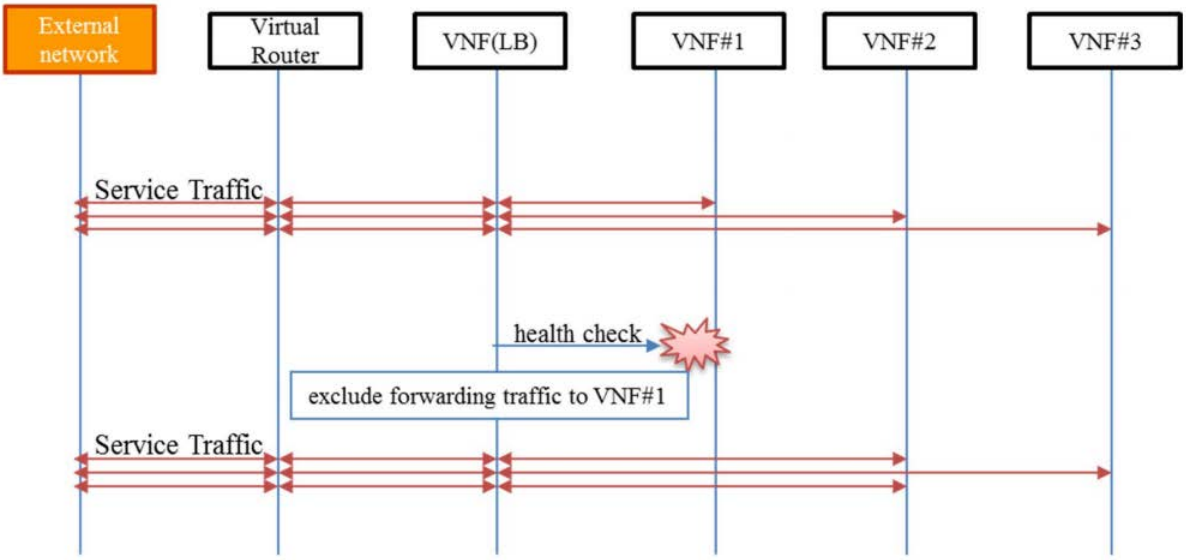


Figure 15 A sample procedure that will occur when a VNF with the service application fails

Note that a virtual load balancer should also be redundant, e.g. Active-Standby, to avoid single point of failure. For Active-Standby virtual load balancers, the same requirements for NFV-MANO as those derived from the investigation of the Active-Standby method.

1.3. Monitoring Mechanism for HA

1.3.1. Fault Management Mechanism

To support High Availability in the NFV environment is more complicated since VNF is composed of hardware level and application level. When fault occurs at NFVI level, VNF also affected by fault of NFVI. For example, when NFVI have some problem such as network, resource sufficient, VNF which belongs to that NFVI also affected by that fault. While, when VNF have some error, if maintenance system doesn't have monitoring algorithm, administrator

doesn't know the fault at the application level. Therefore, both monitoring algorithms are important to support high availability.

1.3.2. Doctor

The goal of Doctor project is to build an NFVI fault management and maintenance framework supporting high availability of the Network Services on top of the virtualized infrastructure. The key feature is immediate notification of unavailability of virtualized resources from VIM, to support failure recovery, or failure avoidance of VNFs running on them. [4]

1.3.2.1. Doctor architecture

As shown in Figure 16, the DOCTOR project defined a function block for status management in VIM such as an Inspector for determining defects with received monitoring information, a controller for managing mapping tables for physical resources and virtual resources, and a Notifier for generating events Respectively. Those function could detect NFVI errors and recover from VNF affected by errors.

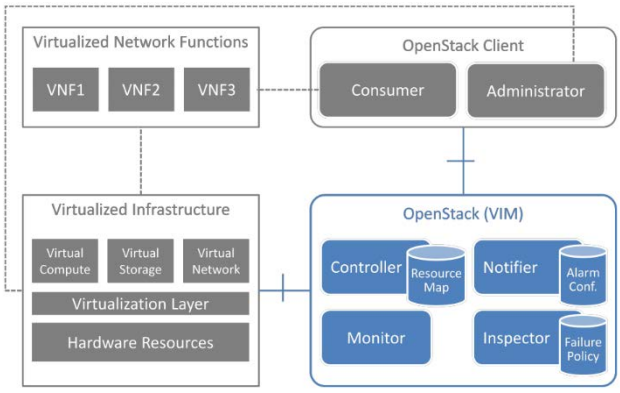


Figure 16 Doctor Project Component

Like a Figure 17, when a failure occurs, the following procedure will initiate a failover to provide high availability.

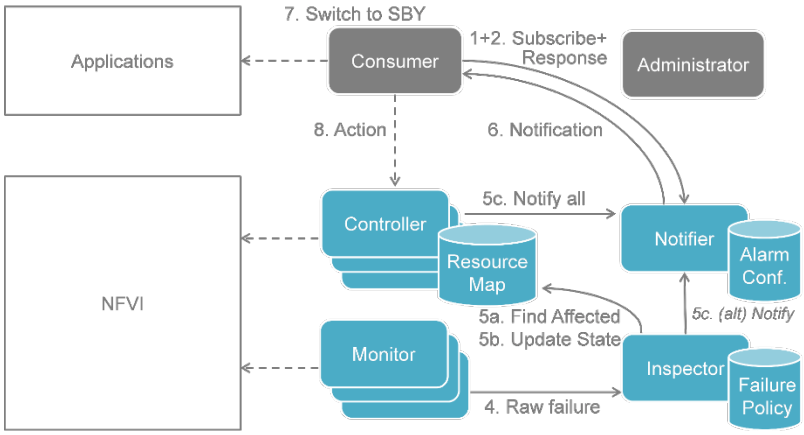


Figure 17 Fault Management Procedure for HA

First, the notification about the failure is registered in the Notifier. Then the Monitor continuously checks the status to see a failure has occurred. When failure occurs, the Monitor passes the fault information to the Inspector, which in turn determines what resource should be changed. According to result, the information is transmitted to the consumer through the Controller and the Notifier and a failure recovery process is performed to support high availability.

1.3.3. Monitoring tool

To support the monitoring framework in the software architecture for the NFV, several solutions have developed such as Zabbix, Nagios, Ceilometer. Nagios is a system and network monitoring project. Zabbix is the most well-known monitoring tool that monitors and tracks numerous kinds of network services, servers, etc. It also could notify the failure quickly since it used agent which is install inside the VNF [5]. In addition, Zabbix also provides APIs in the open source version, and Zabbix has a high performance and ease of development. Ceilometer is a telemeter service which provides resource usage and performance monitoring in the cloud infrastructures [6]. Moreover, it also can further enhance stability in cloud infrastructure environments where VNF is operating.

Table 1 Comparison of monitoring tools

Monitoring Tool	Plugins	Triger/Alerts	WebApp	Service Monitoring	API
Zabbix	Yes	Yes	Full Control	Yes	Yes
Nagios	Yes	Yes	Viewing	Yes	Yes Or Via Plugin
Ceilometer	No	Yes	Full Control	No	Yes

As a Table1, Zabbix has an advantage to integrate with other function since it supports plugin and API. Moreover, it also supports GUI to check the status. While, Ceilometer doesn't support plugin and it doesn't support application monitoring mechanism. However, ceilometer could provide monitoring mechanism without agent.

2. High availability in Tacker VNF Manager

2.1 Problem description

In Telco environment, the reliability of network service (NS) is highly required. Beside auto-healing and auto-scaling solutions, traditional redundancy configuration methods, such as Active-Active or Active-Standby (form a high availability cluster) could be applied to VNFs to ensure the reliability of the NS. These high availability cluster configurations enable fast recovery of VNFs operation in case of failure. Operators will need a way to deploy and manage such kind of high availability clusters via NFVO component. Refer to ETSI-REL [1] for VNF protection schemes in NFV system. it challenges of high availability cluster deployment involve several requirements that need to be handled by the NFV component as described as below:

* Resource usage information of each VIM and availability zone for optimal cluster member placement

* NFVO should find optimal locations for cluster members (based on predefined policies or dynamic network condition and resource usage status)

* Load balancing strategies and monitoring strategies (heartbeat between cluster members or from NFVO) Currently, in Tacker [7], there is no feature to create and manage such kind of high availability clusters. With this proposal, we intend to allow Tacker users to create and manage such kind of high availability clusters [8]. This function enables Tacker to deploy a cluster of Active and Standby VNFs based on predefined operator polices. These high availability policies includes VNF placement locations (i.e. availability zones, VIMs), load balancer configuration. On the other hand, we also define a new **recovery** actions which are going to be triggered when failure occurs from cluster members.

