



GROUP REPORT

Network Functions Virtualisation (NFV); Continuous Development and Integration; Report on use cases and recommendations for VNF Snapshot

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Network Functions Virtualisation (NFV).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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1 Scope

The present document reports on use cases, recommendations and potential solutions for VNF snapshotting, with the following objectives:

- a) Describing use cases that would benefit from VNF Snapshot functionality.
- b) Identifying gaps by studying the conditions for capturing VNF/VNFC Snapshots and VNF data.
- c) Describing end-to-end orchestration procedures and overall framework supporting the capture of VNF data and VNF/VNFC Snapshots.
- d) Analysing recommendations for the support of VNF/VNFC Snapshots.

The present document considers analysing and leveraging available related techniques from Open Source and others.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI GS NFV 003: "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".
- [i.2] ETSI GS NFV-IFA 005: "Network Functions Virtualisation (NFV); Management and Orchestration; Or-Vi reference point - Interface and Information Model Specification".
- [i.3] ETSI GS NFV-IFA 006: "Network Functions Virtualisation (NFV); Management and Orchestration; Vi-Vnfm reference point - Interface and Information Model Specification".
- [i.4] ETSI GS NFV-IFA 007: "Network Functions Virtualisation (NFV); Management and Orchestration; Or-Vnfm reference point - Interface and Information Model Specification".
- [i.5] ETSI GS NFV-IFA 008: "Network Functions Virtualisation (NFV); Management and Orchestration; Ve-Vnfm reference point - Interface and Information Model Specification".
- [i.6] ETSI GS NFV-IFA 011: "Network Functions Virtualisation (NFV); Management and Orchestration; VNF Packaging Specification".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in ETSI GS NFV 003 [i.1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in ETSI GS NFV 003 [i.1].

service consumer: person, device or company consuming a service provided by a Service Provider

VNF provider: person or company providing the VNF

NOTE: This includes, but is not limited to vendor, integrator or in-house developer.

VNF Snapshot: replication of a VNF instance at a specific point in time, containing a consistent set of VNFC Snapshots of all VNFC instances associated to the VNF instance, the VNF Descriptor and the VnfInfo (including state and settings of Virtual Links and Connection Points associated to this VNF)

VNF Snapshot Package: collection of files representing a VNF Snapshot which can be physically stored and transferred

NOTE: A more detailed description of VNF/VNFC Snapshots and their packages is provided in clause 6.1.

VNFC Snapshot: replication of a VNFC instance at a specific point in time, capturing its full or partial state (such as state and content of the disks, memory and devices attached to the VNFC instance plus the infrastructure configuration of the VNFC instance)

VNFC Snapshot Package: collection of files representing a VNFC Snapshot which can be physically stored and transferred

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GS NFV 003 [i.1] apply.

4 Use cases

4.1 Use cases related to testing

4.1.1 VNF Snapshot during online testing

4.1.1.1 Introduction

Service Providers which use NFV technology verify their virtualised network system (i.e. network service) that they developed by testing from various viewpoints, and once all the system behaviours that will happen during operation in the production environment are thoroughly tested in the testing environment, the Service Providers begin to provide the service using the network system on the production environment. However, the virtualised network systems have been getting complicated due to multi-vendor environment, adoption of variety of open source software, etc., hence it has been getting difficult to verify all the system behaviours thoroughly in the testing environment. If a service is provided under such a situation, it is considered that the possibility of service outage would increase because of the underlying bugs in the production system.

Therefore, it is necessary to reveal and remove the underlying bugs from the network system by continually verifying the network system which is already providing the service on the production environment. This clause calls this kind of testing online testing. If the Service Providers verify the systems which are in operation by online testing, they can conduct various tests under the real complex system states which are created by real users. It is expected that the systems are tested under more realistic conditions and that the underlying bugs in the system will be easier to be found and removed compared with the testing environment.

The online testing includes fault injection testing (e.g. by stop a VM at random), load injection testing (e.g. by adding large amount of traffic), etc. to verify reliability/availability of the system. By practicing this kind of tests continually "in a controlled manner", the service provider can discover and fix potential bugs which could not be found in the testing environment, build up more robust system, and prevent the system from major service outages.

The online testing should be done in a controlled manner, as this testing may affect the running system especially when the test fails, which means an underlying bug is revealed by the test. To conduct online tests in a controlled manner, one thing is to reinforce monitoring around tested area and then the Service Provider can react a test failure immediately if it happens. Another is to capture data of the VNF instances which are potentially affected by the test prior to the test. This can be done by taking VNF Snapshots. In case the test fails and the VNF instance cannot recover after restart, the capture data/VNF Snapshots will be used to recover the (failed) VNF instances to a previous normal running status without consuming time to inject any configuration data (If those VNF instances are deleted and re-instantiated without using snapshots, it will take time to make the VNF instances be ready to start the services because no configuration data exist in the VNF instances after instantiation of them. Also, this requires to store the exact data somehow at the time before the test was started.). In this way, the online testing can be done in a controlled and safe manner.

This present use case shows the VNF Snapshot as part of an online testing by injecting failure(s) (e.g. VM stall, network disruption, etc.) to verify the system's reliability. The online testing is supposed to be performed by the Service Provider manually, or an online testing function which may be part of the NFV-MANO or outside of it (e.g. the OSS/BSS) automatically, depending on architectural options. Once VNF Snapshot(s) are created for restore purpose, an actual test scenario is executed. In case the test results in failure, the system is restored using the capture data by hand or automatically.

4.1.1.2 Actors

For this use case, the following actors are involved:

- 1) Service Provider is informed about the availability of captured data.
- 2) VNF Provider is informed about the availability of captured data.

4.1.1.3 Pre-conditions

- 1) A network service which is intended to be tested, is in operation on the production environment, and is providing a service to the Service Consumers.
- 2) The network service is composed of one or more VNF instances, which are composed of one or more VNFC instances. A VNFC instance is running on a virtualised container (e.g. virtual machine, system/application container).
- 3) The VNF instances have a high availability mechanism and they have auto recovery functionality for possible failures.
- 4) The expected recovery time from failures are defined by the network service.
- 5) For the network service to be tested, the execution of the online testing to verify failure recovery is triggered by the Service Provider.

4.1.1.4 Description

The following steps are executed:

- 1) The Service Provider determines the place to be tested and test scenario (e.g. VM shutdown for the simulation of VM stall) for the network service.

- 2) The Service Provider gets the necessary criteria information for the test result judgement (e.g. expected service quality or service traffic volume after the test is finished) by collecting the monitoring information around the area to be tested.
- 3) The Service Provider requests the NFV MANO to create and store the VNF Snapshots including the virtualised containers around the area to be tested. These snapshots are used to restore the network service if the test results fail. The VNF Snapshots may include memory image in some cases (e.g. expected recovery time is less than order of seconds) or in some types of VNFs. If memory level Snapshot is taken for a VNF, it can skip its system's booting process as well as its application's setup process as the result of the process is already in the memory. Also, it may be helpful to restore the states from the memory Snapshot especially when a number of those are stored in the memory.

NOTE 1: The VNF Snapshots include VNFD (including VL) ETSI GS NFV-IFA 011 [i.6] and VnfInfo ETSI GS NFV-IFA 007 [i.4], in addition to the snapshots of virtualised containers.

- 4) The Service Provider executes the test scenario (e.g. performing VM shutdown) determined in the step 1.
- 5) The network service reacts to the test scenario (e.g. the system detect the failure and recover from the situation by invoking the auto recovery functionality).
- 6) To know the test result, once the expected recovery time from the failure elapses, the service provider again gets the same information as step 2 (e.g. actual service quality at this time).
- 7) The Service Provider compares the information (test result) gotten at step 6 with the information (expected test result) at step 2, and if the result is as expected (e.g. the service quality was same as before), the test is terminated. Otherwise, the Service Provider requests the NFV MANO to start the new virtualised containers using the snapshots stored at step 3 and switch the (failed) virtualised containers around tested area to the new virtualised containers by the snapshots, so that the network service is restored from the failure situation, and then the test is terminated.
- 8) If the test results fail, the Service Provider requests the NFV-MANO to create and store the snapshots of the (failed) virtualised containers. These snapshots are used for the root cause analysis by the Service Provider and the VNF Provider(s) so to help fixing the network service.

NOTE 2: The Service Provider's behaviours described above can be programed as online testing functions which may be part of the NFV-MANO or outside of it (e.g. the OSS/BSS), depending on architectural options.

4.1.1.5 Post-conditions

If the test results in successful, the network service provides the service as per normal.

If the test results in fail, the tested area gets back to the running state before the test scenario is executed. That is, the network service is restored to its former state, and it provides the service as per normal. The snapshots of the (failed) virtualised containers are stored in the NFV MANO. These snapshots are used for the root cause analysis by the Service Provider and the VNF Provider(s) so to help fixing the network service. By continuing to test and fix the network service, the Service Provider can remove the underlying bugs from the network service, and hence they can avoid potential major service outages.

4.2 Use cases related to troubleshooting

4.2.1 VNF Snapshot for root cause analysis

4.2.1.1 Introduction

In a virtualised environment, the decoupling of software from hardware makes it difficult to collect sufficient evidence to correlate faults. During a failure situation, the Service Provider with the help of the VNF Provider can perform a root-cause-analysis, e.g. determining whether the failure was internal to the VNF or the source of the failure was external to the VNF (e.g. hypervisor or hardware) and in some cases may request a VNF/VNFC Snapshot. Activation of capturing data may depend on certain policies, e.g. it may only be triggered when the VIM has reported NFVI faults to the VNFM and VNF performance degradation has been observed.

4.2.1.2 Actors

For this use case, the following actors are involved:

- 1) Service Provider is informed about the availability of captured data.

4.2.1.3 Pre-conditions

- 1) VNF instance subject to be executed the VNF Snapshot is running.

4.2.1.4 Description

The use case begins when VNF Snapshot creation has been determined by the VNFM (either automatically or triggered by the EM) to be performed.

The following steps are executed:

- 1) The VNFM requests the VIM to create snapshot(s) of the VM images for a selected list of VNFC instances.
- 2) The snapshot(s) are created by the VIM and images of the snapshots are stored.
- 3) The VIM sends back to the VNFM information to identify and locate the stored snapshots.
- 4) The VNFM extends the VNF Snapshot(s) with information about the VNF including all necessary information for root cause analysis, e.g. VNFM logs, operational information related to that VNF instance.
- 5) The VNFM informs the EM about the completion of the VNF Snapshot(s) procedure including information to identify and locate the stored snapshots. If the create VNF Snapshot procedure is not successful, the VNFM informs about the failure to the EM. The EM then forwards the information about the VNF Snapshot result to the Service Provider.

4.2.1.5 Post-conditions

If the VNF Snapshot creation was successful, the Service Provider has received all data related to the VNF Snapshot (e.g. location of the VNF Snapshot and VNF). If the VNF Snapshot creation failed, the Service Provider is notified with a corresponding error message including additional information about the failure.

4.3 Use cases related to agile lifecycle management of VNF

4.3.1 VNF Snapshot during VNF lifecycle procedure

4.3.1.1 Introduction

NFV enables greater levels of automation in terms of lifecycle management of network entities, now VNF instances. To help minimizing the impact of lifecycle procedures on the service availability, mechanisms to capture data during the lifecycle procedure are needed. For instance, capturing data previous to initiating the actual VNF lifecycle procedure will help recover the VNF instance to a previous known running status in case the procedure fails. Activation of capturing data may also depend on operator policies, resource consumption, etc.; e.g. it may only be triggered by specific lifecycle procedures and critical VNFs.

This present use case shows the VNF Snapshot as part of a VNF lifecycle procedure, wherein information to the Service Provider is provided about the availability of capture data (e.g. VNF Snapshot).

4.3.1.2 Actors

For this use case, the following actors are involved:

- 1) Service Provider is informed about the availability of captured data.

4.3.1.3 Pre-conditions

- 1) VNF instance subject to be executed the VNF Snapshot is running.

4.3.1.4 Description

The use case begins when VNF Snapshot creation has been determined by the VNFM to be performed.

The following steps are executed:

- 1) The VNFM requests the VIM to create snapshot(s) of the VM images for a selected list of VNFC instances.
- 2) The snapshot(s) are created by the VIM and images of the snapshots are stored.
- 3) The VIM sends back to the VNFM information to identify and locate the stored snapshots.
- 4) The VNFM extends the VNF Snapshot(s) with information about the VNF including operational information related to that VNF instance that is necessary to fall back to a previous running status.
- 5) The VNFM informs lifecycle management consumers (i.e. NFVO and/or EM) about the completion of the VNF Snapshot(s) procedure including information to identify and locate the stored snapshots. If the create VNF Snapshot procedure is not successful, the VNFM informs about the failure to the consumers. Those consumers then forward the information about the VNF Snapshot result to the Service Provider.

4.3.1.5 Post-conditions

If the VNF Snapshot creation was successful, the Service Provider has received all data related to the VNF Snapshot (e.g. location of the VNF Snapshot and VNF). If the VNF Snapshot creation failed, the Service Provider is notified with a corresponding error message including additional information about the failure.

4.3.2 VNF Snapshot for quick VNF recovery

4.3.2.1 Introduction

This present use case shows how to restore a VNF instance to a previous running status using a previously captured VNF Snapshot.

4.3.2.2 Actors

For this use case, the following actors are involved:

- 1) Service Provider requests to revert the VNF using a previously captured VNF Snapshot.

4.3.2.3 Pre-conditions

- 1) VNF Snapshot is available, i.e. the VNFM or NFVO can retrieve VNF Snapshot Package information.

4.3.2.4 Description

The use case begins when the Service Provider determines to revert the VNF to a previous VNF Snapshot.

The following steps are executed:

- 1) The Service Provider requests the VNFM or NFVO to use the VNF Snapshot on the VNF instance. In the latter case, the NFVO identifies the VNFM that manages the VNF instance and forwards the request to this VNFM.

- 2) The VNFM retrieves information on how to use the VNF Snapshot on the VNF instance, this involves determining the individual VNFC Snapshots which are part of the VNF Snapshot, as well as operational information related to that VNF instance (minimally VNF instance runtime information, e.g. vnfId, onboardedVnfPkgInfoId, vnfState and vnfConfigurableProperty ETSI GS NFV-IFA 007 [i.4]) that is necessary to revert to the VNF Snapshot.
- 3) The VNFM requests the VIM to execute revert to Snapshot operation on the VM(s) using the individual VNFC Snapshot(s).
- 4) The VIM executes revert to Snapshot operation(s) on the VM(s).
- 5) The VIM sends back to the VNFM information about the success of the operation(s).
- 6) The VNFM informs lifecycle management consumers (i.e. NFVO and/or EM) about the completion of the operation(s).

4.3.2.5 Post-conditions

If the operation was successful, the VNF instance uses the VNF Snapshot (i.e. the VNF instance has reverted its state to the one that was available at the time the VNF Snapshot was created) and the Service Provider has been notified about the successful operation.

If the operation has failed, the Service Provider is notified with a corresponding error message including additional information about the failure.

5 Gap analysis

5.1 Current supporting solutions

5.1.1 Overview

This clause aims at documenting current solutions that can support the execution of VNF/VNFC Snapshots. The analysis leverages available techniques, capabilities of implementations of virtualisation technologies (e.g. KVM/QEMU, LXC/LXD), hypervisors abstraction layers (e.g. libvirt) and virtualisation management solutions (e.g. OpenStack) that can be found in current implementations. The selection of implementations is not exclusive and should be considered as examples sufficient for analysing the current state of the supporting solutions. The analysis is based on the current available versions of the solutions (see annex A).

Figure 5.1.1-1 illustrates the analysed current solutions and their relationship to each other, including the reference points enabling intercommunication with regards to Snapshot operations.