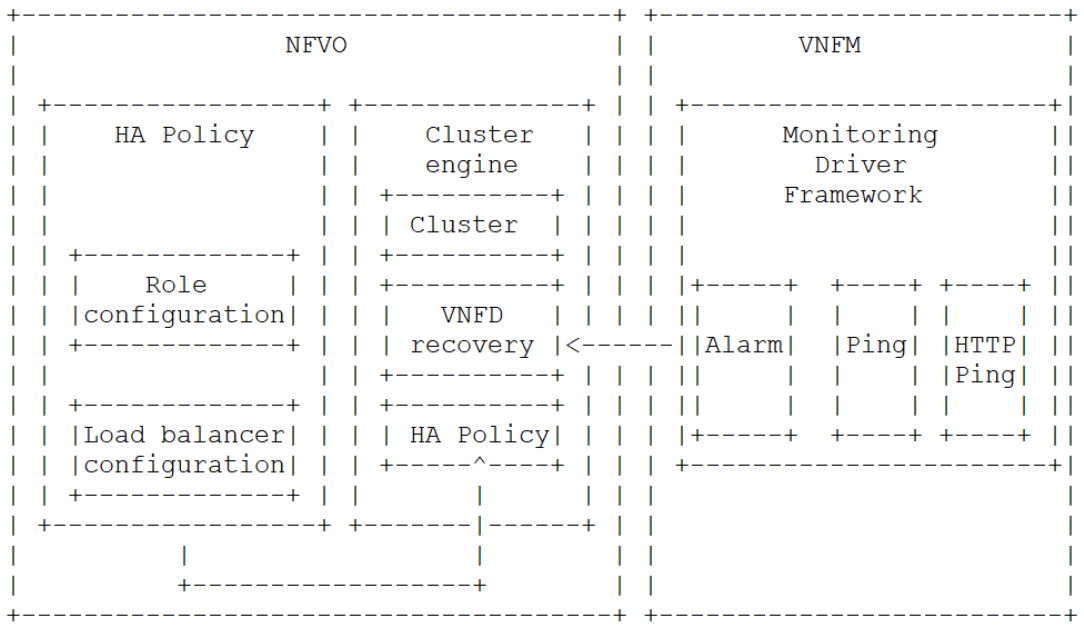


Figure 18 Architecture for HA in Tacker

2.2 Architecture

The high level changes needed to Tacker aim at accommodating a new feature in VNF cluster management will include changes to Tacker Client and Tacker Server. The changes include:

* Adding a cluster REST APIs to Tacker Client which a client can use to CRUD cluster via command line interface. The client can use the REST APIs to deploy VNF cluster from VNFD (from existing VNF will be supported in future). The created cluster should include: (1) The created VNFs that are added to cluster as cluster members, these VNFs must be deployed from the same VNFD, (2) The Neutron load balancer that connects to cluster members aiming at load balancing traffic among cluster members, and (3) the attached deployment policy (Be described in detail as below).

The proposed operations are:

Example of CRUD cluster CLI:

.. code-block:: console

tacker cluster-create

tacker cluster-show

tacker cluster-list

tacker cluster-delete

Example of CRUD cluster-member CLI:

.. code-block:: console

tacker cluster-member-add

tacker cluster-member-show

tacker cluster-member-list

tacker cluster-member-delete

* In order to make cluster creation become more flexible, **--policy-file** argument is added in cluster-related command, Tacker Client changes will read the policy-file and pass the deployment configuration to Tacker Server via REST API. The policy should include a role configuration, placement strategies attached members, and the load balancer configuration.

* Tacker Server will also need to modify the NFVO extensions and NFVO plugin in order to incorporate VNF cluster related operations and resources.

* The drivers for cluster will need to be written in order to handle both of cluster CRUD operations.

Note that this spec is supposed to only provide cluster management in single site, multi-site scenario will be considered in the future.

Because the policy needs to be defined and attached to a cluster, the policyfile needs to be created first, then it will be passed to cluster creation command as an argument via --policy-file. A typical policy template file is be shown as below:

```
.. code-block:: yaml

        properties:

          role:

            active:

              VIM0: 1

            standby:

              VIM0: 1

          load_balancer:

            pool:

              protocol: HTTP
```

```
            protocol_port: 80
            subnet: subnet_mgmt
            lb_method: ROUND_ROBIN
        vip:
            subnet: subnet_mgmt
            protocol: HTTP
            protocol_port: 80
        target: CP1
```

The policy contains **role** and **load_balancer** attributes. The **role** attribute indicates which VIM the VNF should deploy on and which member roles (Active or Standby) will be taken by VNFs. Note that deployment of cluster over multi-VIMs is outside of the scope in this spec, but it might be extended to support multi-VIMs cluster deployment later. The **load_balancer** attribute contains configured parameters that will be used to invoke Neutron Client for deploying a Neutron load balancer. Because the VNF is treated as a cluster member - a basic unit in cluster, in order to deploy the cluster the VNFD template need to be created by the client first. There is no extension of the VNFD compared to the original one. However, in order to archive HA feature for deployed cluster, a new active whose name is **recovery** need to be defined and declared in VNFD as an triggred action in the case of failure. A sample of VNFD with **recovery** action can be seen in the following block:

```
.. code-block:: yaml
    tosca_definitions_version: tosca_simple_profile_for_nfv_1_0_0
    description: Demo example for VNF cluster
    metadata:
      template_name: sample-tosca-vnfd-cluster
```

```
topology_template:
  node_templates:
    VDU1:
      type: tosca.nodes.nfv.VDU.Tacker
      capabilities:
        nfv_compute:
          properties:
            num_cpus: 1
            mem_size: 256 MB
            disk_size: 1 GB
      properties:
        image: cirros-0.3.5-x86_64-disk
        availability_zone: nova
        mgmt_driver: noop
        monitoring_policy:
          name: ping
          parameters:
            monitoring_delay: 45
            count: 3
            interval: 1
            timeout: 2
```

```
            actions:
              failure: recovery
        config: |
          param0: key1
          param1: key2
  CP1:
    type: tosca.nodes.nfv.CP.Tacker
    properties:
      management: true
      order: 0
      anti_spoofing_protection: true
    requirements:
      - virtualLink:
          node: VL1
      - virtualBinding:
          node: VDU1
  VL1:
    type: tosca.nodes.nfv.VL
    properties:
      network_name: net_mgmt
      vendor: Tacker
```

2.3 Data Model

Data model impact includes the creation of clusters, clustermembers tables

* The clusters table will hold all the relevant attributes of cluster resource, while the attributes of the cluster members that belong to the created cluster are stored in the clustermembers table and has an individual cluster_id attribute which is mapped to the cluster resouces.

* **lb_info** and **role_config** in clusters table will store all of the deployment data that are generated during cluster deployment. These attributes will be queried during recovery sessioninclude since the Neutron load balancer and cluster nodes information are included.

Table 2: Cluster table

id	string (UUID)	RO, All	generated	N/A	identity
tenant_id	String (UUID)	RW, All	None, (Required)	uuid	tenant ID to launch vnf-cluster
name	string	RW, All	None, (Required)	string	human-readable name
description	string	RW, All	None	string	description of cluster
status	string	RO, All	generated	string	Status of created cluster
vnfd_id	string (UUID)	RO, All	None (Required)	uuid	VNFD ID to use to deploy cluster members
lb_info	string	RO, All	None, (Required)	string	attributes of created load balancer
role_config	string	RO, All	None, (Required)	string	role configuration of cluster members

Table 3: Cluster member table

id	string (UUID)	RO, All	generated	N/A	identity
tenant_id	String (UUID)	RW, All	None, (Required)	uuid	tenant ID to launch cluster member
name	string	RW, All	None, (Required)	string	human-readable name
cluster_id	string (UUID)	RO, All	generated	uuid	ID of associated cluster
vnf_id	string (UUID)	RO, All	generated	uuid	ID of associated vnf
mgmt_url	string	RO, All	generated	string	Management URL of associated vnf
role	string	RW, All	generated	String	Role of member in cluster
lb_member_id	string (UUID)	RO, All	generated	uuid	ID of associated Neutron load balancer
placement_attr	string	RW, All	None (Required)	string	VIM name where cluster members are deployed

2.4 Demo results

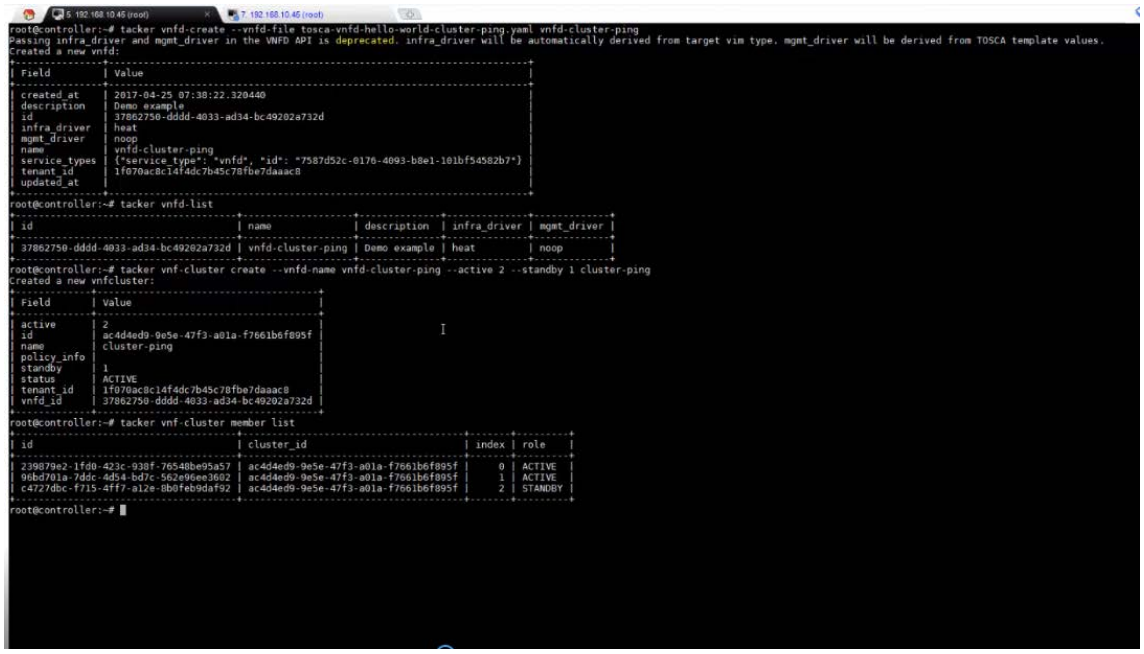


Figure 19 Cluster creation via CLI

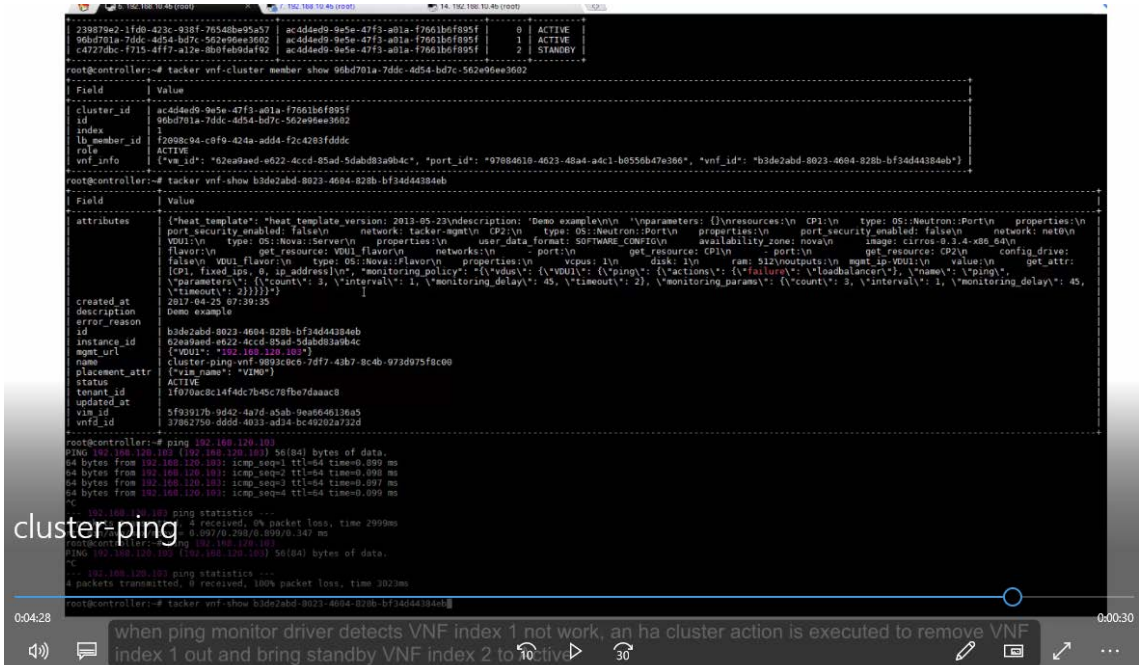


Figure 20 Ping monitor driver detects VNF not working and execute recovery action

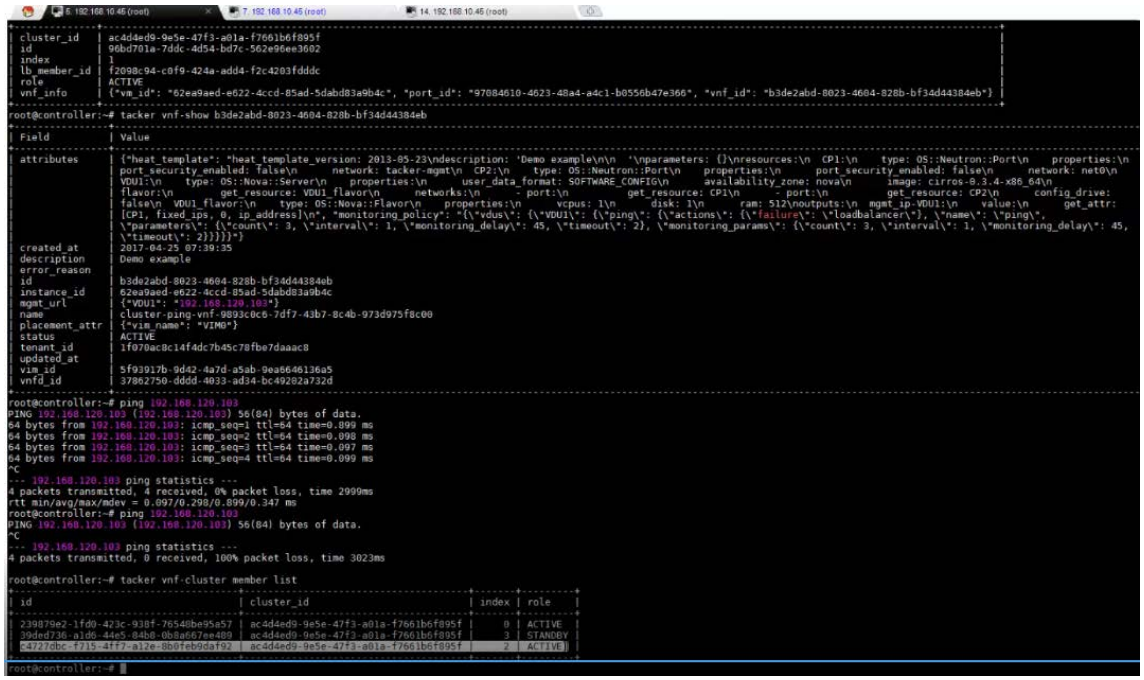


Figure 21 Recover completed

3. Monitoring tool integration in Tacker VNF Manager

3.1. Design and implementation of monitoring tool interworking structure

In order to provide high availability in NFV environment, it is necessary not only to monitor resource usage of VNF and VIM provided by existing MANO but also to monitor services inside VNF through interworking between VNFM constituting MANO and open source monitoring tool do. Open source monitoring tools need to work with VNFM for service management inside VNF. To do this, you must configure a driver for API interoperation between the open source monitoring tool and the VNFM, and make the Rest API request to open source monitoring. Each VNF created by VNFM must have an agent provided by an open source monitoring tool. This is because open source monitoring tools have difficulty to access VNF internally. Therefore, it collects status data about services through agents installed inside VNF and identifies the statuses of services. Open source monitoring tools should be integrated with VNFM by selecting an open source monitoring tool suitable for the infrastructure.