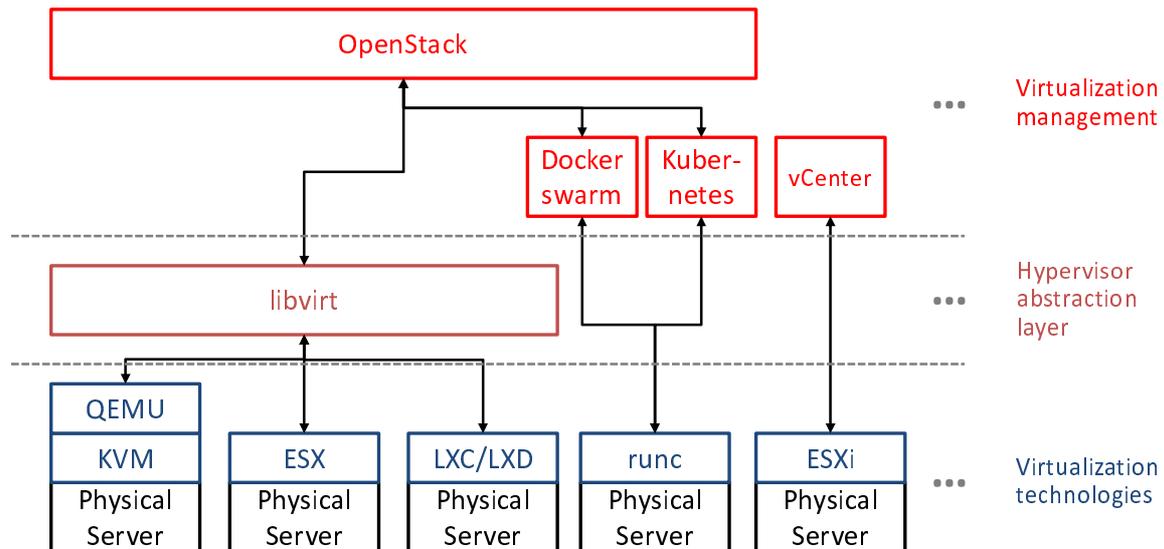


Figure 5.1.1-1: Relations and reference points of exemplary solutions

5.1.2 Snapshot techniques

The current snapshotting solutions of the virtualisation technologies are using different techniques to capture the memory state and the disk state of the instances. Their characteristics can be described as follows:

Memory state

- Internal memory snapshot: The content of the memory of the instance(s) is stored in a file and is placed in the disk image of the instance snapshot. It can only be used in combination with the Snapshot of the disk state of an instance.
- External memory snapshot: The content of the memory of the instance(s) is stored in a dedicated file, external to and independent of the Snapshot of the disk state.

Disk state

- Sequential snapshot: The content of the specified disks of the instance is copied into disk images each time an instance Snapshot is created.
- Incremental snapshot: The first time an instance Snapshot is created, the associated disks of the instance are frozen and represent the baseline Snapshot of the disk state. Additionally delta snapshots for all disks of the instance are created which contain only the changes in the disk state compared to the last snapshot. Creation of consecutive disk state snapshots results in creation of new delta disk snapshots.
- Internal disk snapshot: The same file contains the disk image Snapshot and the changes since the Snapshot creation.
- External disk snapshot: The disk image Snapshot and the changes since the Snapshot creation are stored in different files.

5.1.3 Snapshot capabilities

5.1.3.1 Introduction

The Snapshot capabilities are grouped by operations concerning Snapshot management, such as creating, listing, reverting to or deleting a snapshot. Depending on the underlying virtualisation technology, the instance being snapshotted is different and could be a virtual machine, an OS container or something similar. Each of the snapshotted instances represents a VNFC instance and therefore the resulting Snapshot equals to a VNFC Snapshot.

For each Snapshot operation, current solutions for virtualisation technologies, hypervisor abstraction layer and virtualisation management have been analysed. The results are grouped into four categories and the capabilities of the respective categories are compared in all the tables presented in clause 5.1.3.

All tables presented in clause 5.1.3 indicate a "Yes" for those categories where the capability is supported by at least one of the analysed solutions, whereas a "No" indicates that none of the analysed solutions in that category is supporting the capability.

5.1.3.2 Create instance snapshot

This operation requests the creation of an instance snapshot. Attributes indicate which content of the instance (such as memory or disk state) to capture and also specify the runtime state of the instance during and after taking the snapshot.

Table 5.1.3.2-1 lists the supported create instance (i.e. virtual machine or OS container) Snapshot capabilities for the analysed categories.

Table 5.1.3.2-1: Create instance Snapshot support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
instance	Create Snapshot of the instance.	Yes	Yes	Yes	Yes
memory	Capture memory state of the instance.	Yes	Yes (see note)	Yes	Yes
disk	Capture disk(s) state.	Yes	Yes (see note)	Yes	Yes
metadata	Capture metadata for the snapshot.	Yes	Yes	Yes	Yes
live	Take a live instance snapshot.	Yes	Yes	Yes	Yes
leave-running	Leave the process running after the Snapshot was created.	No	Yes	No	No
stop/halt	Optionally stop/halt the instance after the Snapshot was created.	No	Yes	Yes	No
quiesce/lock files	Quiesce/lock the file system in the virtual machine if the virtual machine is powered on when the Snapshot is taken.	Yes	Yes	Yes	Yes
tcp-established	Allow open tcp connections during snapshot.	No	Yes	No	No
atomic	Require atomic operation.	Yes	No	Yes	No
path	Target path for saving instance snapshots and logs.	Yes	Yes	Yes	No
NOTE: Supported by default and not configurable.					

5.1.3.3 Revert instance to Snapshot

Revert an instance to the state of the snapshot. Optionally specify the runtime state of the instance after reverting.

Table 5.1.3.3-1 lists the supported revert instance Snapshot capabilities for the analysed categories.

Table 5.1.3.3-1: Revert instance to Snapshot support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
revert snapshot	Reverts the instance to the current (i.e. last available) snapshot.	Yes	Yes	Yes	Yes
tcp-established	Allow open tcp connections during revert operation.	No	Yes	No	No
restore file-locks	Handle file locks, for safety.	No	Yes	No	No
state	After reverting, apply instance state to e.g. "running", "paused", or "power off". By default, the state of the instance at the time when the Snapshot was taken is applied.	Yes	Yes	Yes	Yes
force	Try harder on risky reverts (e.g. force reverting process even if not all instance rollback information is available).	Yes	No	Yes	No
reverttosnapshot host	If a Snapshot was taken while a virtual machine was powered on, this parameter can be used to specify a choice of host where the virtual machine should power on.	Yes	No	No	Yes

5.1.3.4 Update instance Snapshot

Update the whole Snapshot (overwriting all/some of the existing files) or update the metadata only.

Table 5.1.3.4-1 lists the supported update instance Snapshot capabilities for the analysed categories.

Table 5.1.3.4-1: Update instance Snapshot support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
update snapshot	Update an existing snapshot.	No	No	Yes	Yes
metadata	Update metadata/description for existing snapshot.	No	No	Yes	Yes
rename	Rename this snapshot.	No	No	Yes	Yes

5.1.3.5 List instance snapshots

List the set of existing/available snapshots based on a set of filters.

Table 5.1.3.5-1 lists the supported list instance snapshots capabilities for the analysed categories.

Table 5.1.3.5-1: List instance snapshots support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
list snapshots	List existing instance snapshots.	Yes	Yes	Yes	Yes
filter	Set of different filters such that only snapshots matching the filter criteria are returned.	No	No	Yes	Yes

5.1.3.6 Show instance Snapshot details

With this operation details of one or more selected snapshots can be shown.

Table 5.1.3.6-1 lists the supported show instance Snapshot details capabilities for the analysed categories.

Table 5.1.3.6-1: Show instance Snapshot details support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
show details	Show details of selected snapshot(s).	Yes	Yes	Yes	Yes

5.1.3.7 Delete instance snapshot

Delete one or multiple instance snapshots, optionally specify instructions on how to handle remaining snapshots.

Table 5.1.3.7-1 lists the supported delete instance Snapshot capabilities for the analysed categories.

Table 5.1.3.7-1: Delete instance Snapshot support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
filter	Specify whether to remove selected (by filter criteria) or all snapshots.	Yes	Yes	Yes	Yes
delete Snapshot consolidate	The virtual disk associated with this Snapshot will be merged with other disk if possible.	Yes	No	No	Yes

5.1.3.8 Export instance snapshot

Export instance snapshots.

Table 5.1.3.8-1 lists the supported export instance Snapshot capabilities for the analysed categories.

Table 5.1.3.8-1: Export instance Snapshot support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
image files	Export (external) Snapshot image files.	Yes	Yes	Yes	Yes

5.1.3.9 Import instance snapshot

Import instance snapshots.

Table 5.1.3.9-1 lists the supported import instance Snapshot capabilities for the analysed categories.

Table 5.1.3.9-1: Import instance Snapshot support by category

Attribute	Description	Virtualisation technology		Hypervisor abstraction	Virtual. mgmt.
		VM instance	OS container		
image files	Import Snapshot image files.	Yes	Yes	Yes	Yes

5.2 Analysis of use cases and conditions on VNF/VNFC Snapshots

5.2.1 VNF Snapshot lifecycle

The analysis of the use cases described in clause 4 reveals basic procedures concerning VNF Snapshots. Table 5.2.1-1 lists the identified VNF Snapshot procedures and their mapping to the analysed use cases.

Table 5.2.1-1: VNF Snapshot procedures and use case mapping

VNF Snapshot procedure	Applicable VNF Snapshot use cases
Create a VNF Snapshot	VNF Snapshot during online testing; VNF Snapshot for root cause analysis; VNF Snapshot during VNF lifecycle procedure
Revert a VNF Snapshot	VNF Snapshot during online testing; VNF Snapshot for quick VNF recovery
Create a VNF Snapshot Package	VNF Snapshot during online testing; VNF Snapshot for root cause analysis
Extract a VNF Snapshot Package	VNF Snapshot during online testing; VNF Snapshot for root cause analysis
Export a VNF Snapshot Package	VNF Snapshot during online testing; VNF Snapshot for root cause analysis
Import a VNF Snapshot Package	VNF Snapshot during online testing; VNF Snapshot for root cause analysis

Each of the procedures can be interpreted as a life cycle operation for VNF Snapshots and is further described in the respective clauses 5.2.2 to 5.2.9. Figure 5.2.1-1 illustrates the VNF Snapshot lifecycle.

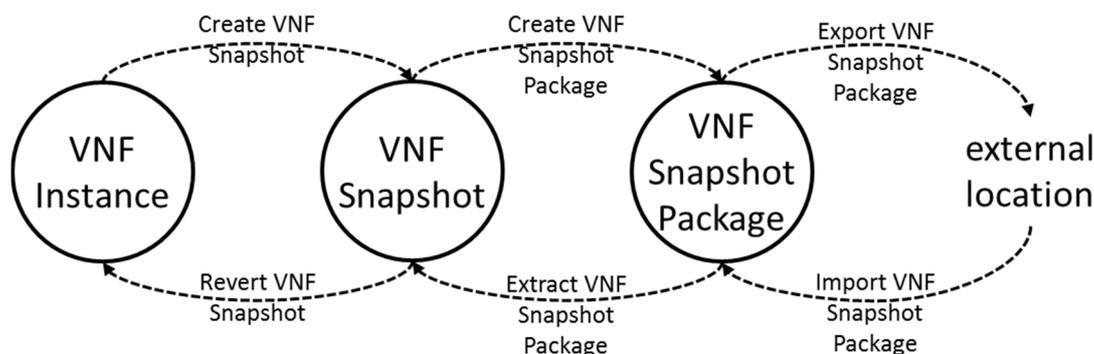


Figure 5.2.1-1: VNF Snapshot lifecycle

Additional operations for the management of VNF Snapshot Packages are Query VNF Snapshot Package Information, and Delete a VNF Snapshot Package.

5.2.2 Create a VNF Snapshot

Creating a VNF Snapshot results in the VNF Snapshot content being captured. The created VNF Snapshot can be utilized to restore a VNF instance or to create a VNF Snapshot package.

The procedure consists of the steps:

- 1) Request a VNF Snapshot creation.
- 2) Grant the VNF Snapshot creation.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Identify the VNF Snapshot creation parameters.

- 4) Resolve the VNFC Snapshots
(Identify the VNFC's and their elements to be included in the VNF Snapshot).
- 5) Take VNFC Snapshots.
- 6) Take VNF Snapshot.
- 7) Return VNF Snapshot creation result.

5.2.3 Revert a VNF Snapshot

Restoring a VNF instance to a previous state via snapshot revert requires the VNF Snapshot being created. The identifier of the VNF Snapshot to restore from needs to be known by the requesting entity and the content of the VNF Snapshot needs to be known and accessible by the MANO functional blocks.

The procedure consists of the steps:

- 1) Request a VNF Snapshot reversion.
- 2) Grant the VNF Snapshot reversion.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Identify the VNF Snapshot reversion parameters.
- 4) Resolve the VNFC Snapshots
(Identify the VNFC Snapshots and their elements to be reverted for the VNF Snapshot).
- 5) Revert the VNFC instances.
- 6) Revert the VNF instance.
- 7) Return VNF Snapshot restore result.

5.2.4 Create a VNF Snapshot Package

Creating a VNF Snapshot package requires the VNF Snapshot being available. The identifier of the VNF Snapshot to package needs to be known by the requesting entity and the content of the VNF Snapshot needs to be known and accessible by the MANO functional blocks. The created VNF Snapshot Package consists of a collection of files which are stored in a VNF Snapshot Package repository and can be exported to another location.

The procedure consists of the steps:

- 1) Request a VNF Snapshot Package creation.
- 2) Grant the VNF Snapshot Package creation.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Identify VNF Snapshot Package creation parameters.
- 4) Create VNFC Snapshot Packages.
- 5) Create VNF Snapshot Package.
- 6) Return VNF Snapshot Package result.

5.2.5 Extract a VNF Snapshot Package

Extracting a VNF Snapshot Package requires the VNF Snapshot Package being stored in the VNF Snapshot Package repository. The identifier of the VNF Snapshot Package to be extracted needs to be known by the requesting entity.

The procedure consists of the steps:

- 1) Request a VNF Snapshot Package extraction.

- 2) Grant the VNF Snapshot Package extraction.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Extract the VNF Snapshot Package
(Store the VNFC Snapshot packages and the VNF Snapshot meta-data).
- 4) Extract the VNFC Snapshot Packages
(Store the VNFC Snapshots including the VNFC Snapshot meta-data).
- 5) Return the VNF Snapshot Package extraction result.

5.2.6 Export a VNF Snapshot Package

Exporting a VNF Snapshot Package requires a VNF Snapshot Package being stored in the VNF Snapshot Package repository. The identifier of the VNF Snapshot Package needs to be known by the requesting entity. The VNF Snapshot Package files are physically transferred to another location for further external processing.

The procedure consists of the steps:

- 1) Request a VNF Snapshot Package export.
- 2) Grant the VNF Snapshot Package export.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Transfer the VNF Snapshot Package files.
- 4) Return the VNF Snapshot Package export result.

5.2.7 Import a VNF Snapshot Package

Importing a VNF Snapshot Package stores a VNF Snapshot Package in the VNF Snapshot Package repository. The files of the VNF Snapshot Package are physically transferred from an external location and are available for extraction.

The procedure consists of the steps:

- 1) Request a VNF Snapshot Package import.
- 2) Grant the VNF Snapshot Package import.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Transfer the VNF Snapshot Package files.
- 4) Return the VNF Snapshot Package import result.

5.2.8 Query VNF Snapshot Package Information

Querying VNF Snapshot Package Information returns information on the VNF Snapshot Packages available in the VNF Snapshot Package repository. The query request may contain filter criteria and selected attributes to only return certain selected attributes for the VNF Snapshot Packages matching the filter criteria.

The procedure consists of the steps:

- 1) Request a Query VNF Snapshot Package Information.
- 2) Grant the Query VNF Snapshot Package Information.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Return the selected attributes of the VNF Snapshot Packages matching the input filter criteria.

5.2.9 Delete a VNF Snapshot Package

This procedure allows to delete a VNF Snapshot Package stored in the VNF Snapshot Package repository.

The procedure consists of the steps:

- 1) Request a VNF Snapshot Package deletion.
- 2) Grant the VNF Snapshot Package deletion.

NOTE: The granting is optional, depending on policies and/or configuration.

- 3) Return the result of the VNF Snapshot Package deletion.

5.3 Identification of gaps

This clause is intended to document gaps in between the current supported solutions as outlined in clause 5.1 and the desired functionality and conditions identified in the use case analysis according to clause 5.2.

A significant gap already becomes evident when comparing the scope of the current supported solutions and the scope of the use case analysis. The identified supported solutions are all concerning the capabilities of instance snapshots, i.e. VNFC Snapshots, while the use case analysis identifies procedures concerning VNF Snapshots and VNF Snapshot Packages. VNFC Snapshot and VNFC Snapshot Package operations are only addressing a subset of the individual procedure steps described in the use case analysis while all other identified operations from the use case analysis are not covered by the current supported solutions. The reason for this gap is that the analysed supported solutions are residing in the NFVI and VIM functional blocks while the not covered procedural steps are envisioned in the use cases to be implemented by other functional blocks of the NFV architecture.

Without foreclosing detailed solutions, table 5.3-1 provides a mapping of the identified procedure steps from the use case analysis to targeted NFV functional blocks envisioned to provide and expose the corresponding operations. Furthermore the table indicates the existence of solutions for the listed operations.