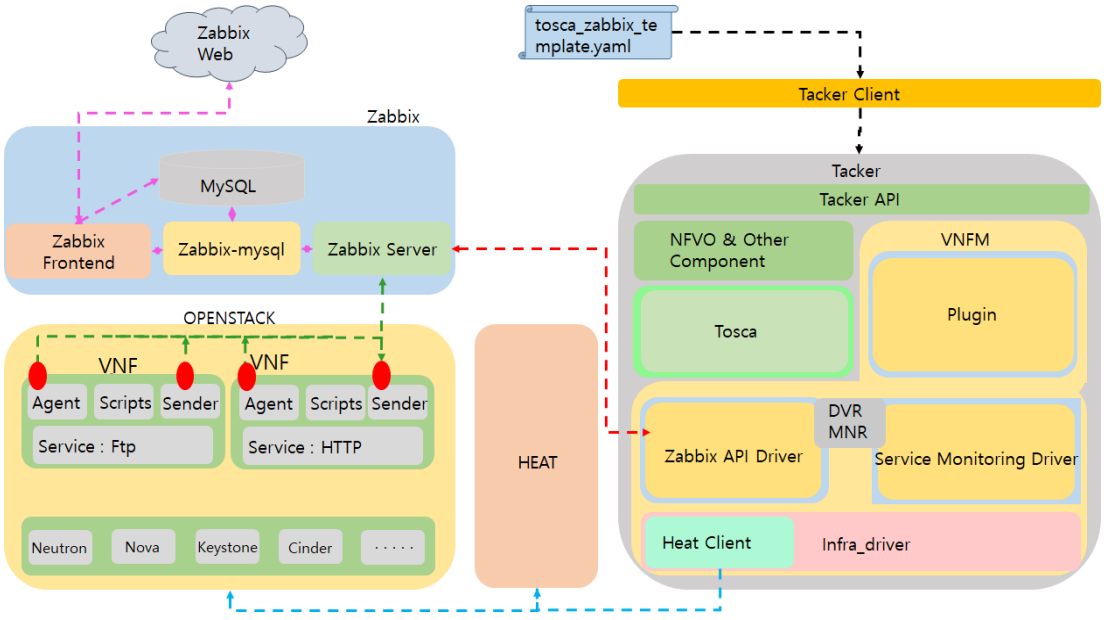


Figure 22 Interworking between and Open source monitoring tool in NFV environment

Figure 22 shows the overall design of open source monitoring tools and VNFM in a cloud NFV environment. Tacker provides VNFM, Zabbix is a monitoring server, and Openstack provides cloud infrastructure. Based on the information defined in the Tacker Template, the Zabbix Api Driver asks the Zabbix server for the API to generate templates, triggers, actions, and items. We also implemented a service monitoring driver to add plugins for additional open source monitoring tools.

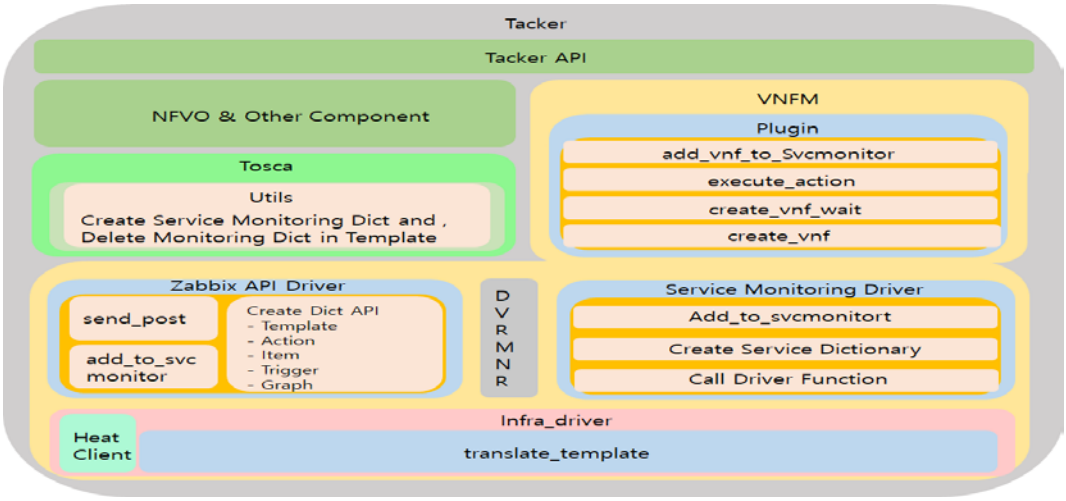


Figure 23 VNFM monitoring driver design structure

Figure 23 shows the driver structure for interworking between VNFM and Monitoring Tool. Send_post is a component for requesting an API to the Zabbix server. All driver functionality is requested from the server via Send_post. add_to_svc_monitor is a component for the service monitoring driver to call the Zabbix API driver. Dict API creation creates and requests dictionaries for each request in the Zabbux API format. Service monitoring driver is a driver that manages all open source monitoring tools and invokes the corresponding monitoring driver according to the monitoring name defined in the template. Service dictionary creation extracts only the service monitoring policy from the delivered template information, creates it in advance, and passes it through the Zabbix API. The plug-in determines if the template has a service monitoring policy and performs certain functions defined in the template.

This article uses the project shown in Figure 24 to monitor the services inside VNF. OpenStack is used by VIM to monitor services inside VNF. Openstack Tacker is used as VNFM and Zabbix is easy to develop, implemented and tested with monitoring tools. In a physical environment,

three mini-PCs were used to configure the controller, calculation, and monitor nodes, respectively.

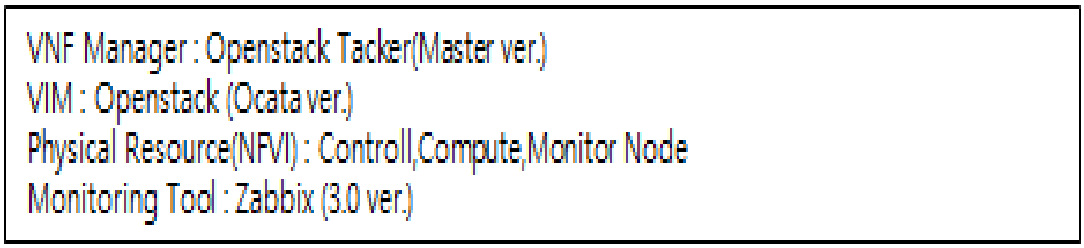


Figure 24 NFV environment configuration component

In this implementation, the policy for service monitoring is defined in the TOSCA Template and the user specifies the condition value of the desired trigger.

```
app_monitoring_policy:
  name: zabbix
  zabbix_username: Admin
  zabbix_password: zabbix
  zabbix_server_ip: 192.168.11.53
  zabbix_server_port: 80
  parameters:
    application:
      app_name: apache2
      app_port: 80
      ssh_username: ubuntu
      ssh_password: ubuntu
      app_status:
        condition: [down]
        actionname: cmd
        cmd-action: sudo service apache2 restart
      app_memory:
        condition: [greater,22]
        actionname: cmd
        cmd-action: sudo service apache2 stop
    OS:
      os_agent_info:
        condition: [down]
        actionname: cmd
        cmd-action: sudo service zabbix-agent restart
      os_proc_value:
        condition: [and less,22]
        actionname: cmd
        cmd-action: sudo reboot
      os_cpu_load:
        condition: [and greater,30]
        actionname: cmd
        cmd-action: sudo reboot
      os_cpu_usage:
        condition: [less,30]
        actionname: cmd
        cmd-action: sudo reboot
```

Figure 25 Zabbix VNFD Tosca Template

Figure 25 shows the Tosca template with the VNFD used by Tacker to create the VNF. Users

can configure various settings related to application monitoring in their VNFDs. Policies are largely divided into applications and operating systems. For an application, you can specify the type, state, memory, and recovery method of the application. Similarly, for the OS, you can set up multiple policies to monitor the inside of the VNF. When the Tacker generates the VNF, the monitoring driver sends the information to Zabbix.

In addition, scripts for automatic agent installation and configuration are created in the User_data parameter after the VNF is created, and in the initialization step after the VNF is created. Figure 26 shows the script created with the User_data parameter used in this document. Use the apt-get command to install the Zabbix agent and Apache for service monitoring. The sed statement finds the string in the file and replaces it with the desired value used to configure the zabbix -agentd.conf file and network.

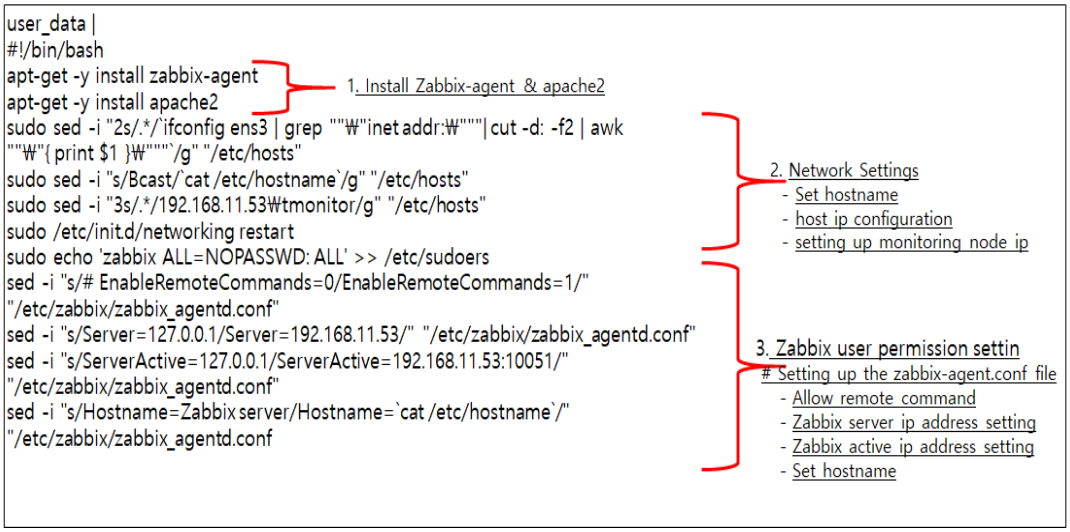


Figure 26 Open source monitoring tool in VNF Agnet Automatically install script

3.2 Verification and analysis

Tacker writes to the Zabbix driver in a pre-form for the API request, converts it to the Json format, and then sends it to the Zabbix server via the Post function. The Zabbix server receives the requested information and performs operations according to the API. Figure 27 shows the API request and response.

```
# API Request

{"params": {"templates": [{"templateid": "10641"}], "host": "vdu2", "interfaces": [{"ip":
"192.168.11.185", "useip": 1, "dns": "", "main": 1, "type": 1, "port": "10050"}], "groups":
[{"groupid": "4"}]}, "jsonrpc": "2.0", "method": "host.create", "auth":
"283be614672bda4d329c3891be3c2670", "id": 4}

# API Response

('[ Response from Zabbix Server] : ', {u'jsonrpc': u'2.0', u'result': {u'hostids': [u'10642']}, u'id': 4})
```

Figure 27 API Request & Response

Tacker asks the Zabbix server to register the VNF information through an API that contains information about the VNF. The Zabbix server starts monitoring and operates according to each procedure. The VNFD to which the service monitoring policy applies is loaded from the database when the VNF is created.

```
[    56.010162] cloud-init[1252]: The following NEW packages will be installed:
[    56.010406] cloud-init[1252]: zabbix-agent
[    57.015316] cloud-init[1252]: 0 upgraded, 1 newly installed, 0 to remove and 12 not upgraded.
[    57.016550] cloud-init[1252]: Need to get 184 kB of archives.
[    57.017581] cloud-init[1252]: After this operation, 798kB of additional disk space will be used.
[    57.018557] cloud-init[1252]: Get:1 http://nova.clouds.archive.Ubuntu.com/ubuntu xenial-
updates/universe amd64 zabbix-agent admd64 1:2.4.7+dfsg-2ubuntu2.1 [184kB]
```

Figure 28 When the VNF generation is initialized, the user-data script log

Figure 28 shows a log of the execution of 'apt-get install zabbix-agent' in the user_data script of the template for which the service monitoring policy is defined, and executes the sed script to configure the Zabbix agent's conf file as the next operation.

Name	Application	Item	Trigger	Graph	Interface	Template	Status	ZBXStatus
VDU1	Application	7	6	4	192.168.11.189:10050	Template Tacker VDU1	Active	Zbx On
VDU2	Application	7	6	4	192.168.11.189:10050	Template Tacker VDU2	Active	Zbx On

Figure 29 Monitoring Information for each VDU

Figure 29 shows two VNFs registered on the Zabbix server. After creating the VNF, Tacker invokes the Zabbix Api driver to request the creation of item, graph, and trigger actions that contain information about the data collection. Then, in order to register the monitoring VNF as a host, the VNF Host Create API is requested by transferring the template ID generated by the Zabbix Api driver in advance. When Zabbix server and Zabbix agent are connected

normally, Zbx lights up in green.

Having a separate template for each VNF is to be able to monitor with different conditions and items. Figure 30 shows that the user created a trigger based on the condition values specified in the template.

Severity	Name ▲	Expression	Status
Average	Template Tacker VDU1: Disk I/O is overloaded on {HOST.NAME}	{vdu1:system.cpu.util[,iowait].avg(1m)}>20	Enabled
Average	Template Tacker VDU1: Process Memory is lacking on {HOST.NAME}	{vdu1:proc.mem[apache2,root].avg(5)}>20	Enabled
Average	Template Tacker VDU1: Processor load is too high on {HOST.NAME}	{vdu1:system.cpu.load[percpu,avg1].avg(1m)}>5	Enabled
Average	Template Tacker VDU1: service is down on {HOST.NAME}	{vdu1:net.tcp.service[http].max(#3)}=0	Enabled
Average	Template Tacker VDU1: Too many processes running on {HOST.NAME}	{vdu1:proc.num[,,run].avg(5s)}>2	Enabled
Average	Template Tacker VDU1: Zabbix agent on {HOST.NAME} is unreachable for 5 minutes	{vdu1:agent.ping.nodata(5m)}=1	Enabled

Figure 30 Trigger list based on condition value

Figure 31 shows the occurrence of a fault according to the data collected through the agent installed in the VNF according to the specified trigger condition. The time of the fault, the type of fault, and the location of the fault. If a failover occurs, the state is marked as resolved.

Severity	Status	Info	Time ▼	Age	Ack	Host	Name	Description
Average	PROBLEM		10/13/2017 11:28:42 AM	13s	No 4604	vdu2	Too many processes running on vdu2	Add
Average	PROBLEM		10/13/2017 11:28:37 AM	18s	No 9	vdu1	Process Memory is lacking on vdu1	Add
Average	OK		10/13/2017 11:28:37 AM	18s	No 8	vdu1	service is down on vdu1	Add
Average	PROBLEM		10/13/2017 11:28:30 AM	25s	No 4254	vdu1	Too many processes running on vdu1	Add
Average	PROBLEM		10/10/2017 10:29:12 PM	2d 12h 59m	No 1	vdu2	service is down on vdu2	Add

Figure 31 Trigger Alarm Check for Fault Occurrence

Figure 32 is a graphical representation of the changes in data collected for services running through agents in the VNF. The Y axis represents the number of data to be collected, and the X axis represents the time. The data collected from the service through the agent at 1-second intervals appears constant, but at the point where the service is stopped, the graph drops sharply and 0 is displayed. After an interval of about 4 seconds, the service is restored to failure and can be seen to show a rising graph.

Figure 32 Data collection changes due to outages

When the operation of the service is stopped, the Zabbix server does not have collected data, so a trigger occurs and an action command for the trigger is executed through the agent. The action generated according to the request is shown in Figure 33.

Figure 33 Custom actions based on tirggers

The Zabbix agent receives the command to execute the command from the server and executes the corresponding command using the Zabbix user generated in advance. These actions are generated for each service and VNF.