Table 5.3-1: Target providing NFV FBs and existing solutions for VNF Snapshot procedures

VNF Snapshot procedure step	Target providing NFV functional block	Existing solution
Create a VNF Snapshot		
Request a VNF Snapshot creation	NFVO VNFM	No explicit solution; For VNFM could potentially be encapsulated in "HealVNFRequest" referencing a snapshot creation script as in ETSI GS NFV-IFA 008 [i.5], clause 7.2.10.2
Grant the VNF Snapshot creation	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Identify the VNF Snapshot creation parameters	VNFM	None
Resolve the VNFC Snapshots	VNFM	None
Take VNFC Snapshots	VIM NFVI	As detailed in clause 5.1.3.2 "Create instance snapshot"
Take VNF Snapshot	VNFM	None
Return VNF Snapshot creation result	NFVO VNFM	No explicit solution; For VNFM could potentially be encapsulated in "HealVNFResponse" as in ETSI GS NFV-IFA 008 [i.5], clause 7.2.10.4

VNF Snapshot procedure step	Target providing NFV functional block	Existing solution
Revert a VNF Snapshot		
Request a VNF Snapshot reversion	NFVO VNFM	No explicit solution; For VNFM could potentially be encapsulated in "HealVNFRequest" referencing a snapshot reversion script as in ETSI GS NFV-IFA 008 [i.5], clause 7.2.10.2
Grant the VNF Snapshot reversion	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Identify the VNF Snapshot reversion parameters	VNFM	None
Resolve the VNFC Snapshots	VNFM	None
Revert the VNFC instances	VIM NFVI	As detailed in clause 5.1.3.3 "Revert instance to snapshot"
Revert the VNF instance	VNFM	None
Return VNF Snapshot restore result	NFVO VNFM	No explicit solution; For VNFM could potentially be encapsulated in "HealVNFResponse" as in ETSI GS NFV-IFA 008 [i.5], clause 7.2.10.4
Create a VNF Snapshot Package		
Request a VNF Snapshot Package creation	NFVO VNFM	None
Grant the VNF Snapshot Package creation	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Identify VNF Snapshot Package creation parameters	VNFM	None
Create VNFC Snapshot Packages	VIM NFVI	Partly covered by clause 5.1.3.8 "Export instance snapshot"
Create VNF Snapshot Package	VNFM	None
Return VNF Snapshot Package result	NFVO VNFM	None
Extract a VNF Snapshot Package		
Request a VNF Snapshot Package extraction	NFVO VNFM	None
Grant the VNF Snapshot Package extraction	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Extract the VNF Snapshot Package	VNFM	None
Extract the VNFC Snapshot Packages	VIM NFVI	Partly covered by clause 5.1.3.9 "Import instance snapshot"
Return the VNF Snapshot Package extraction result	NFVO VNFM	None
Export a VNF Snapshot Package		
Request a VNF Snapshot Package export	NFVO VNFM	None
Grant the VNF Snapshot Package export	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Transfer the VNF Snapshot Package files	VNFM VIM	Partly covered by clause 5.1.3.8 "Export instance snapshot" for VIM
Return the VNF Snapshot Package export result	NFVO VNFM	None
Import a VNF Snapshot Package		
Request a VNF Snapshot Package import	NFVO VNFM	None
Grant the VNF Snapshot Package import	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Transfer the VNF Snapshot Package files	VNFM VIM	Partly covered by clause 5.1.3.9 for VIM
Return the VNF Snapshot Package import result	NFVO VNFM	None

VNF Snapshot procedure step	Target providing NFV functional block	Existing solution
Query VNF Snapshot Package Information		
Request a Query VNF Snapshot Package Information	NFVO VNFM	None
Grant the Query VNF Snapshot Package Information	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Return the selected attributes of the VNF Snapshot Packages matching the input filter criteria	NFVO VNFM	None
Delete a VNF Snapshot Package		
Request a VNF Snapshot Package deletion	NFVO VNFM	None
Grant the VNF Snapshot Package deletion	NFVO	No explicit solution; Could potentially be covered by general LCM granting as in ETSI GS NFV-IFA 007 [i.4], clause 6.3.2
Return the result of the VNF Snapshot Package deletion	NFVO VNFM	None

Besides the procedural steps, the use case analysis also indicates the need for policies for and configuration of the VNF and VNFC Snapshot procedures. So far no VNF/VNFC Snapshot policies and configurations are present in the existing NFV descriptor specifications. Initial options for snapshot descriptors are discussed in clause 6.1.2.

Additionally, an analysis of the details of the current supported solutions reveal other gaps in between them. Table 5.3-2 shows the result of this analysis.

NOTE: "Priority" is used here to indicate the relative importance of the identified gap.

Table 5.3-2: Identified gaps

Gap	Description	Priority
Supported snapshot techniques/capabilities cannot be advertised	As described in clause 5.1.1, the virtualisation technologies use different snapshot techniques to capture the state of the instances. Virtualisation technologies should be able to report/expose supported snapshot techniques/capabilities to upper layers in figure 5.1-1.	High
Virtualisation management layer cannot utilize snapshot capabilities	The virtualisation management layer should be able to utilize the snapshot capabilities supported by the virtualisation technologies, as e.g. configuration of the snapshot operation based on the supported techniques is currently not supported (see table 5.1.3.2-1).	High
Missing quiesce/unquiesce interface between the virtualisation management layer and VNFM/NFVO	For consistent VNF Snapshots, the VNFM/NFVO should be able to quiesce/unquiesce the virtualised compute resources used by the VNFC instances.	High
Target host cannot be exposed to the virtualisation management layer	The virtualisation management layer may be able to include the target host in the "revert instance to snapshot" request to the hypervisor abstraction layer and/or the virtualisation technologies layer as described in table 5.1.3.3-1.	Medium

6 Framework, procedures and solutions analysis

6.1 Introduction/Concept

6.1.1 What is a snapshot?

From components point of view two main types of snapshots are considered, VNFC Snapshots and VNF Snapshots. As defined in clause 3.1, a VNFC Snapshot is a replication of a VNFC instance at a specific point in time, capturing its full or partial state, including the state and content of the attached disks, memory and devices. The VNFC Snapshot is recommended to include references such as identifiers of the related VNF instance and associated Virtual Infrastructure Manager (VIM). Furthermore the VNFC Snapshot is recommended to contain the infrastructure configuration of the VNFC instance, e.g. power state, allocated resources, device settings, etc.

A VNFC Snapshot is different from an image in the sense that the image does not capture the state/user data.

A VNF Snapshot instead is a replication of a VNF instance at a specific point in time. Because a VNF instance is composed of one to many VNFC instances, a VNF Snapshot consists of all associated VNFC Snapshots, the VNF Descriptor (VNFD) and the VNF instance runtime information (VnfInfo), including the state and settings of Virtual Links and Connection Points associated to this VNF. Including both, VNFD and VnfInfo, in the VNF Snapshot enables the comparison between configuration settings from the descriptor and runtime values from the record.

The differentiation between these two main snapshot types enables a separation of concern. Due to the fact that the VIM is responsible for resources allocated to VNFC instances, while the VNF Manager (VNFM) is responsible for VNF lifecycle management and VNF instances, separate operations and policies for the respective VNFC and VNF Snapshots can be assigned.

From the captured data's point of view there are also two types of snapshots, cold snapshot when only the disks of the VNFC's are captured and warm snapshots when not only the disks, but also the memory and device states of the VNFC's are captured. A cold snapshot is useful to create backups of the VNF/VNFC while the warm snapshot can be used to debug the VNF/VNFC state after a critical error or can be used for backup purposes if the operating system and application of the VNF/VNFC is able to handle the restoration of past state.

In case of multi VNFC VNF-s where the data in the source of snapshots of the different VNFC-s have dependencies between each other the snapshot should be taken in a way that the data in the different snapshots are consistent. Since only the VNF is aware of the needed configuration to preserve the consistency before the snapshot creation, the VNF should be notified by the VNFM.

Certain VNF's might support taking a snapshot, while others may not allow snapshots. Certain policies may restrict that VNF Snapshot, based on legal or regulatory constraints.

Typically some VNF will perform some operations outside of the VNF, for instance, storing some data in an external database and updating these data regularly. Providing a snapshot of such VNF will be challenging if the objective was to snapshot also the data in this database, unless very clear guidelines are given on how to capture these data for a snapshot.

Similarly a VNF composed of multiple VNFCs may have some VNFC's that do not allow snapshot, in that case the VNF Snapshot is selective. That VNF Snapshot will only contain VNFC Snapshots that are allowed.

Also some disks attached to certain VNFC's of a given VNF instance may not allow snapshot. In that case the VNF Snapshot will capture information about all the VNFC's that allow snapshot but exclude the disk information related to 'independent' disks attached to certain VNFC's.

Snapshots may occur on powered on, powered off or suspended VNFC instances. The state of the different VM's that constitute the VNFC instance will then indicate if they were powered on, off or suspended. The main snapshot types could be extended by adding verbs to further qualify the snapshot types to include the purpose, e.g. "live VNF Snapshot", "cold snapshot", "warm snapshot", etc. for backup, post mortem analysis or recovery.

Snapshots need to be stored. Therefore VNFC Snapshot Package and VNF Snapshot Package are defined in clause 3.1 as collections of respective snapshot files which can be physically stored and transferred.

NOTE: VNF/VNFC Snapshot Packages are expected to be stored in a repository similar to the VNF instance image repository. This repository is accessible by the VNF Manager of that VNF being snapshotted and the NFVO.

When a new VNF Snapshot is captured, it may replace the previous VNF Snapshot or be stored separately.

6.1.2 Operations and commands on a VNF Snapshot

Operations and commands that may occur on a VNF Snapshot include:

- Request a VNF Snapshot.
- Grant a VNF Snapshot.
- Take a VNF Snapshot:
 - This operation would have options to select which VNFC Snapshot to include, and which element in each VNFC to snapshot.
- Revert to a VNF Snapshot:
 - This operation may occur for backup, revert to a working environment after some upgrade failure, or to restore a working environment after migration.
- Query VNF Snapshot Package Information based on certain filter conditions.
- Delete a VNF Snapshot Package.
- Import a VNF Snapshot Package.
- Export a VNF Snapshot Package:
 - For instance towards an external troubleshooting platform.

A given VNF may have options for VNF Snapshot, to be specified in a snapshot descriptor:

- Allow VNF Snapshot anytime or within one or more time periods.
- Allow only consistent VNF Snapshot.
- Do not allow VNF or VNFC Snapshot.
- Allow to capture the disk state and/or memory state of the VNFC instance.
- Take a VNFC Snapshot when powering off the VNFC instance.
- Ask if a VNFC Snapshot should be taken when powering off the VNFC instance.
- Revert to VNFC Snapshot when powering on the VNFC instance.
- Etc.

6.2 Overview

Based on the use cases (clause 4) and gap analysis (clause 5), an overall VNF Snapshot framework, clarifying the roles and responsibilities of the NFV-MANO functional blocks to support VNF/VNFC Snapshots functionality, has been derived and is described in clause 6.3. In accordance with this framework, four types of procedures have been identified and are detailed in the following clauses:

- VNFC Snapshot Procedures. See clause 6.4.
- VNF Snapshot Procedures. See clause 6.5.
- VNFC Snapshot Package Procedures. See clause 6.6.

- VNF Snapshot Package Procedures. See clause 6.7.

VNFC Snapshot (Package) Procedures are described both in direct and indirect resource management modes ETSI GS NFV-IFA 007 [i.4] and are executed for every VNFC of the VNF in the corresponding VNF Snapshot (Package) Procedures.

6.3 Framework

The artifacts to be maintained by a framework are, as defined in clause 3.1, VNF/VNFC Snapshots and VNF/VNFC Snapshot Packages. The proposed framework extends the NFV architecture in order to support the basic procedures for VNF/VNFC Snapshots and VNF/VNFC Snapshot Packages as introduced in clause 5.2.

In addition to enhanced roles of the functional blocks of the NFV architecture, the concepts of VNF Snapshot repository and VNF Snapshot Package repository are introduced. The repositories are additional features intended to contain references and attributes of the respective artifacts. It is to be noted that the location of the repositories is not expected to be the same as the physical location of their referenced artifacts. Figure 6.3-1 illustrates the framework for VNF/VNFC snapshotting.

Based on the identified gaps described in clause 5.3, the following roles and responsibilities per functional block of the NFV architecture are foreseen to provide the framework for VNF/VNFC snapshotting:

NFV Orchestrator:	Granting of VNF/VNFC Snapshot operations
VNF Manager:	Maintain the VNF Snapshot repository Maintain the VNF Snapshot Package repository Supervise and manage the VNF/VNFC Snapshot operations Resolve descriptors for and content of VNF/VNFC Snapshots and their packages Execute VNF Snapshot and VNF Snapshot Package operations
VIM:	Expose NFVI capabilities for VNFC snapshotting Support VNFC Snapshot operations Execute VNFC Snapshot Package operations
NFVI:	Execute VNFC Snapshot operations

Clauses 6.4 to 6.7 describe procedures for the VNF/VNFC Snapshot and VNF/VNFC Snapshot Package operations. They are generalized in a way that the originating request for an operation is sent by a "Sender" entity. The "Sender" can be one of multiple options for functional blocks of the NFV architecture, dependent on the use case. Figure 6.3-1 depicts the potential "Sender" functional blocks.

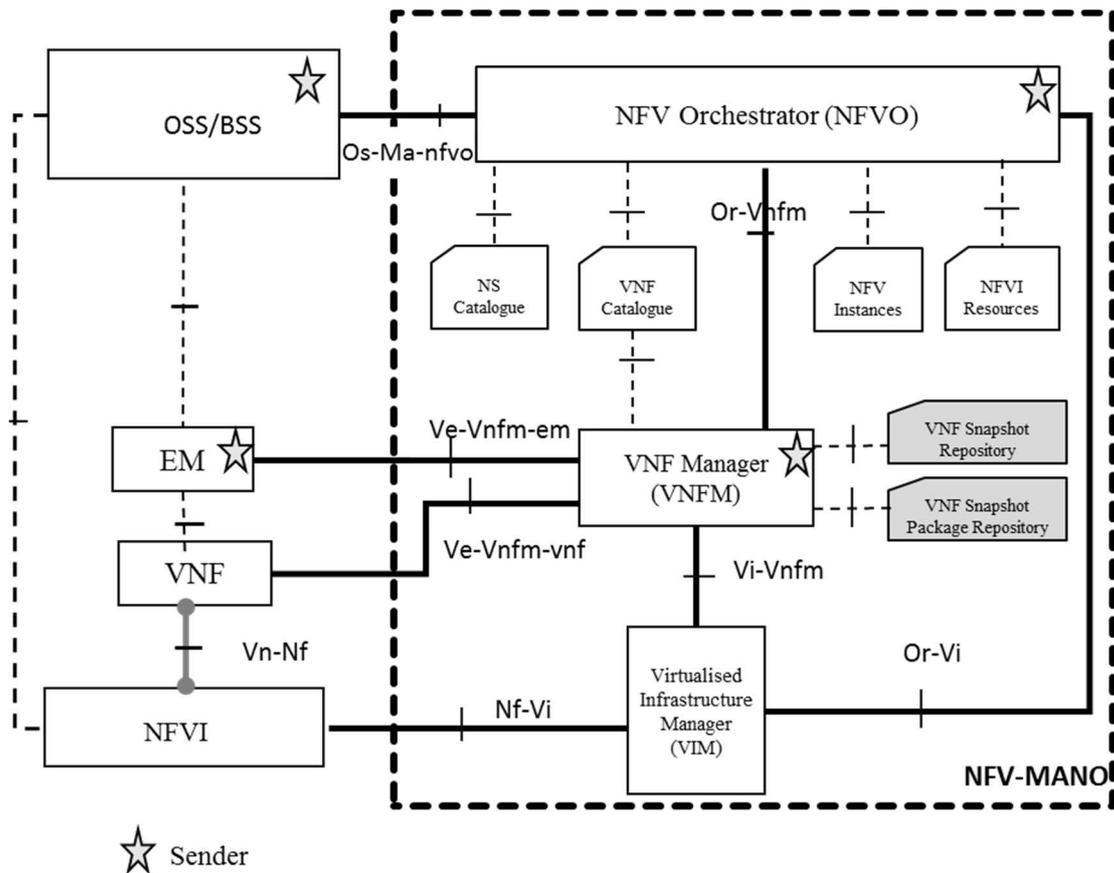


Figure 6.3-1: Framework for VNF/VNFC snapshotting

6.4 VNFC Snapshot Procedures

6.4.1 Create VNFC Snapshot Procedure in direct resource management mode

Figure 6.4.1-1 illustrates the procedure of creating a VNFC Snapshot in direct resource management mode. Creation of a VNFC Snapshot is directly triggered by a request message. The request can be an internal request of the VNFM when the Snapshot creation is an optional sub-procedure of other operations. The main steps of this procedure are:

- 1) A Sender requests a Snapshot of a VNFC by sending a request message. The request message includes the identifier of the VNFC instance and optionally further parameters specifying the VNFC Snapshot creation.
- 2) Based on the requested action and the run-time information of the VNF Instance, the VNFM decides to take a VNFC Snapshot.
- 3) Optionally the VNFM requests grant for Snapshot creation from the NFVO.
- 4) Optionally the NFVO grants the Snapshot creation request to the VNFM.
- 5) Optionally, the VIM receives a request from the VNFM to stop/shutdown the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 006 [i.3], clause 7.3.1.6).
- 9) Optionally, the VIM receives a request from the VNFM to detach the volume from the virtualised compute resource.
- 13) Optionally, if consistent snapshots are needed, the VNFM sends a request to the VIM to quiesce the virtualised compute resource used by the VNFC instance.