In order to check whether the service is actually recovered according to the occurrence of the service failure, the service should be stopped in the VNF. After that, you can stop the service and check the fault detection on Zabbix web. In case of error, red message is displayed when solving red notification. Recovery time after failure occurrence is about 5 seconds, and according to action script execution speed, recovery according to action script execution is performed at the same time when a failure occurs. As a result, the notification of the failure occurs as if the recovery has already been completed. According to the development test, the tacker creates the VNF and registers it as the monitoring host of the Zabbix server. In addition, template, action, item, graph, and trigger were generated through API request and confirmed

the operation. In addition, we confirmed the API request and its response. Figure 34 shows the workflow of the above-mentioned series of processes, from generation of VNF to monitoring, trigger, and action generation.

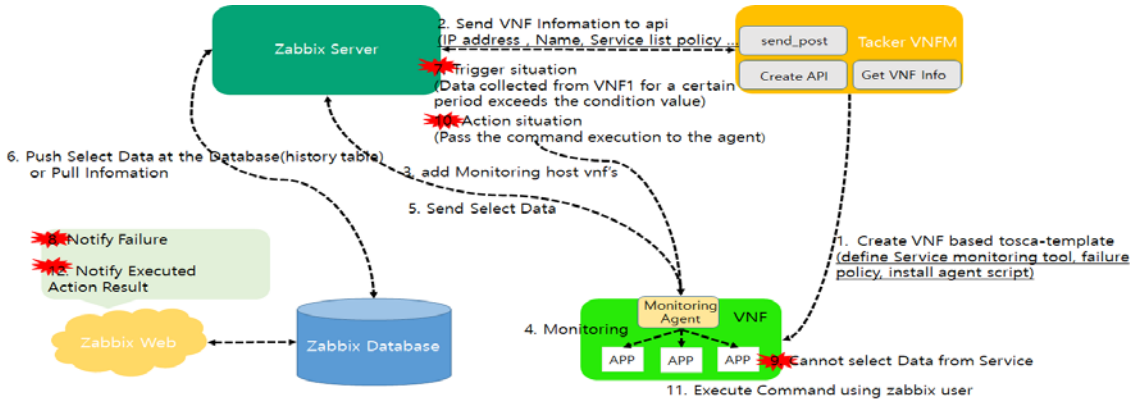


Figure 34 Test Workflow

Through this series of processes, Tacker can operate stable VNF using Zabbix. Zabbix's performance is one of the best monitoring tools for monitoring applications. Common monitoring tools must support the API in order to be able to easily add additional monitoring tools to the plug-in format.

3.3. Conclusion

In this document, we have designed a structure for monitoring services in VNF in conjunction with VNFM and open source monitoring tools, and implemented and tested performance and multi-time measurement experiments. This is important because the stability of the VNFM and cloud infrastructures that provide VNF incrementally is an important technology, so it is important to manage the inside of the VNF to ensure stability. However, additional research is needed to provide additional services based on monitoring results. In future research, we plan to study the high availability structure that can cope with various obstacles based on the currently developed service monitoring.

4. Usecase - high availability for SFC

4.1. Introduction

The high availability for SFC is ensured by the high availability for individual service chain components and the adjustment of service function path. Depending on customer type and traffic type. Mostly, HA feature is provided by redundancy methods for each service chain component such as computing, networking resources and the adjustment of service function path.

In ETSI standard about Network Function Virtualization (NFV), each network service is defined by Virtual Network Functions (which is known as VNFs). Network service is a composition of multiple VNFs and VNF Forwarding graph (it is other name to call Service Function Chaining - SFC).

In our proposal, high availability for SFC will base on adjustment of VNF-FG path. Whenever there are changes in network service such as a VNF went down by lost connectivity or VNFs is scaling out-in due to resource load changes, VNF-FG should update their change automatically to ensure high availability immediately.

This work uses OpenStack projects, such as Networking-sfc, Tacker, Ceilometer, to set up the environment to provide the platform for high availability SFC.

4.2. Networking-SFC

4.2.1. Definition

Networking-sfc is a project on OpenStack, that provide Service Function Chaining feature for network services. Service function chaining routes packets through one or more service functions in the defined order instead of conventional routing that routes packets using destination IP address.

Examples of typical service function include: Firewall, NAT, QoS, and DPI. In the context of Network Function Virtualization, the service function will be a Virtual Network Function, that usually is deployed on Virtual Machines.

Networking-sfc provide Service Function Chaining feature for Compute instances by creating a traffic steering model for service chaining using only ports. Including these ports in a port chain enables steering of traffic through one or more instances providing service functions.

In the detail, Networking-sfc [9] implement the Service Function Chaining feature by defining port chain or service function path (Port chain can be known as SFC in this context):

- A set of ports that define the sequence of service functions.
- A set of flow classifiers that specify the classified traffic flows entering the chain.

4.2.2. Architecture

For implementing SFC in real life, Networking-sfc defined its resources as below:

- Port chain: A port chain consists of a sequence of port pair groups. Each port pair group is a hop in the port chain. A group of port pairs represents service functions providing equivalent functionality. For example, a group of firewall service functions
- Port pair group: A port pair group may contain one or more port pairs which have the same function. This is the main feature to providing high availability for Service Function Chaining.
- Port pair: A port pair represents a service function instance that includes an ingress and egress port. The port pair is created from ports of VM that a Network Function or Virtual Network Function running on.
- Flow classifier: A flow classifier is used as a filter to get on Service Function Chaining in Networking-sfc. Flow classifier includes a combination of the source attributes defines the source of the flow, and destination attributes defines the destination of the flow.

In the Figure 35, Networking-sfc define a OVS driver to communicate with OVS agent of Open vSwitch in Compute and Networking nodes of OpenStack. They model SFC as Port Chain component and other Driver components such as Port pair group, Port pair and Flow classifier. In the bottom, Port chain will be implemented as flow entries in flow table of Open vSwitches.

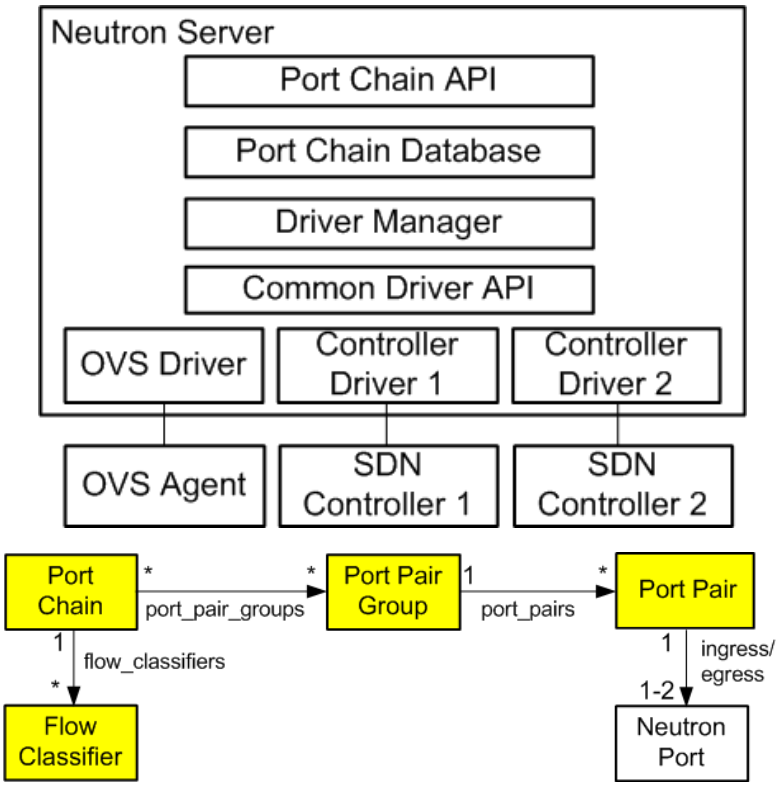
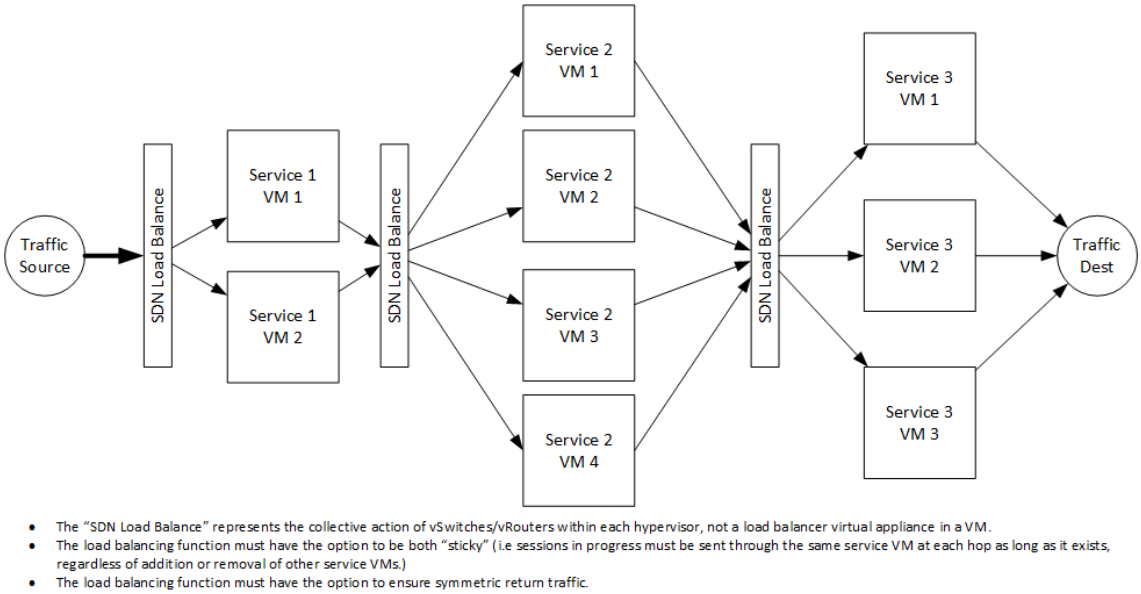