- 17) Conditionally, if the previous steps are successfully completed and dependent on the VNFC Snapshot creation parameters, the VNFM then sends a request to the VIM to create the Snapshot as defined in ETSI GS NFV-IFA 006 [i.3], clause 7.3.1.6. The request message may indicate for example if the memory state of the virtualised compute resource (identified by computeId) needs to be captured.
- 21) Conditionally, if the previous steps are successfully completed and dependent on the VNFC Snapshot creation parameters, the VNFM sends a request to the VIM to Snapshot the volume identified by volumeId (see ETSI GS NFV-IFA 006 [i.3], clause 7.5.1.6).
- 25) The VNFM creates and saves the VNFC Snapshot.
- 26) Optionally, if consistent snapshots are needed, the VNFM sends a request to the VIM to unquiesce the virtualised compute resource used by the VNFC instance.
- 30) Optionally, the VIM receives a request from the VNFM to attach the volume to the virtualised compute resource.
- 34) Optionally, the VIM receives a request from the VNFM to start the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 006 [i.3], clause 7.3.1.6).
- 38) A response is returned from the VNFM to the Sender.

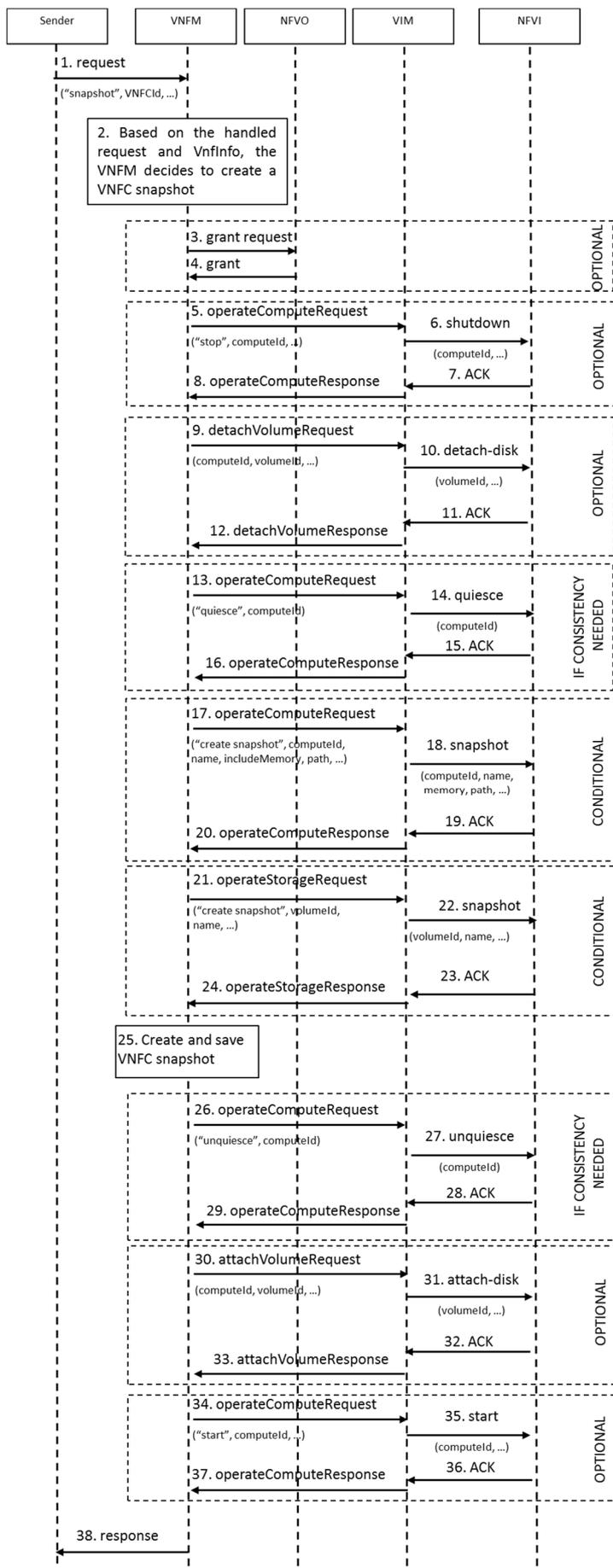


Figure 6.4.1-1: Create VNFC Snapshot Procedure in direct resource management mode

6.4.2 Create VNFC Snapshot Procedure in indirect resource management mode

Figure 6.4.2-1 illustrates the procedure of creating a VNFC Snapshot in indirect resource management mode. Creation of a VNFC Snapshot is directly triggered by a request message. The request can be an internal request of the VNFM when the Snapshot creation is an optional sub-procedure of other operations. The main steps of this procedure are:

- 1) A Sender requests a Snapshot of a VNFC by sending a request message. The request message includes the identifier of the VNFC instance and optionally further parameters specifying the VNFC Snapshot creation.
- 2) Based on the requested action and the run-time information of the VNF Instance, the VNFM decides to take a VNFC Snapshot.
- 3) Optionally the VNFM requests grant for Snapshot creation from the NFVO.
- 4) Optionally the NFVO grants the Snapshot creation request to the VNFM.
- 5) Optionally, the VIM receives a request from the VNFM via the NFVO to stop/shutdown the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 005 [i.2], clause 7.3.1.6).
- 11) Optionally, the VIM receives a request from the VNFM via the NFVO to detach the volume from the virtualised compute resource.
- 17) Optionally, if consistent snapshots are needed, the VNFM sends a request to the VIM via the NFVO to quiesce the virtualised compute resource used by the VNFC instance.
- 23) Conditionally, if the previous steps are successfully completed and dependent on the VNFC Snapshot creation parameters, the VNFM sends a request to the VIM via the NFVO to create the Snapshot as defined in ETSI GS NFV-IFA 005 [i.2], clause 7.3.1.6. The request message may indicate for example if the memory state of the virtualised compute resource (identified by computeId) needs to be captured.
- 29) Conditionally, if the previous steps are successfully completed and dependent on the VNFC Snapshot creation parameters, the VNFM sends a request to the VIM via the NFVO to Snapshot the volume identified by volumeId (see ETSI GS NFV-IFA 005 [i.2], clause 7.5.1.6).
- 35) VNFM creates and saves the VNFC Snapshot.
- 36) Optionally, if consistent snapshots are needed, the VNFM sends a request to the VIM via the NFVO to unquiesce the virtualised compute resource used by the VNFC instance.
- 42) Optionally, the VIM receives a request from the VNFM via the NFVO to attach the volume to the virtualised compute resource.
- 48) Optionally, the VIM receives a request from the VNFM via the NFVO to start the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 005 [i.2], clause 7.3.1.6).
- 54) A response is returned from the VNFM to the Sender.

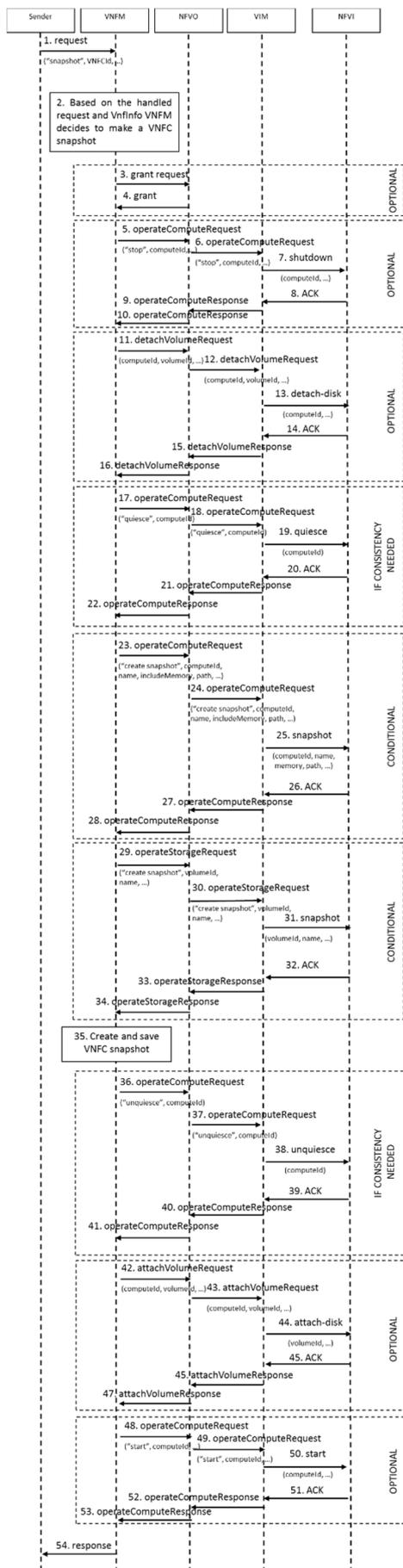


Figure 6.4.2-1: Create VNFC Snapshot Procedure in indirect resource management mode

6.4.3 Revert to VNFC Snapshot Procedure in direct resource management mode

Figure 6.4.3-1 illustrates the procedure of reverting to a VNFC Snapshot in direct resource management mode. The "Revert to VNFC Snapshot" is directly triggered by a request message. The request can be an internal request of the VNFM when the Snapshot reversion is an optional sub-procedure of other operations. The main steps of this procedure are:

- 1) A Sender sends a request to the VNFM to revert to the VNFC Snapshot. The request message includes the identifier of the VNFC Snapshot, the identifier of the VNFC instance to be reverted and optionally further parameters specifying the VNFC Snapshot reversion.
- 2) Based on the requested action and the run-time information of the VNF instance, the VNFM decides to revert to a VNFC Snapshot.
- 3) Optionally, the VNFM requests grant for Snapshot reversion from the NFVO.
- 4) Optionally, the NFVO grants the Snapshot reversion request to the VNFM.
- 5) Optionally, the VIM receives a request from the VNFM to stop/shutdown the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 006 [i.3], clause 7.3.1.6).
- 9) Optionally, the VIM receives a request from the VNFM to detach the volume from the virtualised compute resource.
- 13) Conditionally, if the previous steps are successfully completed and dependent on if the VNFC Snapshot contains compute resources and dependent on VNFC Snapshot parameters to be reverted, the VNFM sends a request to the VIM to revert to the VNFC Snapshot as defined in see ETSI GS NFV-IFA 006 [i.3], clause 7.3.1.6. The request message indicates the identifier of the VNFC Snapshot, the identifier of the compute resource to be reverted and may indicate the path where the Snapshot is located.
- 17) Conditionally, if the previous steps are successfully completed and dependent on if the VNFC Snapshot contains storage resources and dependent on VNFC Snapshot parameters to be reverted, the VNFM sends a request to the VIM to revert to the VNFC Snapshot as defined in see ETSI GS NFV-IFA 006 [i.3], clause 7.5.1.6. The request message indicates the identifier of the VNFC Snapshot, the identifier of the storage resource to be reverted and may indicate the path where the Snapshot is located.
- 21) Optionally, the VIM receives a request from the VNFM to attach a volume to the virtualised compute resource.
- 25) Optionally, the VIM receives a request from the VNFM to start the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 006 [i.3], clause 7.3.1.6).
- 29) Finally, the Sender is informed about the completion of the VNFC revert procedure.

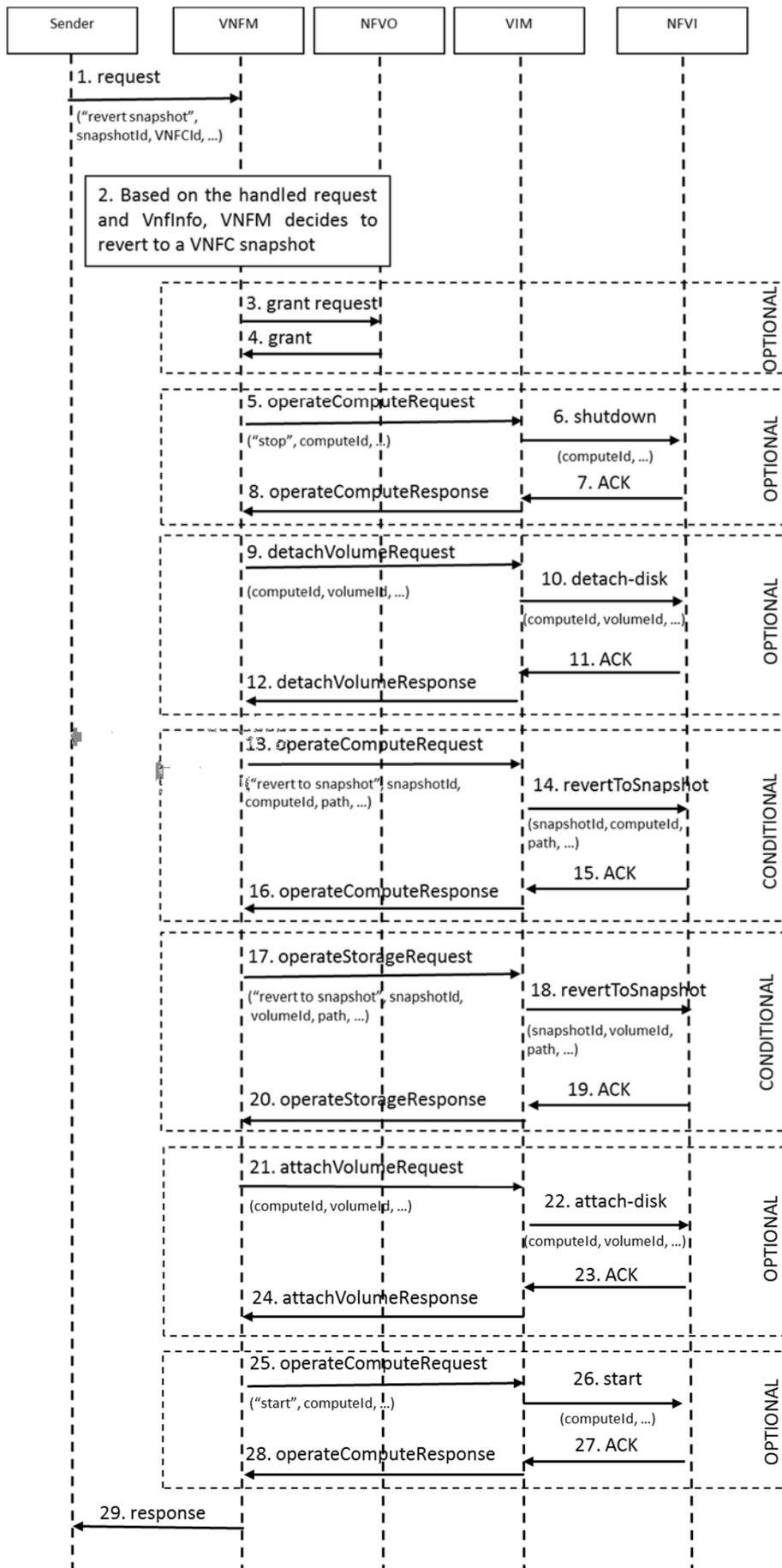


Figure 6.4.3-1: Revert to VNFC Snapshot Procedure in direct resource management mode

6.4.4 Revert to VNFC Snapshot Procedure in indirect resource management mode

Figure 6.4.4-1 illustrates the procedure of reverting to a VNFC Snapshot in indirect resource management mode. The "Revert to VNFC Snapshot" is directly triggered by a request message. The request can be an internal request of the VNFM when the Snapshot reversion is an optional sub-procedure of other operations. The main steps of this procedure are:

- 1) A Sender sends a request to the VNFM to revert to the VNFC Snapshot. The request message includes the identifier of the VNFC Snapshot, the identifier of the VNFC instance to be reverted and optionally further parameters specifying the VNFC Snapshot reversion.
- 2) Based on the requested action and the run-time information of the VNF Instance, the VNFM decides to revert to a VNFC Snapshot.
- 3) Optionally the VNFM requests grant for Snapshot reversion from the NFVO.
- 4) Optionally the NFVO grants the Snapshot reversion request to the VNFM.
- 5) Optionally, the VIM receives a request from the VNFM via the NFVO to stop/shutdown the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 005 [i.2], clause 7.3.1.6).
- 11) Optionally, the VIM receives a request from the VNFM via the NFVO to detach the volume from the virtualised compute resource.
- 17) Conditionally, if the previous steps are successfully completed and dependent on if the VNFC Snapshot contains compute resources and dependent on VNFC Snapshot parameters to be reverted, the VNFM sends a request to the VIM via the NFVO to revert to the VNFC Snapshot of the compute resource as defined in ETSI GS NFV-IFA 005 [i.2], clause 7.3.1.6. The request message indicates the identifier of the VNFC Snapshot, the identifier of the compute resource to be reverted and may indicate the path where the Snapshot is located.
- 23) Conditionally, if the previous steps are successfully completed and dependent on if the VNFC Snapshot contains storage resources and dependent on VNFC Snapshot parameters to be reverted, the VNFM sends a request to the VIM via the NFVO to revert to the VNFC Snapshot of the storage resource as defined in ETSI GS NFV-IFA 005 [i.2], clause 7.5.1.6. The request message indicates the identifier of the VNFC Snapshot, the identifier of the storage resource to be reverted and may indicate the path where the Snapshot is located.
- 29) Optionally, the VIM receives a request from the VNFM via the NFVO to attach a volume to the virtualised compute resource.
- 35) Optionally, the VIM receives a request from the VNFM via the NFVO to start the virtualised compute resource used by the VNFC instance (see ETSI GS NFV-IFA 005 [i.2], clause 7.3.1.6).
- 41) Finally, the Sender is informed about the completion of the VNFC revert procedure.