Figure 35 Networking-sfc architecture



- The "SDN Load Balance" represents the collective action of vSwitches/vRouters within each hypervisor, not a load balancer virtual appliance in a VM.
- The load balancing function must have the option to be both "sticky" (i.e sessions in progress must be sent through the same service VM at each hop as long as it exists, regardless of addition or removal of other service VMs.)
- The load balancing function must have the option to ensure symmetric return traffic.

Figure 36 Logical Service Function Chaining in Networking-sfc

Figure 36 shows the logical Port chain of Networking-sfc. A Port pair simply is known as Service 1 that running on VM1, it is defined by ingress and egress port of VM1. A port pair group, for example: it contains VM1 and VM2; both VMs run the same service such as Firewall. Port chain is composed of Service1, Service2 and Service3 in the sequence; and combination of the source and destination attributes.

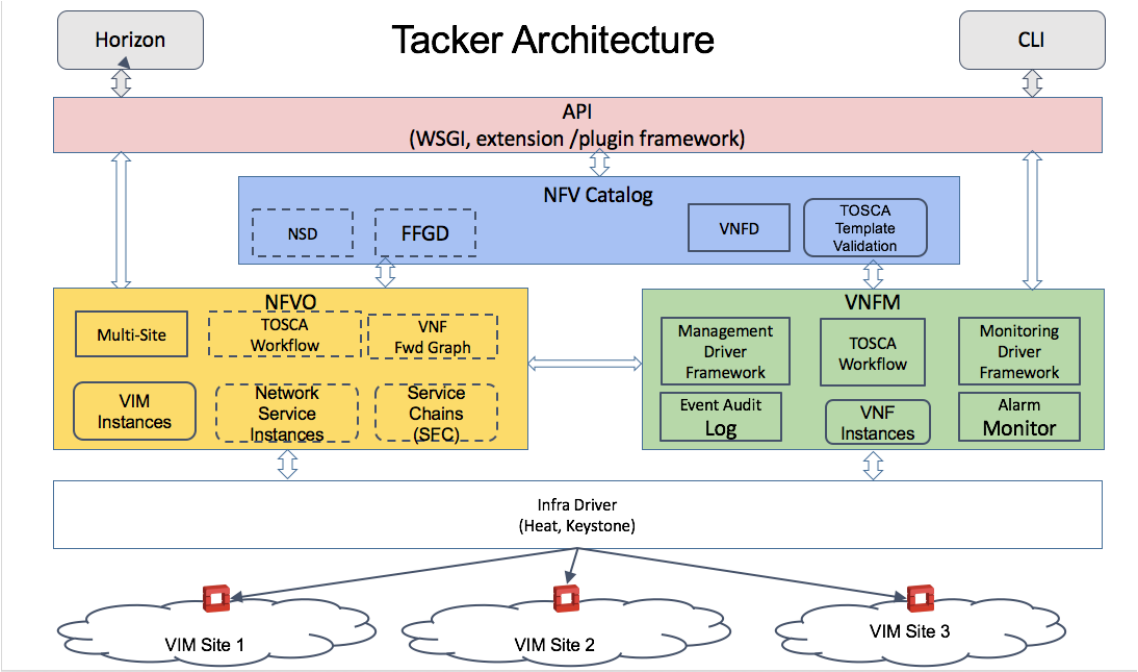


Figure 37 Tacker Architecture

Tacker is an OpenStack based NFV Orchestrator service, that provides VNF manager to deploy and operate Virtual Network Functions (VNFs) and NFV orchestrator to make Service Function Chaining between network services. In Figure 37, Tacker support to create VNF and Network Service (NS) from descriptor such VNFD and NSD respectively. Tacker API will send requests to VNFM plugin to create and apply management and monitor drivers on VNFs. NFVO plugin mostly, has a responsibility for create VNF Forwarding graph (or SFC).

Figure 38 shows applying Service Function Chaining as VNF Forwarding Graph[10] in Tacker. VNFM plugin API receives user requests for creating VNFs, it invokes Heat driver to launch VNFs from VNFD after translating to Heat template. Then, VNFM send VM's information of

VNFs to NFVO plugin API, that includes id of Neutron ingress and egress ports, to create VNF Forwarding Graph. Tacker NFVO API call Networking-sfc driver to create Port Chain from Neutron ports from above steps.

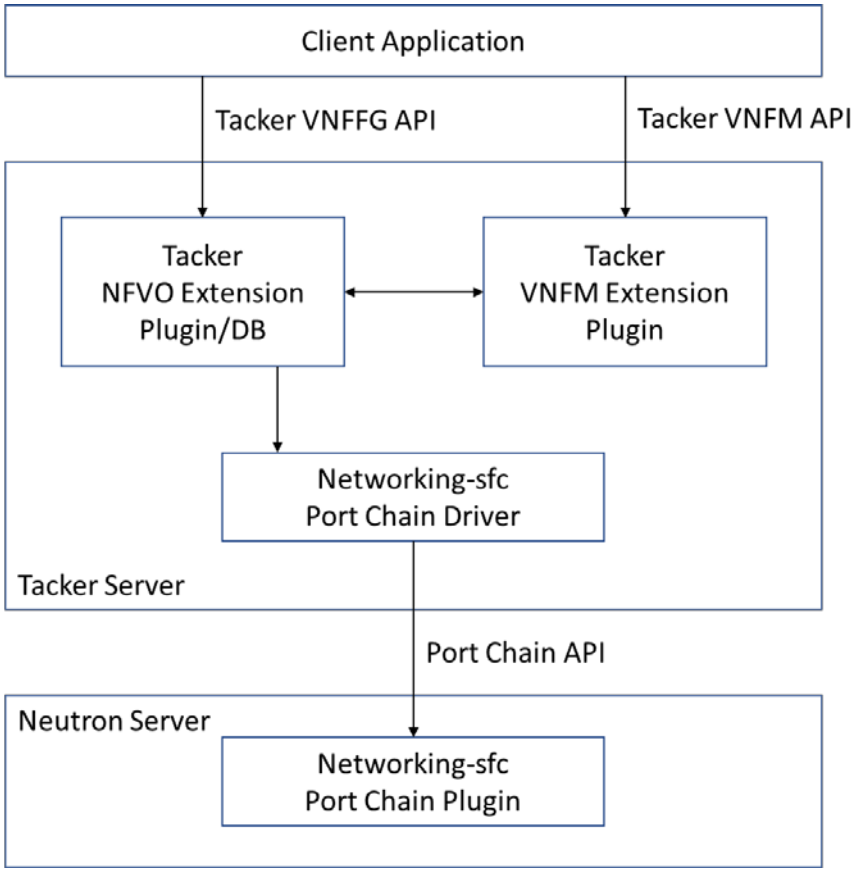


Figure 38 Tacker Extension for SFC

4.2.3. High availability SFC in Tacker

The architecture for high availability SFC is presented in Figure 39. We propose vnffg-ha engine in Tacker NFVO functional block to process policy actions from VNFM.