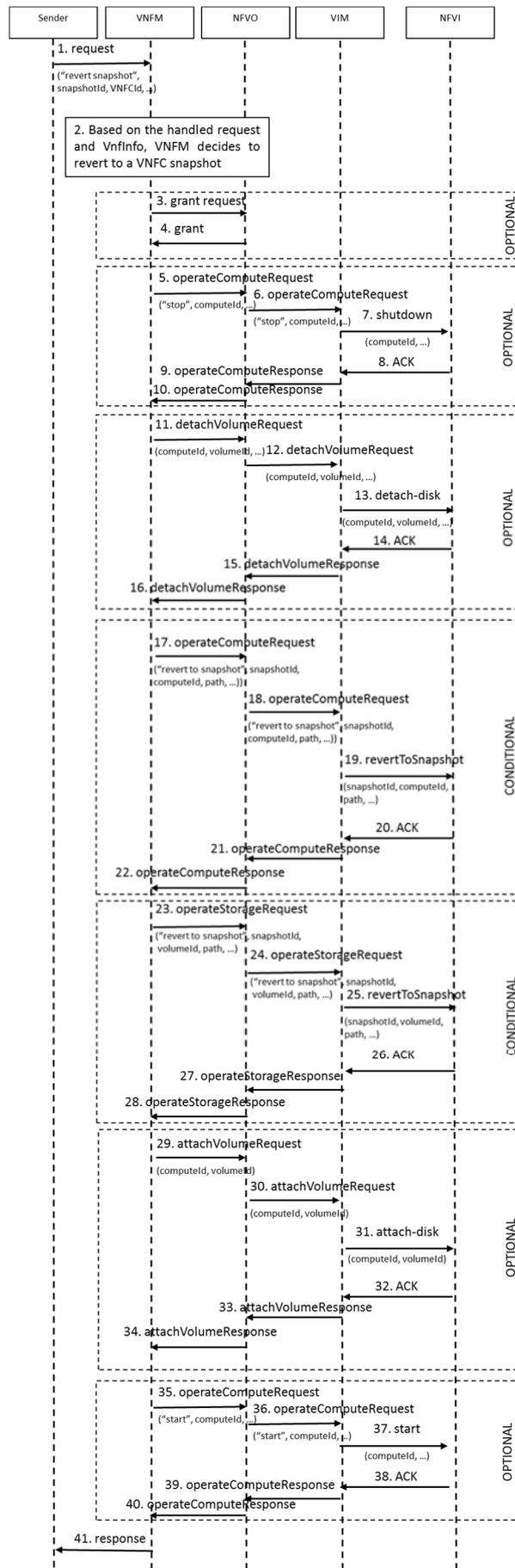


Figure 6.4.4-1: Revert to VNFC Snapshot Procedure in indirect resource management mode

6.5 VNF Snapshot Procedures

6.5.1 Create VNF Snapshot Procedure

Figure 6.5.1-1 illustrates the procedure of creating a VNF Snapshot. There can be several triggers for the Snapshot creation from several components (e.g. Heal VNF operation from the EM (see ETSI GS NFV-IFA 008 [i.5], clause 7.2.10.2)).

The main steps of this procedure are:

- 1) The Sender sends a request to the VNFM to execute certain action on the VNF. The request message includes the identifier of the VNF instance.
- 2) The VNFM retrieves run-time information about the VNF instance (e.g. `vnfcResourceInfo` as specified in ETSI GS NFV-IFA 008 [i.5], clause 9.4.3) and checks if Snapshot is needed to execute the requested actions and if all conditions are met to take the VNF Snapshot.
- 3) Optionally, depending on the policies, the VNFM sends a grant request to NFVO to create a snapshot.
- 4) Optionally, depending on the policies, the NFVO returns a grant response to the VNFM.
- 5) Optionally, if consistent snapshots are needed, the VNFM sends a notification about the Snapshot creation to the VNF with the list of affected VNFC(s).
- 6) Optionally, if consistent snapshots are needed, the VNF makes the needed preparation for the Snapshot creation (e.g.: flushes databases, makes shared filesystems read only).
- 7) Optionally, if consistent snapshots are needed, the VNF responds to the notification. Step 8 is repeated for every VNFC.
- 8) Create VNFC Snapshot procedure is executed as it is described in clauses 6.4.1 or 6.4.2.
- 9) The VNFM creates and saves the VNF Snapshot.
- 10) Optionally, if consistent snapshots are needed, the VNFM sends a notification to the VNF about the end of Snapshot creation.
- 11) Optionally, if consistent snapshots are needed, the VNF prepares for the normal operation (e.g. enables database access, makes shared filesystem writeable).
- 12) Optionally, if consistent snapshots are needed, the VNF responds to the notification about the end of Snapshot creation.
- 13) The requested actions are executed.
- 14) Finally, the Sender is informed about the completion of the requested actions. The response message includes the `snapshotId` of the created VNF Snapshot.

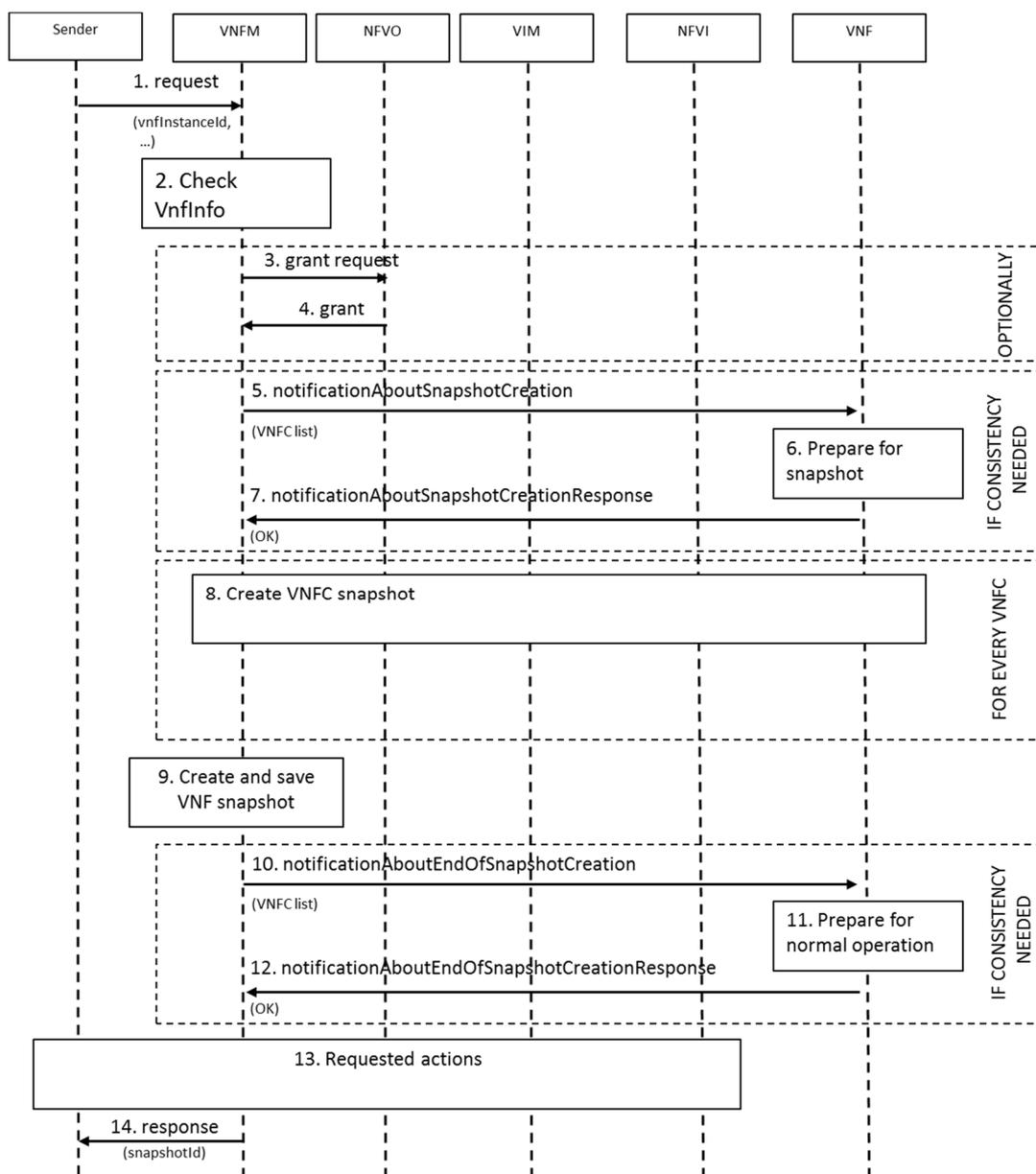


Figure 6.5.1-1: Create VNF Snapshot Procedure

6.5.2 Revert to VNF Snapshot Procedure

Figure 6.5.2-1 illustrates the procedure of reverting to a VNF Snapshot. There can be several triggers for the Snapshot reversion from several components (e.g. Heal VNF operation from the EM (see ETSI GS NFV-IFA 008 [i.5], clause 7.2.10.2)).

The main steps of this procedure are:

- 1) The Sender sends a request to the VNFM to execute a certain action on the VNF. The request message includes the identifier of the VNF Snapshot and the identifier of the VNF instance to be reverted.
- 2) The VNFM retrieves run-time information about the VNF instance (e.g. vnfResourceInfo as specified in ETSI GS NFV-IFA 008 [i.5], clause 9.4.3) and determines that a "Revert to VNF Snapshot" is needed to execute the requested actions after having checked that all conditions are met to revert to the VNF Snapshot. In case no reversion to a Snapshot is needed to execute the requested action, proceed with step 12.
- 3) Optionally, depending on (internal) policies, the VNFM sends a grant request to NFVO to revert to a snapshot.
- 4) Optionally, depending on (internal) policies, the NFVO returns a grant response to the VNFM.

- 5) If consistent reversion to snapshots is needed, the VNFM sends a notification about the Snapshot reversion to the VNF with the list of affected VNFC(s).
- 6) If consistent reversion to snapshots is needed, the VNF makes the needed preparation for the Snapshot reversion (e.g.: flushes databases, makes shared filesystems read only).
- 7) If consistent reversion to snapshots is needed, the VNF responds to the notification.
- 8) Revert to VNFC Snapshot procedure is executed as it is described in clauses 6.4.3 or 6.4.4. Step 8 is repeated for every VNFC.
- 9) If consistent reversion to snapshots is needed, the VNFM sends a notification to the VNF about the end of Snapshot reversion.
- 10) If consistent reversion to snapshots is needed, the VNF prepares for the normal operation (e.g. enables database access, makes shared filesystem writeable).
- 11) If consistent reversion to snapshots is needed, the VNF responds to the notification.
- 12) The requested actions are executed.
- 13) Finally, the Sender is informed about the completion of the requested actions.

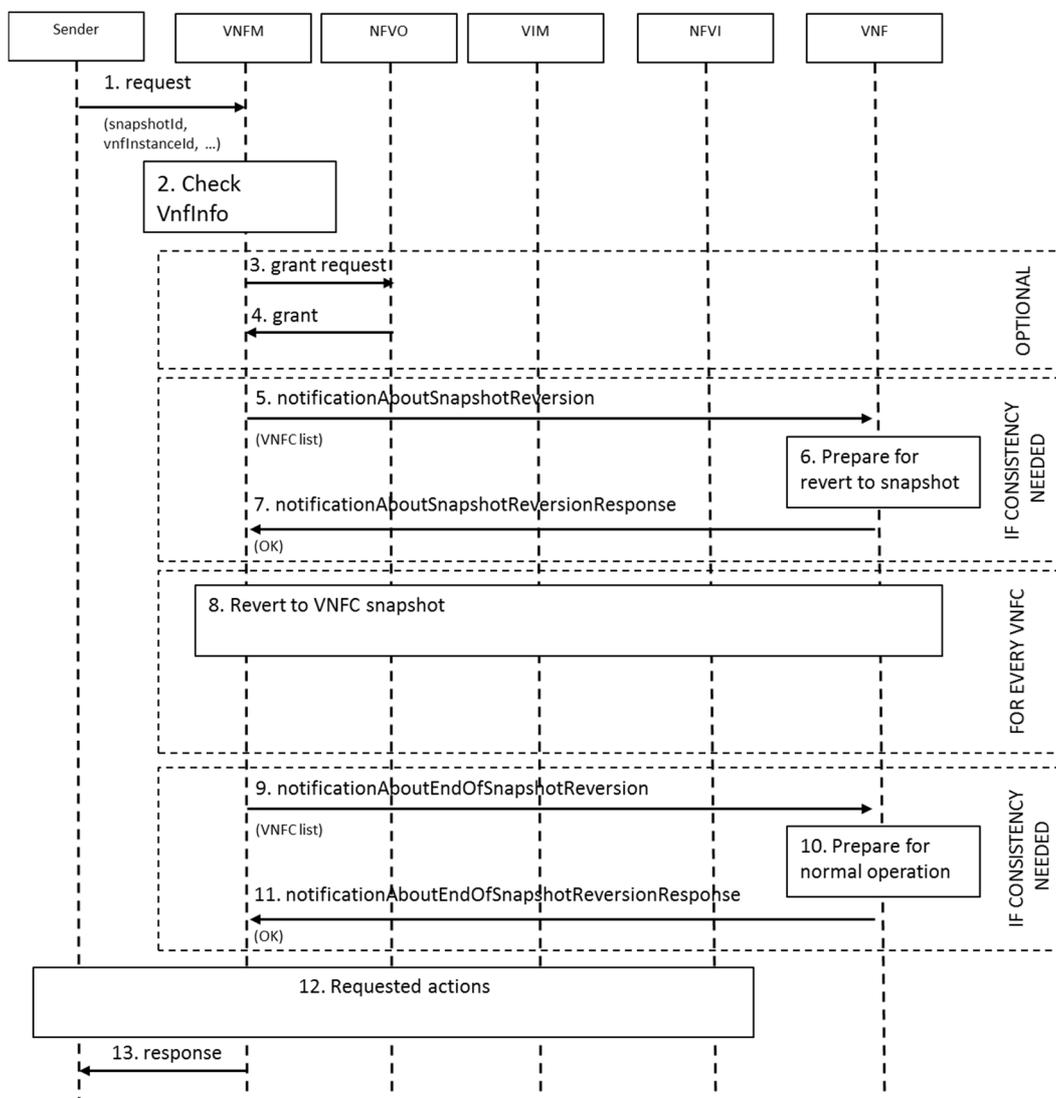


Figure 6.5.2-1: Revert to VNF Snapshot Procedure

6.6 VNFC Snapshot Package Procedures

6.6.1 Create VNFC Snapshot Package Procedure in direct resource management mode

Figure 6.6.1-1 illustrates the procedure of creating a VNFC Snapshot Package in direct resource management mode. The main steps of this procedure are:

- 1) Based on the run-time information of the VNFC instance, the VNFM decides to create a VNFC Snapshot Package.
- 2) Optionally, the VNFM requests grant for the create operation from the NFVO.
- 3) Optionally, the NFVO grants the create operation request to the VNFM.
- 4) The VNFM sends a request to the VIM to download the captured state of the VNFC instance and save it as a VNFC Snapshot Package.
- 5) A response is returned from the VIM to the VNFM.