4.2.4. vnffg-ha engine

Firstly, users must define policy actions, which is imported in VNF descriptor in designing time. VNFM triggers events when there are some things happen to VNF lifecycle, such as VNFs were

downed, lost connectivity, or scaling in-out. The event information is sent to vnffg-ha engine, at here, vnffg-ha will invoke NFVO plugin to update the chain path to new updated Neutron ports due to respawned or scaled VNFs.

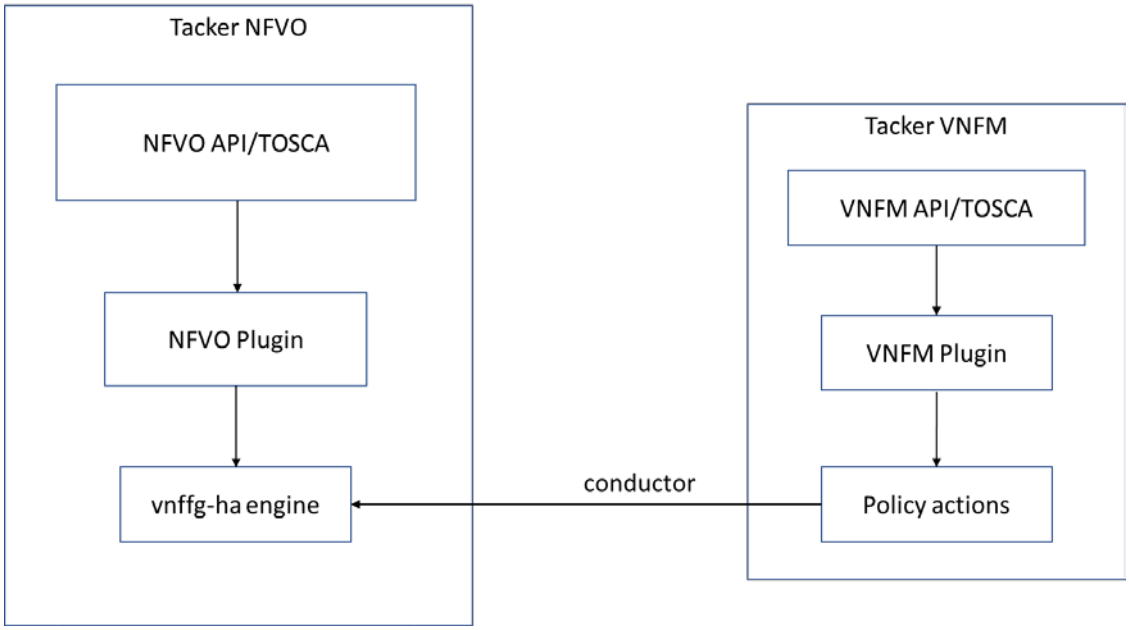


Figure 39 Architecture for VNFFG high availability

4.2.4.1. Scaling

Tacker has already supported scaling function for individual VNFs by using alarm driver. When a VNF was scaled, new neutron port will be added to VNF or removed when scale out/in respectively. Vnffg-ha engine uses networking-sfc client to do this job with the vnffg-update command calls:

Tacker VNFFG-HA engine	Networking-sfc client CLI
vnffg-update/ scale out	neutron port-pair-create --ingress [new neutron port id] --egress [new neutron portid] neutron port-pair-group-update --port-pairs [new list of port pairs]

In scaling out, new port pair will be created from new neutron port, and port pair group update new port pair to its list. When scaling in, the following commands will be called:

Tacker VNFFG-HA engine	Networking-sfc client CLI
vnffg-update/ scale in	neutron port-pair-group-update --port-pairs [new list of port pairs] neutron port-pair-delete [old neutron port id]

There is slightly different, port pair group update its port pair list by removing port pair id of scaled in VMs. After that, delete the old port pair.

VNFD template of the VNF is described as bellow:

```
tosca_definitions_version: tosca_simple_profile_for_nfv_1_0_0
description: Demo example
metadata:
  template_name: sample-tosca-vnfd1
topology_template:
  node_templates:
    VDU1:
      type: tosca.nodes.nfv.VDU.Tacker
      capabilities:
        nfv_compute:
          properties:
            num_cpus: 1
            mem_size: 512 MB
            disk_size: 1 GB
  properties:
    image: cirros-0.3.5-x86_64-disk
    availability_zone: nova
    mgmt_driver: noop
    config: |
      param0: key1
      param1: key2
    metadata: {metering.vnf: VDU1}

CP11:
  type: tosca.nodes.nfv.CP.Tacker
  properties:
```

```
      management: true
      order: 0
      anti_spoofing_protection: false
   requirements:
      - virtualLink:
            node: VL11
      - virtualBinding:
            node: VDU1
VL11:
   type: tosca.nodes.nfv.VL
   properties:
      network_name: net_mgmt
      vendor: Tacker
policies:
- vdu1_cpu_usage_monitoring_policy:
      type: tosca.policies.tacker.Alarming
      triggers:
            vdu_hcpu_usage_respawning:
                  event_type:
                        type: tosca.events.resource.utilization
                        implementation: ceilometer
                  metrics: cpu_util
                  condition:
                        threshold: 50
                        constraint: utilization greater_than 50%
                        period: 600
                        evaluations: 1
                        method: avg
                        comparison_operator: gt
                  metadata: VDU1
                  action: [respawn, notify]
```

In above template, we define alarm policy for scaling function. When the scaling event is triggered, action "notify" will send request to vnffg-ha to update VNFFG.

4.2.4.2. Respawning

Tacker VNFFG-HA engine	Networking-sfc client CLI
vnffg-update/ respawn	neutron port-pair-delete [old neutron port id] neutron port-pair-create --ingress [new neutron port id] --egress [new neutron port id] neutron port-pair-group-update --port-pairs [new list of port pairs]

When a VNF is respawned, neutron VM port id will be assigned to that VNF. Tacker will delete the old port pair then create new port pair from the change in neutron port. After that, Tacker calls port pair group update command to update the list of new port pairs.

```
tosca_definitions_version: tosca_simple_profile_for_nfv_1_0_0
description: Demo example
metadata:
  template_name: sample-tosca-vnfd
topology_template:
  node_templates:
    VDU1:
      type: tosca.nodes.nfv.VDU.Tacker
      capabilities:
        nfv_compute:
          properties:
            num_cpus: 1
            mem_size: 2 GB
            disk_size: 20 GB
      properties:
        image: ubuntu
        availability_zone: nova
        mgmt_driver: noop
        config: |
          param0: key1
          param1: key2
```

```
        monitoring_policy:
          name: http_ping
          parameters:
            retry: 5
            timeout: 10
            port: 8000
          actions:
            failure: respawn, notify
    CP1:
      type: tosca.nodes.nfv.CP.Tacker
      properties:
        management: true
        order: 0
        anti_spoofing_protection: false
      requirements:
        - virtualLink:
            node: VL1
        - virtualBinding:
            node: VDU1
    VL1:
      type: tosca.nodes.nfv.VL
      properties:
        network_name: net_mgmt
        vendor: Tacker
```

References

[1] ETSI GS NFV-REL 003 v1.1.1, Report on models and features for end-to-end reliability

[2] ETSI GS NFV-REL 001 v1.1.1, NFV Resiliency requirements

[3] ETSI GS NFV-REL 002 v1.1.1, NFV, Report on Scalable for reliability management

[4] OPNFV Doctor Project, https://wiki.opnfv.org/display/doctor/Doctor+Home(Accessed 02.03.18).

[5] Zabbix, http://www.zabbix.com/ (Accessed 02.03.18).

[6] Openstack Ceilometer, https://docs.openstack.org/ceilometer/latest/(Accessed 02.03.18).

[7] Openstack Tacker project, https://wiki.openstack.org/wiki/Tacker

[8] Tacker HA deployment specification https://review.openstack.org/#/c/502216/

[9]Networking-SFC, https://docs.openstack.org/newton/networking-guide/config-sfc.html

[10]Tacker VNFFG, https://github.com/openstack/tacker-specs/blob/master/specs/newton/tacker-vnffg.rst

K-ONE Technical Document

○ The technical contents of this document can be changed without a notification due to the progress of the project.

○ Refer website below for getting more information of this document.

(Homepage: http://opennetworking.kr/projects/k-one-collaboration-project/wiki, E-mail: k1@opennetworking.kr)

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