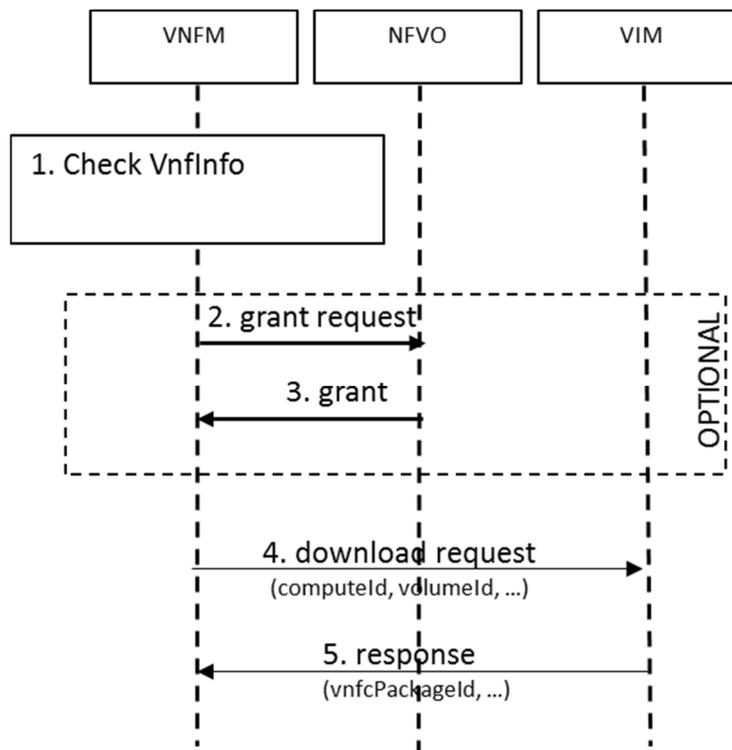


Figure 6.6.1-1: Create VNFC Snapshot Package Procedure in direct resource management mode

6.6.2 Create VNFC Snapshot Package Procedure in indirect resource management mode

Figure 6.6.2-1 illustrates the procedure of creating a VNFC Snapshot Package in indirect resource management mode. The main steps of this procedure are:

- 1) Based on the run-time information of the VNFC instance, the VNFM decides to create a VNFC Snapshot Package.
- 2) Optionally, the VNFM requests grant for the create operation from the NFVO.
- 3) Optionally, the NFVO grants the create operation request to the VNFM.

- 4-5) The VNFM sends a request to the VIM via the NFVO to download the captured state of the VNFC instance and save it as a VNFC Snapshot Package.
- 6-7) A response is returned from the VIM to the VNFM via the NFVO.

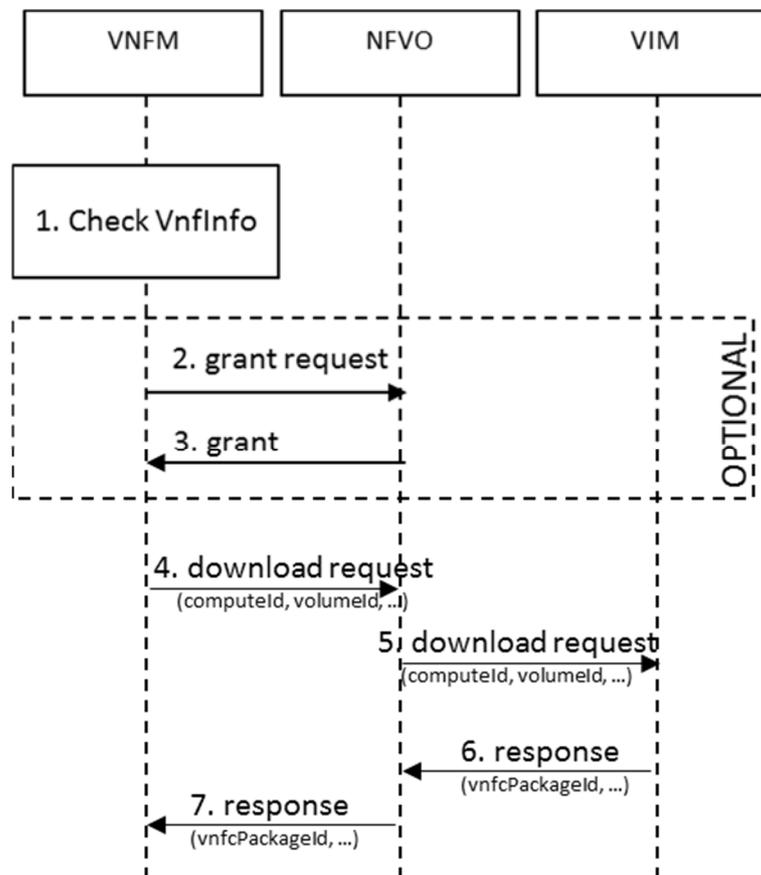


Figure 6.6.2-1: Create VNFC Snapshot Package Procedure in indirect resource management mode

6.6.3 Extract VNFC Snapshot Package Procedure in direct resource management mode

Figure 6.6.3-1 illustrates the procedure of extracting a VNFC Snapshot Package in direct resource management mode. The main steps of this procedure are:

- 1) Based on the run-time information of the VNFC instance, the VNFM decides to extract a VNFC Snapshot Package.
- 2) Optionally, the VNFM requests grant for the extract operation from the NFVO.
- 3) Optionally, the NFVO grants the extract operation request to the VNFM.
- 4) The VNFM sends a request to the VIM to retrieve the VNFC Snapshot Package, including the captured state of the VNFC instance, from the VNFM.
- 5) A response is returned from the VIM to the VNFM.

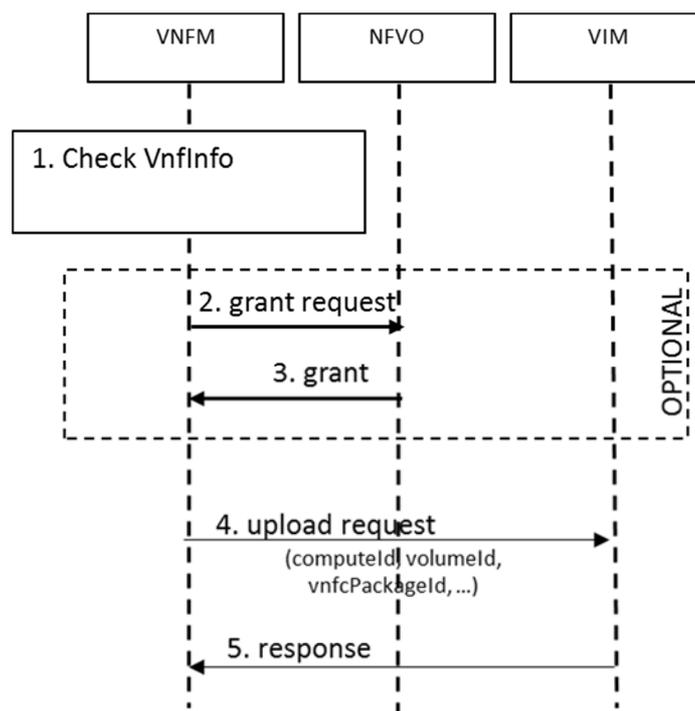


Figure 6.6.3-1: Extract VNFC Snapshot Package Procedure in direct resource management mode

6.6.4 Extract VNFC Snapshot Package Procedure in indirect resource management mode

Figure 6.6.4-1 illustrates the procedure of extracting a VNFC Snapshot Package in direct resource management mode. The main steps of this procedure are:

- 1) Based on the run-time information of the VNFC instance, the VNFM decides to extract a VNFC Snapshot Package.
- 2) Optionally, the VNFM requests grant for the extract operation from the NFVO.
- 3) Optionally, the NFVO grants the extract operation request to the VNFM.
- 4-5) The VNFM sends a request to the VIM via the NFVO to retrieve the VNFC Snapshot Package, including the captured state of the VNFC instance, from the VNFM.
- 6-7) A response is returned from the VIM to the VNFM via the NFVO.

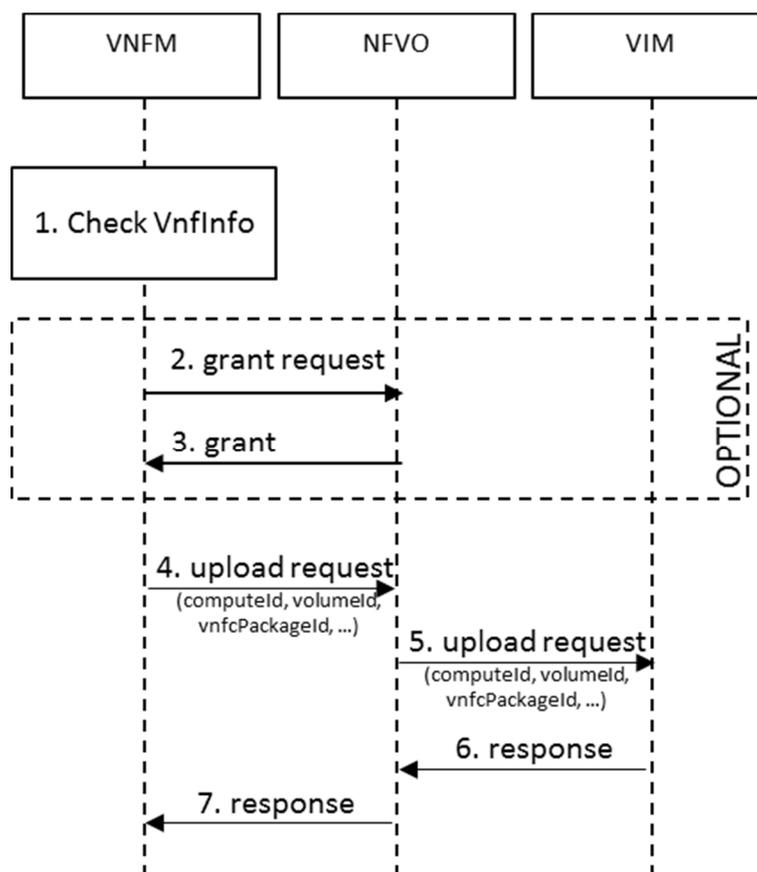


Figure 6.6.4-1: Extract VNFC Snapshot Package Procedure in indirect resource management mode

6.7 VNF Snapshot Package Procedures

6.7.1 Create VNF Snapshot Package Procedure

Figure 6.7.1-1 illustrates the procedure of creating a VNF Snapshot Package as defined in clause 3.1.

The main steps of this procedure are:

- 1) The Sender sends a request to the VNFM to create a VNF Snapshot Package. The request message includes the identifier of the Snapshot to be packaged.
- 2) The VNFM identifies the parameters to create the VNF Snapshot Package.
- 3) Optionally, depending on the policies, the VNFM requests grant for the create operation from the NFVO.
- 4) Optionally, depending on the policies, the NFVO grants the create request to the VNFM.
- 5) Create VNFC Snapshot Package procedure is executed for every VNFC as it is described in clause 6.6.1.
- 6) The VNFM creates the VNF Snapshot Package by compiling a collection of files representing the VNF Snapshot.
- 7) The VNFM uploads the VNF Snapshot Package to a pre-defined storage location.
- 8) A response is returned from the VNFM to the Sender.

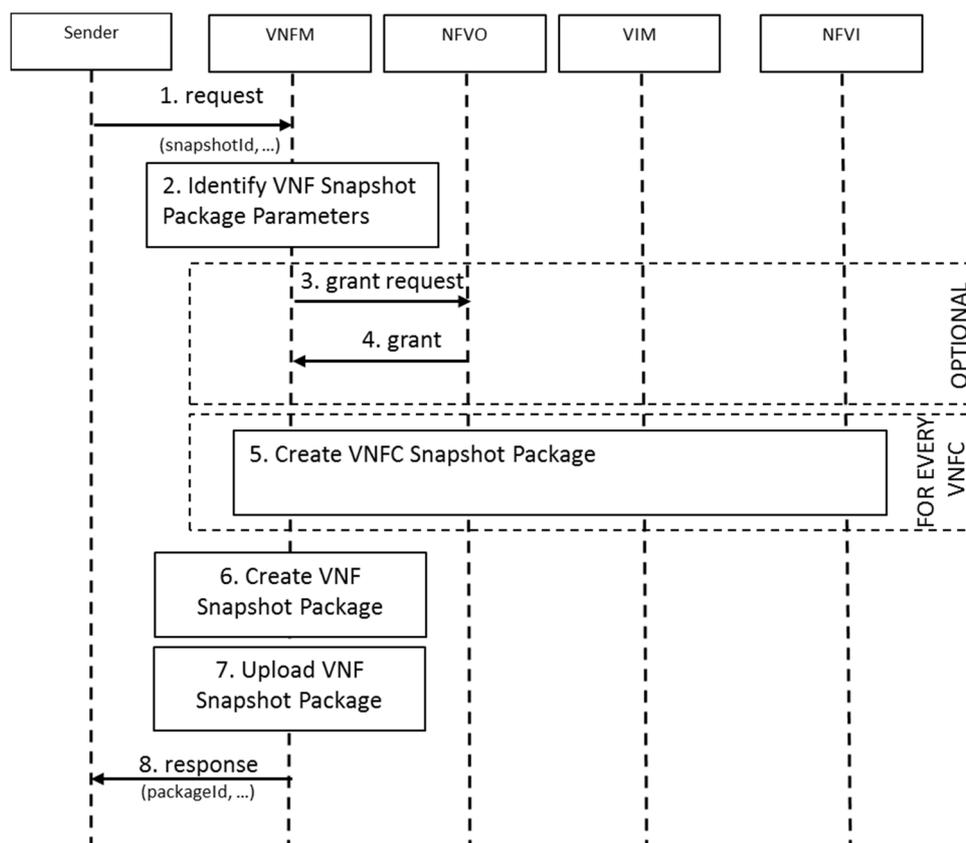


Figure 6.7.1-1: Create VNF Snapshot Package Procedure

6.7.2 Extract VNF Snapshot Package Procedure

Figure 6.7.2-1 illustrates the procedure of extracting a VNF Snapshot Package as defined in clause 3.1.

The main steps of this procedure are:

- 1) The Sender sends a request to the VNFM to extract a VNF Snapshot Package. The request message includes the identifier of the VNF Snapshot Package to be extracted.
- 2) Optionally, depending on the policies, the VNFM request grant for the extract operation from the NFVO.
- 3) Optionally, depending on the policies, the NFVO grants the extract request to the VNFM.
- 4) The VNFM downloads the VNF Snapshot Package.
- 5) The VNFM extracts the VNF Snapshot Package by storing the VNFC Snapshot Packages and the VNF Snapshot meta-data.
- 6) Extract VNFC Snapshot Package procedure is executed for every VNFC as it is described in clause 6.6.2.
- 7) A response is returned from the VNFM to the Sender.

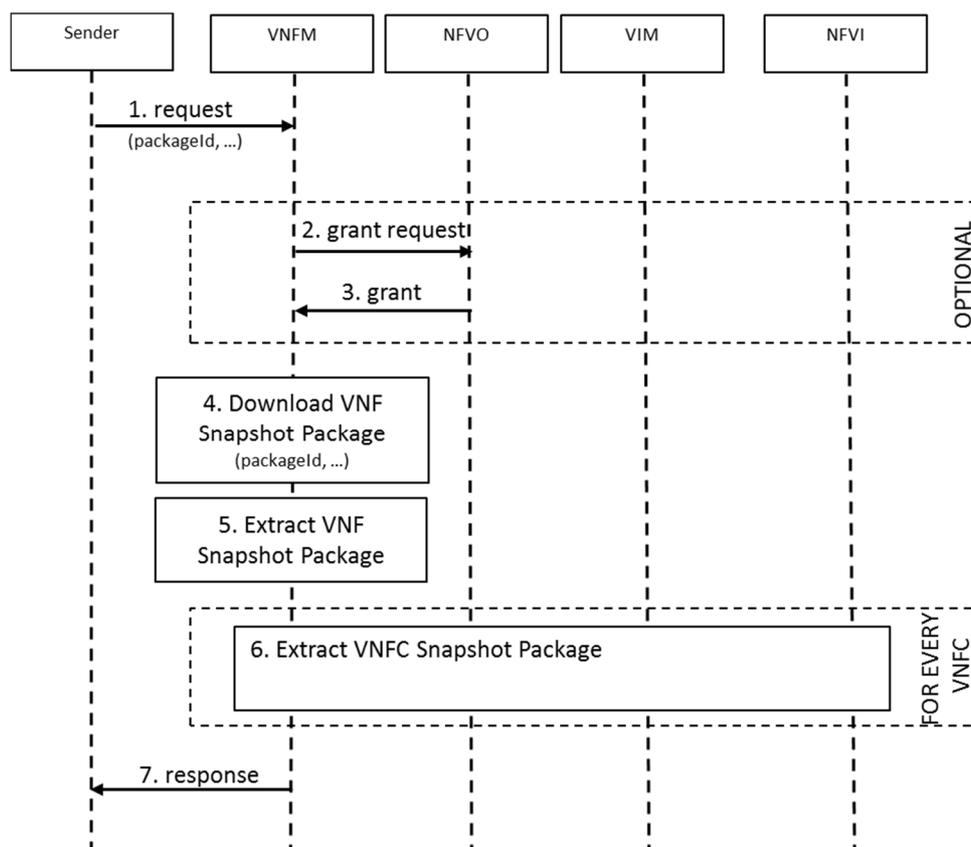


Figure 6.7.2-1: Extract VNF Snapshot Package Procedure

6.7.3 Export VNF Snapshot Package Procedure

Figure 6.7.3-1 illustrates the procedure of exporting an existing VNF Snapshot Package from the VNF Snapshot Package repository to an external location. The main steps of this procedure are:

- 1) A Sender requests to export a VNF Snapshot Package from the VNF Snapshot Package repository to an external location by sending a request message to the VNFM.
- 2) Optionally, the VNFM requests grant for the export operation from the NFVO.
- 3) Optionally the NFVO grants the export operation request to the VNFM.
- 4) If the previous steps are successfully completed, the VNFM transfers the VNF Snapshot Package files to the external location specified in the request message.
- 5) A response is returned from the VNFM to the Sender.

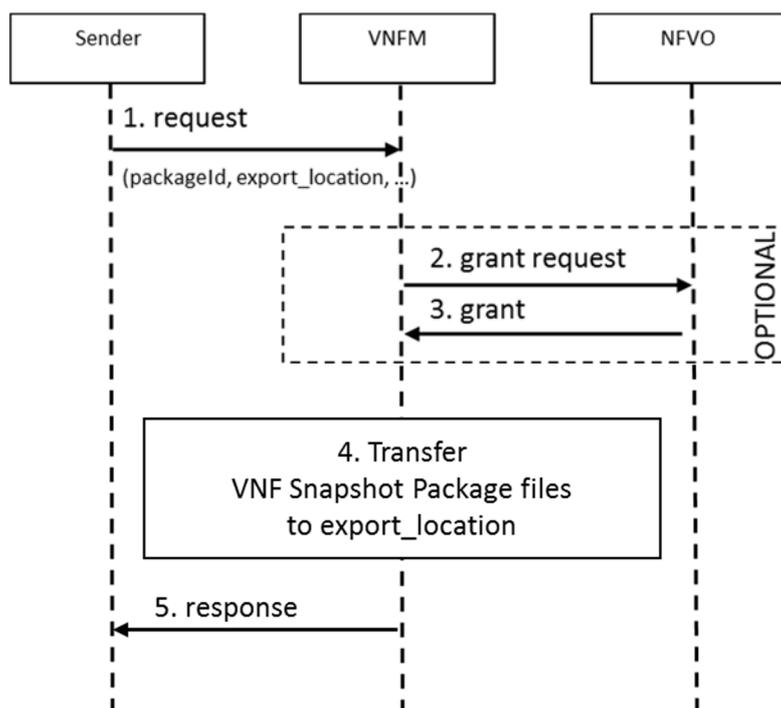


Figure 6.7.3-1: Export VNF Snapshot Package Procedure

6.7.4 Import VNF Snapshot Package Procedure

Figure 6.7.4-1 illustrates the procedure of importing a VNF Snapshot Package from an external location to the VNF Snapshot Package repository. The main steps of this procedure are:

- 1) A Sender requests to import a VNF Snapshot Package from an external location to the VNF Snapshot Package repository by sending a request message to the VNFM.
- 2) Optionally, the VNFM requests grant for the import operation from the NFVO.
- 3) Optionally the NFVO grants the import operation request to the VNFM.
- 4) If the previous steps are successfully completed, the VNFM transfers the VNF Snapshot Package files from the external location specified in the request.
- 5) A response is returned from the VNFM to the Sender.

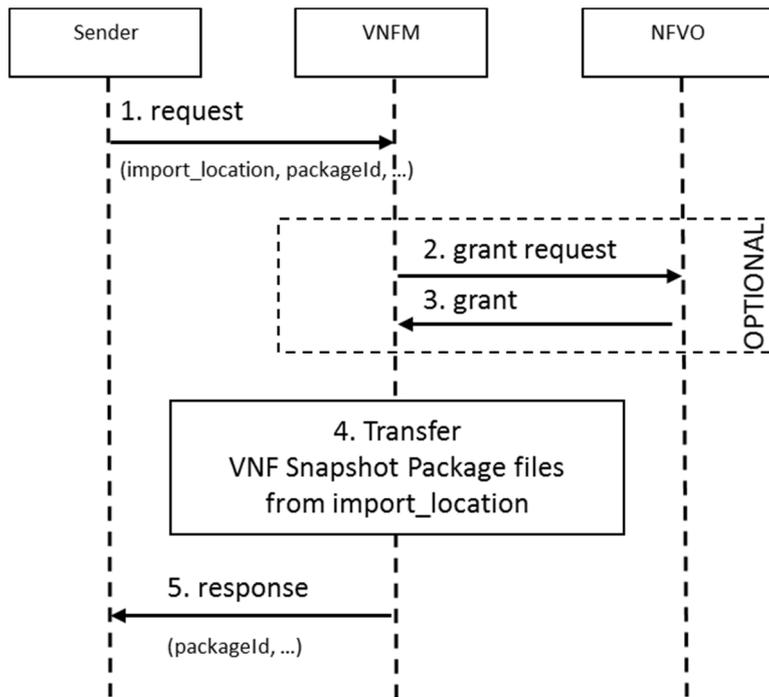


Figure 6.7.4-1: Import VNF Snapshot Package Procedure

6.7.5 Query VNF Snapshot Package Information Procedure

Figure 6.7.5-1 illustrates the procedure of querying VNF Snapshot Package information as defined in clause 3.1.

The main steps of this procedure are:

- 1) The Sender sends a request to the VNFM to query for information it has stored about one or more VNF Snapshot Packages. The request message may include a filter defining the package(s) on which the query applies and selected attributes to be returned matching the filter.
- 2) Optionally, depending on the policies, the VNFM requests grant for the query operation from the NFVO.
- 3) Optionally, depending on the policies, the NFVO grants the query request to the VNFM.
- 4) The VNFM gets the package(s) information satisfying the filter criteria from the VNF Snapshot Package Repository.
- 5) The VNFM returns the package(s) information to the Sender.

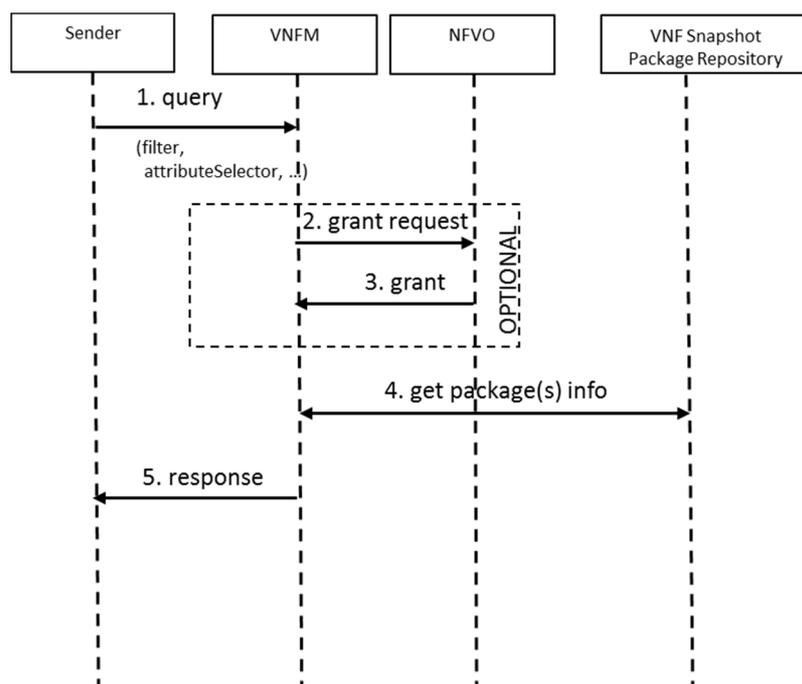


Figure 6.7.5-1: Query VNF Snapshot Package Information Procedure

6.7.6 Delete VNF Snapshot Package Procedure

Figure 6.7.6-1 illustrates the procedure of deleting a VNF Snapshot Package as defined as term in clause 3.1.

The main steps of this procedure are:

- 1) The Sender sends a request to the VNFM to delete a VNF Snapshot Package. The request message includes the identifier of the package to be deleted.
- 2) Optionally, depending on the policies, the VNFM sends a grant request to NFVO.
- 3) Optionally, depending on the policies, the NFVO grants the delete request to the VNFM.
- 4) The VNF Snapshot Package information is deleted from the VNF Snapshot Package repository.
- 5) The VNFM returns the result of the VNF Snapshot Package deletion to the Sender.

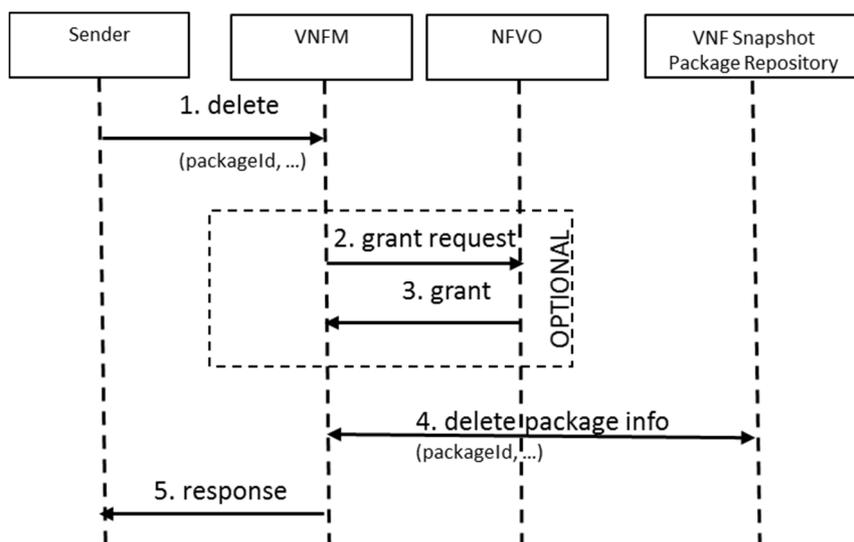


Figure 6.7.6-1: Delete VNF Snapshot Package Procedure

7 Recommendations

7.1 Overview

The recommendations proposed in this clause are based on the gap analysis results described in clause 5.3 and the procedures and solution analysis for VNF/VNFC snapshotting from clause 6. Three types of recommendations are outlined in the following clauses:

- Functional recommendations for the functional blocks of the NFV architecture.
- Recommendations for VNF Snapshot descriptors.
- Recommendations for the reference points and interfaces of the NFV architecture.

The functional recommendations are proposing to specify requirements on the NFVO, VNFM, VIM and NFVI functional blocks in order to extend these functional blocks to support operations on VNF/VNFC Snapshots and VNF/VNFC Snapshot Packages.

The recommendations for VNF Snapshot descriptors list descriptive parameters for the VNF/VNFC Snapshot operations.

The recommendations for the reference points and interfaces are proposing to specify requirements to extend the existing reference points in order to support the identified operations on VNF/VNFC Snapshots and VNF/VNFC Snapshot Packages. Additionally, they recommend to specify requirements for new VNF Snapshot Package management and VNF Snapshot notification interfaces.

All recommendations aim for extending the existing NFV architecture and its respective specifications.

7.2 Recommendations for the NFV-MANO

7.2.1 Recommendations for the NFVO

Table 7.2.1-1 provides functional recommendations for the NFVO.

Table 7.2.1-1: Functional recommendations for the NFVO

Number	Recommendation	Comment
Nfvo.001	It is recommended that a requirement be specified on the NFVO functional block to support granting for VNF/VNFC Snapshot operations.	VNF/VNFC Snapshot operations include VNF/VNFC Snapshot creation and reversion and VNF/VNFC Snapshot Package creation, deletion, extraction, query, import and export.

7.2.2 Recommendations for the VNFM

Table 7.2.2-1 provides functional recommendations for the VNFM.

Table 7.2.2-1: Functional recommendations for the VNFM

Number	Recommendation	Comment
Vnfm.001	It is recommended that a requirement be specified on the VNFM functional block to support the identification of parameters for VNF/VNFC Snapshot operations.	The parameters may be included in incoming requests or provided by means of VNF/VNFC Snapshot descriptors. VNF/VNFC Snapshot operations include VNF/VNFC Snapshot creation and reversion and VNF/VNFC Snapshot Package creation, deletion, extraction, query, import and export.
Vnfm.002	It is recommended that a requirement be specified on the VNFM functional block to support resolving VNFC Snapshots for VNF Snapshot creation and reversion.	Identify the VNFC's and their elements to be included in/reverted for the VNF Snapshot.
Vnfm.003	It is recommended that a requirement be specified on the VNFM functional block to support the creation of and reversion to a VNFC Snapshot.	For content description of a VNFC Snapshot refer to clauses 3.1 and 6.1.1.
Vnfm.004	It is recommended that a requirement be specified on the VNFM functional block to support the creation of and reversion to a VNF Snapshot.	For content description of a VNF Snapshot refer to clauses 3.1 and 6.1.1.
Vnfm.005	It is recommended that a requirement be specified on the VNFM functional block to support the creation, storage, deletion, extraction, import and export of a VNF Snapshot Package.	
Vnfm.006	It is recommended that a requirement be specified on the VNFM functional block to support the query of VNF Snapshot Package Information.	
Vnfm.007	It is recommended that a requirement be specified on the VNFM functional block to support the creation, storage, deletion and extraction of a VNFC Snapshot Package.	
Vnfm.008	It is recommended that a requirement be specified on the VNFM functional block to maintain a VNF/VNFC Snapshot repository.	The VNFM is requested to keep track of the location, content and availability of the VNF/VNFC Snapshots. The physical location of the VNF/VNFC Snapshots may be external to the VNFM.
Vnfm.009	It is recommended that a requirement be specified on the VNFM functional block to maintain a VNF/VNFC Snapshot Package repository.	The VNFM is requested to keep track of the location, content and availability of the VNF/VNFC Snapshot Packages. The physical location of the VNF/VNFC Snapshot Packages may be external to the VNFM.

7.2.3 Recommendations for the VIM

Table 7.2.3-1 provides functional recommendations for the VIM.

Table 7.2.3-1: Functional recommendations for the VIM

Number	Recommendation	Comment
Vim.001	It is recommended that a requirement be specified on the VIM functional block to utilize the Snapshot capabilities supported by the virtualisation technologies.	See tables 5.1.3.2-1 and 5.3-2.
Vim.002	It is recommended that a requirement be specified on the VIM functional block to support the creation of and reversion to a VNFC Snapshot.	For content description of a VNFC Snapshot refer to clauses 3.1 and 6.1.1.
Vim.003	It is recommended that a requirement be specified on the VIM functional block to support the creation and extraction of a VNFC Snapshot Package.	

7.3 Recommendations for VNF Snapshot Descriptor(s)

As outlined in clause 6.1, certain descriptive parameters for VNF Snapshot operations are required. These parameters are recommended to be included in a VNF Snapshot Descriptor. Table 7.3-1 presents a non-exhaustive list of recommended VNF Snapshot Descriptor parameters. It is out of the scope of this report to further specify the format of such a VNF Snapshot Descriptor. The VNF Snapshot Descriptor may be included as part of the VNF Descriptor or may be provided as separate entity, that is also out of the scope of this report and is left for further study.

Table 7.3-1: Recommended VNF Snapshot Descriptor parameters

Number	Recommended parameter	Comment
Vnfsd.001	Indicator if a VNF Snapshot is allowed or forbidden.	
Vnfsd.002	Indicator if a VNF is allowed or forbidden to revert to a VNF Snapshot.	
Vnfsd.003	Identifiers of VNFCs to be snapshotted and to be included in the VNF Snapshot.	
Vnfsd.004	Time periods when a VNF Snapshot is allowed to be taken.	E.g. days of the week and start and stop times.
Vnfsd.005	Indicator per VNFC of Snapshot type, either cold or warm.	Cold snapshots only capture the disks. Warm snapshots capture the disks plus the memory and device states.
Vnfsd.006	Indicator per VNFC of memory Snapshot type, either internal or external.	Only applicable for warm Snapshot type. Refer to clause 5.1.2 "Snapshot techniques".
Vnfsd.007	Indicator per VNFC of disk Snapshot type, either internal or external and either sequential or incremental.	Refer to clause 5.1.2 "Snapshot techniques".
Vnfsd.008	Indicator if the VNF/VNFC Snapshot will be taken in a consistent way.	Consistent snapshots may require to quiesce the resources and preparations in the VNF and unquiesce the resources after the Snapshot was taken.
Vnfsd.009	Indicator per VNFC if the compute resource will be powered off before or after snapshotting.	Values could be [no before after].
Vnfsd.010	Indicator per VNFC if the compute resource will be powered on after snapshotting.	
Vnfsd.011	Indicator per VNFC if the disks will be detached before snapshotting.	
Vnfsd.012	Indicator per VNFC if the disks will be attached after snapshotting.	
Vnfsd.013	Indicator per VNFC if a Snapshot will be taken when the compute resource is powered off.	
Vnfsd.014	Indicator per VNFC if a compute resource will be reverted to a VNFC Snapshot when it is powered on.	
Vnfsd.015	Granting policies for VNF/VNFC Snapshot operations.	VNF/VNFC Snapshot operations include VNF/VNFC Snapshot creation and reversion and VNF/VNFC Snapshot Package creation, query, deletion, extraction, import and export.
Vnfsd.016	Identifier per VNFC of attached volumes to be included in the snapshot.	
Vnfsd.017	Indicator on the order of VNFCs to be snapshotted during VNF Snapshot creation.	
Vnfsd.018	Indicator on the order of VNFCs to be reverted during revert to VNF Snapshot.	

7.4 Recommendations for the NFVI

This clause proposes recommendations for the NFVI functional block of the NFV architecture. The recommendations only address functional capabilities, recommendations on reference points and interfaces are provided in clause 7.5.

Table 7.4-1 provides functional recommendations for the NFVI.

Table 7.4-1: Functional recommendations for the NFVI

Number	Recommendation	Comment
Nfvi.001	It is recommended that a requirement be specified on the NFVI functional block to report/expose supported Snapshot techniques/capabilities to the VIM.	See table 5.3-2 and figure 5.1.1-1.
Nfvi.002	It is recommended that a requirement be specified on the NFVI functional block to support the creation of and reversion to a VNFC Snapshot.	For content description of a VNFC Snapshot refer to clauses 3.1 and 6.1.1.
Nfvi.003	It is recommended that a requirement be specified on the NFVI functional block to support the creation and extraction of a VNFC Snapshot Package.	
Nfvi.004	It is recommended that a requirement be specified on the NFVI functional block to support attaching/detaching virtualised storage resources to/from virtualised compute resources.	
Nfvi.005	It is recommended that a requirement be specified on the NFVI functional block to support quiescing and unquiescing compute resources.	
Nfvi.006	It is recommended that a requirement be specified on the NFVI functional block to support shutting down and starting compute resources.	

7.5 Recommendations for the reference points and interfaces

7.5.1 Recommendations for the Vi-Vnfm reference point

Table 7.5.1-1 provides recommendations for the Virtualised Compute Resources Management interface on the Vi-Vnfm reference point.

Table 7.5.1-1: Recommendations for the Virtualised Compute Resources Management interface on the Vi-Vnfm reference point

Number	Recommendation	Comment
ViVnfm-Vcrm.001	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support detaching virtualised storage resources from virtualised compute resources.	See clause 6.4.1 (Step 9).
ViVnfm-Vcrm.002	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support attaching virtualised storage resources to virtualised compute resources.	
ViVnfm-Vcrm.003	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support quiescing virtualised compute resources.	See clause 6.4.1 (Step 13).
ViVnfm-Vcrm.004	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support unquiescing virtualised compute resources.	See clause 6.4.1 (Step 26).
ViVnfm-Vcrm.005	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support revert to Snapshot virtualised compute resources.	See clause 6.4.3.

Table 7.5.1-2 provides recommendations for the Virtualised Storage Resources Management interface on the Vi-Vnfm reference point.

Table 7.5.1-2: Recommendations for the Virtualised Storage Resources Management interface on the Vi-Vnfm reference point

Number	Recommendation	Comment
ViVnfm-Vsrm.001	It is recommended that a requirement be specified on the Virtualised Storage Resources Management interface to support revert to Snapshot virtualised storage resources.	See clause 6.4.3

7.5.2 Recommendations for the Or-Vi reference point

Table 7.5.2-1 provides recommendations for the Virtualised Compute Resources Management interface on the Or-Vi reference point.

Table 7.5.2-1: Recommendations for the Virtualised Compute Resources Management interface on the Or-Vi reference point

Number	Recommendation	Comment
OrVi-Vcrm.001	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support detaching virtualised storage resources from virtualised compute resources.	See clause 6.4.2 (Step 11).
OrVi-Vcrm.002	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support attaching virtualised storage resources to virtualised compute resources.	
OrVi-Vcrm.003	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support quiescing virtualised compute resources.	See clause 6.4.2 (Step 17).
OrVi-Vcrm.004	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support unquiescing virtualised compute resources.	See clause 6.4.2 (Step 36).
OrVi-Vcrm.005	It is recommended that a requirement be specified on the Virtualised Compute Resources Management interface to support revert to Snapshot virtualised compute resources.	See clause 6.4.4.

Table 7.5.2-2 provides recommendations for the Virtualised Storage Resources Management interface on the Or-Vi reference point.

Table 7.5.2-2: Recommendations for the Virtualised Storage Resources Management interface on the Or-Vi reference point

Number	Recommendation	Comment
OrVi-Vsrm.001	It is recommended that a requirement be specified on the Virtualised Storage Resources Management interface to support revert to Snapshot virtualised storage resources.	See clause 6.4.4.

7.5.3 Recommendations for the Or-Vnfm reference point

Table 7.5.3-1 provides recommendations for the Or-Vnfm reference point.

Table 7.5.3-1: Recommendations for the Or-Vnfm reference point

Number	Recommendation	Comment
Or-Vnfm.001	It is recommended that a requirement be specified on the Or-Vnfm reference point to support a VNF Snapshot Package Management interface (see clause 7.5.4).	

7.5.4 Recommendations for a VNF Snapshot Package Management interface

Table 7.5.4-1 provides recommendations for a VNF Snapshot Package Management interface on the Or-Vnfm reference point.

Table 7.5.4-1: Recommendations for a VNF Snapshot Package Management interface on the Or-Vnfm reference point

Number	Recommendation	Comment
OrVnfm-Vspm.001	It is recommended that a requirement be specified for the VNF Snapshot Package Management interface that the interface is produced by the VNFM.	
OrVnfm-Vspm.002	It is recommended that a requirement be specified on the interface to support querying information about available VNF Snapshot Packages based on input filter criteria.	See clause 5.2.8 and table 5.3-1 Query VNF Snapshot Package Information
OrVnfm-Vspm.003	It is recommended that a requirement be specified on the interface to support deleting VNF Snapshot Packages.	See clause 5.2.9 and table 5.3-1 Delete a VNF Snapshot Package
OrVnfm-Vspm.004	It is recommended that a requirement be specified on the interface to support transferring VNF Snapshot Packages.	See clause 5.2.6 and table 5.3-1 Export a VNF Snapshot Package
OrVnfm-Vspm.005	It is recommended that a requirement be specified on the interface to support storing VNF Snapshot Packages.	See clause 5.2.7 and table 5.3-1 Import a VNF Snapshot Package

7.5.5 Recommendations for the Ve-Vnfm-vnf reference point

Table 7.5.5-1 provides recommendations for the Ve-Vnfm-vnf reference point.

Table 7.5.5-1: Recommendations for the Ve-Vnfm-vnf reference point

Number	Recommendation	Comment
Ve-Vnfm-vnf.001	It is recommended that a requirement be specified on the Ve-Vnfm-vnf reference point to support a VNF Snapshot Notification interface (see clause 7.5.6).	See clauses 6.5.1 and 6.5.2.

7.5.6 Recommendations for a VNF Snapshot Notification interface

Table 7.5.6-1 provides recommendations for a VNF Snapshot Notification interface on the Ve-Vnfm-vnf reference point.

Table 7.5.6-1: Recommendations for a VNF Snapshot Notification interface on the Ve-Vnfm-vnf reference point

Number	Recommendation	Comment
VeVnfmvnf-Vsn.001	It is recommended that a requirement be specified for the VNF Snapshot Notification interface that the interface is produced by the VNFM.	
VeVnfmvnf-Vsn.002	It is recommended that a requirement be specified for the interface to support providing notifications about the Snapshot creation with the list of affected VNFC(s) to the VNF.	See figure 6.5.1-1
VeVnfmvnf-Vsn.003	It is recommended that a requirement be specified for the interface to support providing notifications about the Snapshot reversion with the list of affected VNFC(s) to the VNF.	See figure 6.5.2-1

7.5.7 Recommendations for the Ve-Vnfm-em reference point

Table 7.5.7-1 provides recommendations for the VNF Lifecycle Management interface on the Ve-Vnfm-em reference point.

Table 7.5.7-1: Recommendations for the VNF Lifecycle Management interface on the Ve-Vnfm-em reference point

Number	Recommendation	Comment
VeVnfmem-Vlm.001	It is recommended that a requirement be specified on the VNF Lifecycle Management interface to support requesting to create a Snapshot of a VNF/VNFC instance.	See figures 6.4.1-1, 6.4.2-1 and 6.5.1-1.
VeVnfmem-Vlm.002	It is recommended that a requirement be specified on the VNF Lifecycle Management interface to support requesting to revert to a VNF/VNFC Snapshot.	See figures 6.4.3-1, 6.4.4-1 and 6.5.2-1.

7.5.8 Recommendations for the Os-Ma-Nfvo reference point

Table 7.5.8-1 provides recommendations for the NS Lifecycle Management interface on the Os-Ma-Nfvo reference point.

Table 7.5.8-1: Recommendations for the NS Lifecycle Management interface on the Os-Ma-Nfvo reference point

Number	Recommendation	Comment
OsMaNfvo-Nslm.001	It is recommended that a requirement be specified on the NS Lifecycle Management interface to support requesting to create a Snapshot of a VNF instance.	See table 5.3-1.
OsMaNfvo-Nslm.002	It is recommended that a requirement be specified on the NS Lifecycle Management interface to support requesting to revert to a VNF Snapshot.	See table 5.3-1.

Annex A: Solutions analysed in clause 5 Gap analysis

The analysis of the solutions in clause 5 is based on the following versions of the respective implementations:

Virtualisation technologies:

- QEMU™/KVM: 2.3.1
- ESXi™:ESXi/vSphere® 6.0 Update 2
- runc®: 1.0.0-rc1
- LXC/LXD: lxc-2.0.3; lxd-2.0

Hypervisor abstraction layer:

- Libvirt:1.2.9

Virtualisation management:

- OpenStack: Mitaka
- VMware/vCenter®: 6.0 Update 2
- Docker swarm®: Docker remote API v1.24
- Kubernetes®: v1.3.4

NOTE: QEMU™, ESXi™, vSphere®, vCenter®, Kubernetes®, runc™, DOCKER SWARM™ are examples of suitable products available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of these products.

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Annex C: Change History

Version	Date	Information about changes
V0.0.1	March 2016	Skeleton and ToC based on NFVTST(16)000029r1 Clause 1 - Scope based on NFVTST(16)000034r1 Template for use case descriptions in clause 4 based on NFVTST(16)000035
V0.0.2	May 2016	Clause 4.1.1 on VNF Snapshot during online testing based on NFVTST(16)000053r3 Clause 4.2.1 on VNF Snapshot for root cause analysis based on NFVTST(16)000052r4 Clause 4.3.1 on VNF Snapshot during VNF lifecycle procedure based on NFVTST(16)000047r3 Clause 6.1 Introduction/Concept based on NFVTST(16)000056 r1
V0.0.3	May 2016	Clause 3.1 Term definitions based on NFVTST(16)000070
V0.0.4	July 2016	Clause 4.3.2 on VNF Snapshot for quick VNF recovery based on NFVTST(16)000080r1 Clause 6.1 Introduction/Concept enhanced based on NFVTST(16)000079r1
V0.0.5	July 2016	Document template changed into Group Report according to ETSI template and based on NFVTST(16)000089 Clause 2.1 updated according to ETSI rules and based on NFVTST(16)000088r1
V0.0.6	August 2016	Clause 5.1 on current supporting solutions and new annex A on solutions analysed in clause 5 gap analysis based on NFVTST(16)000096r1
V0.0.7	August 2016	Figure and table captions changed in clause 5.1 to be aligned with NFVTST(16)000096r1 Export/Import instance Snapshot capabilities added to clause 5.1 on current supported solutions based on NFVTST(16)000104 Clause 5.2 on use case analysis based on NFVTST(16)000109
V0.0.8	October 2016	Extensions to definitions and explanations in clauses 3.1 and 6.1.1 to introduce consistent snapshots, based on NFVTST(16)000126r3 Clause 6.4.1 on Create VNFC Snapshot Procedure triggered by EM based on NFVTST(16)000127r2 Clause 6.4.2 on Revert to VNFC Snapshot Procedure triggered by EM based on NFVTST(16)000128r1
V0.0.9	November 2016	Clause 5.3 on Identification of gaps based on NFVTST(16)000149 Alignment with IFA specifications based on NFVTST(16)000153r1
V0.0.10	December 2016	Additions to clause 5.3 Identification of gaps based on NFVTST(16)000156r1 Replaced clause 6.4.1 Create VNFC Snapshot Procedure in direct resource management mode, new clause 6.4.2 Create VNFC Snapshot Procedure in indirect resource management mode, new clause 6.5.1 Create VNF Snapshot Procedure, all based on NFVTST(16)000160r3

Version	Date	Information about changes
V0.1.1	December 2016	<p>Clarification on internal and external disk snapshots in clause 5.1.1 based on NFVTST(16)000210r2</p> <p>Additional VNF Snapshot management procedures for clauses 5.2 and 6.1.2, based on NFVTST(16)000171r2</p> <p>Editorial changes based on NFVTST(16)000178</p> <p>Add missing optional requests to attach the volume and start the compute to the Create VNFC Snapshot procedures in clauses 6.4.1 and 6.4.2 based on NFVTST(16)000200r2</p> <p>Updated clause 6.4.3 "Revert to VNFC Snapshot procedure in direct resource management mode" based on NFVTST(16)000179r1</p> <p>New clause 6.4.4 "Revert to VNFC Snapshot procedure in indirect resource management mode" based on NFVTST(16)000180r1</p> <p>New clause 6.5.2 "Revert to VNF Snapshot procedure" based on NFVTST(16)000181</p> <p>New clause 6.6.1 "Create VNFC Snapshot Package" based on NFVTST(16)000201r1</p> <p>New clause 6.6.2 "Extract VNFC Snapshot Package" based on NFVTST(16)000202</p> <p>New clause 6.7.1 "Create VNF Snapshot Package Procedure" based on NFVTST(16)000189r2</p> <p>New clause 6.7.2 "Extract VNF Snapshot Package Procedure" based on NFVTST(16)000199r1</p> <p>New clause 6.7.3 "Export VNF Snapshot Package Procedure" based on NFVTST(16)000195r2</p> <p>New clause 6.7.4 "Import VNF Snapshot Package Procedure" based on NFVTST(16)000197r1</p> <p>New clause 6.7.5 "Query VNF Snapshot Package Information Procedure" based on NFVTST(16)000196r2</p> <p>New clause 6.7.6 "Delete VNF Snapshot Package Procedure" based on NFVTST(16)000198r1</p> <p>New clause 7.2 "Recommendations for the NFV-MANO" based on NFVTST(16)000182</p> <p>New clause 7.3 "Recommendations for VNF Snapshot Descriptor(s)" based on NFVTST(16)000184r2</p> <p>New clause 7.4 "Recommendations for the NFVI" based on NFVTST(16)000183</p> <p>New clause 7.5.1 "Recommendations for the Vi-Vnfm reference point" based on NFVTST(16)000193</p> <p>New clause 7.5.2 "Recommendations for the Or-Vi reference point" based on NFVTST(16)000191</p> <p>New clauses 7.5.3 "Recommendations for the Or-Vnfm reference point" and 7.5.4 "Recommendations for a VNF Snapshot Package Management interface" based on NFVTST(16)000192</p> <p>New clauses 7.5.5 "Recommendations for the Ve-Vnfm-vnf reference point" and 7.5.6 "Recommendations for a VNF Snapshot Notification interface" based on NFVTST(16)000190</p> <p>New clause 7.5.7 "Recommendations for the Ve-Vnfm-em reference point" based on NFVTST(16)000188</p> <p>New clause 7.5.8 "Recommendations for the Os-Ma-Nfvo reference point" based on NFVTST(16)000194</p>
V0.2.0	January 2017	<p>New definitions of Service Consumer and VNF Provider in clause 3.1, removal of editor's note in clause 4.3.1.2 based on NFVTST(17)000002</p> <p>Inconsistency fixtures for the VNF Snapshot Package repository based on NFVTST(17)000003</p> <p>New clauses 6.6.2 "Create VNFC Snapshot Package Procedure in indirect resource management mode" and 6.6.4 "Extract VNFC Snapshot Package Procedure in indirect resource management mode" based on NFVTST(17)000004</p>
V0.3.1	January 2017	<p>New clause 6.2 "Overview" based on NFVTST(17)000009</p> <p>New clause 6.3 "Framework" based on NFVTST(17)000008</p> <p>New clause 7.1 "Overview" based on NFVTST(17)000007</p> <p>Fixing inconsistencies on the Snapshot repositories based on NFVTST(17)000010</p> <p>Minor editorial changes (fixing spelling, adjust format to ETSI styles)</p>
V0.3.2	January 2017	<p>Editorial changes for compliance to ETSI drafting rules (IDs for informative references changed, heading levels 5.1.1 and 5.2.1 inserted, "shall" replaced by "has to" in clause 7.3)</p>
V0.3.3	February 2017	<p>Editorial changes, adding header 5.1.3.1 and removing leading paragraph in 7.2</p>

History

Document history		
V3.1.1	March 2017	Publication