O-RAN.WG6.ORCH-USE-CASES-v01.00
Technical Specification

Orchestration Use Cases and Requirements for O-RAN Virtualized RAN

Revision History

Date	Revision	Company	Description
11/18/19	David Kinsey, Guy Turgeon, Gil Bullard, Lyndon Ong	AT&T, WRS, Ciena	Updated relationship, functional description and Use Case text
03/11/2020	David, Guy, Lyndon	AT&T, WRS, Ciena	Incorporates CR with comments from Nokia, Ericsson and others
3/20/2020	David, Lyndon, Raghu, Torbjorn	AT&T, Ciena, Ericsson	Incorporates final comments and corrections

Table of Contents

1 Contents

Table of Figures

1. Scope

This Technical Specification has been produced by the O-RAN Alliance.

The contents of the present document are subject to continuing work within O-RAN and may change following formal O-RAN approval. Should O-RAN modify the contents of the present document, it will be re-released by O-RAN with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc. (the initial approved document will have x=01).

y the second digit is incremented when editorial only changes have been incorporated in the document.

z the third digit included only in working versions of the document indicating incremental changes during the editing process.

1.1 References

The following documents contain provisions which, through reference in this text, constitute provisions of this specification.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] ETSI GS NFV 003 V1.4.1, “Terminology for Main Concepts in NFV”

[3] O-RAN-WG1-O-RAN Architecture Description - v01.00.00, “O-RAN Architecture Description”

[4] O-RAN White Paper: “O-RAN: Towards an Open and Smart RAN”, October 2018.

[5] O-RAN.WG1.OAM-Architecture-v03.00: “O-RAN Operations and Maintenance Architecture”.

[6] O-RAN.WG1.O1-Interface.0-v03.00: “O-RAN Operations and Maintenance Interface Specification”.

[7] O-RAN-WG6.CAD-v02.00: “Cloud Architecture and Deployment Scenarios for O-RAN Virtualized RAN”.

[8] O-RAN-WG2. Use Case Requirements v01.00, “Use Case and Requirements Specification v01.00”

1.2 Definitions and Abbreviations

1.2.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

Managed Function	Term used in O-RAN OAM to refer to a distinct *logical* function that is managed. Examples include Near-RT RIC, O-CU-CP, O-CU-UP, O-DU, and O-RU. *From the OAM Framework document:* 3GPP TS 28.622 states that a Managed Function (MF) can represent a telecommunication function either realized by software running on dedicated hardware or realized by software running on NFVI. Each managed function instance communicates with a manager (directly or indirectly) over one or more management interfaces exposed via its containing managed element instance.
Managed Element	Term used in O-RAN OAM to refer to a distinct *physical* or *virtual* element that is managed. The ME will expose its contained MFs and their information models to the SMO through its management interfaces. *From the OAM Framework document:* 3GPP TS 28.622 states that a Managed Element (ME) communicates with a manager (directly or indirectly) over one or more management

interfaces for the purpose of being monitored and/or controlled. Managed elements may or may not additionally perform element management functionality.

1.2.2 Abbreviations

For the purposes of this document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

3GPP	Third Generation Partnership Project
5G	Fifth-Generation Mobile Communications
CNF	Containerized Network Function
DMS	O-Cloud Deployment Management Services
IM	Information Model
IMS	O-Cloud Infrastructure Management Services
LCM	Life Cycle Management
NF	Network Function
NFVI	Network Function Virtualization Infrastructure
O-CU	O-RAN Central Unit as defined by O-RAN Alliance
O-CU-CP	O-CU Control Plane
O-DU-UP	O-CU User Plane
O-DU	O-RAN Distributed Unit (uses Lower-level Split)
O-RU	O-RAN Radio Unit
PNF	Physical Network Function
RAN	Radio Access Network
SMO	Service Management and Orchestration Framework
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
WG	Working Group

2 Objectives

2.1 Context and Relationship to other WG6 and O-RAN Work

This document introduces different use cases for O-RAN orchestration of virtualized RAN and the interfaces used for management and orchestration, in particular the O1 interface between the service management and orchestration framework and the RAN managed functions and the O2 interface between the service management and orchestration framework and the O-Cloud Infrastructure Management Services/Deployment Management Services that controls resource assignment for Virtualized Network Functions.

This document relies on WG1 architecture documents for the overall architecture. WG6 focuses on end-to-end orchestration in O-RAN and virtualization/cloudification of O-RAN functions.

The following documents are used as input on high level O-RAN OAM architecture and functions:

- WG1 O-RAN architecture [3]
- WG1 OAM architecture [5]
- WG1 OAM interface specification (O1) [6]

In addition, the WG6 CADS specification [7] is referenced for input on cloud architecture and terminology.

The details of implementing orchestration interfaces and models will be covered in follow on documents, such as are shown in purple in Figure 1. The dashed lines indicate where documents are to be added at a future date.

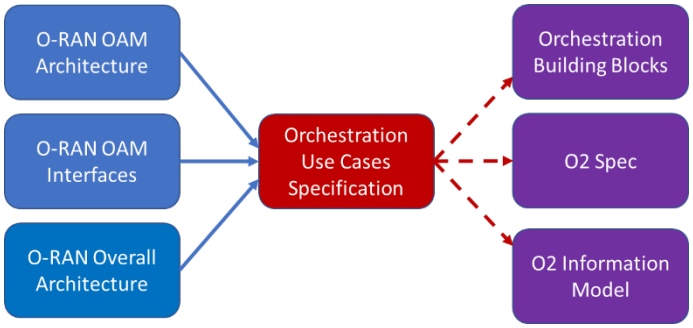


Figure 2-1: Relationship of this Document to Scenario Documents and O-RAN Management Documents

This document also draws on some other work from other O-RAN working groups such as WG2 for Non-RT RIC details, as well as sources from other industry bodies.

2.2 Objectives of this Document

The O-RAN Alliance seeks to improve RAN flexibility and deployment velocity, while at the same time reducing the capital and operating costs through the adoption of cloud-based architectures.

A key principle is the decoupling of RAN hardware and software for all components including O-CU, O-DU, and O-RU, and the deployment of software components on commodity server architectures supplemented with programmable accelerators where necessary.

Given that the RAN environment will consist of a range of different components that can be realized by either PNFs or VNFs/CNFs it is critical to understand the coordination of RAN components done by the Service Management and Orchestration Framework to deploy and operate RAN services in an O-RAN architecture.

This document defines example end-to-end use cases and OAM interface requirements to support the O-RAN architecture.

2.3 Relationship to O-RAN OAM Architecture

This document follows the high level O-RAN OAM Architecture defined in O-RAN WG1. The high level OAM Architecture is given below in Figure 2 as taken from [3] but focusing on OAM interfaces O1 and O2 only.

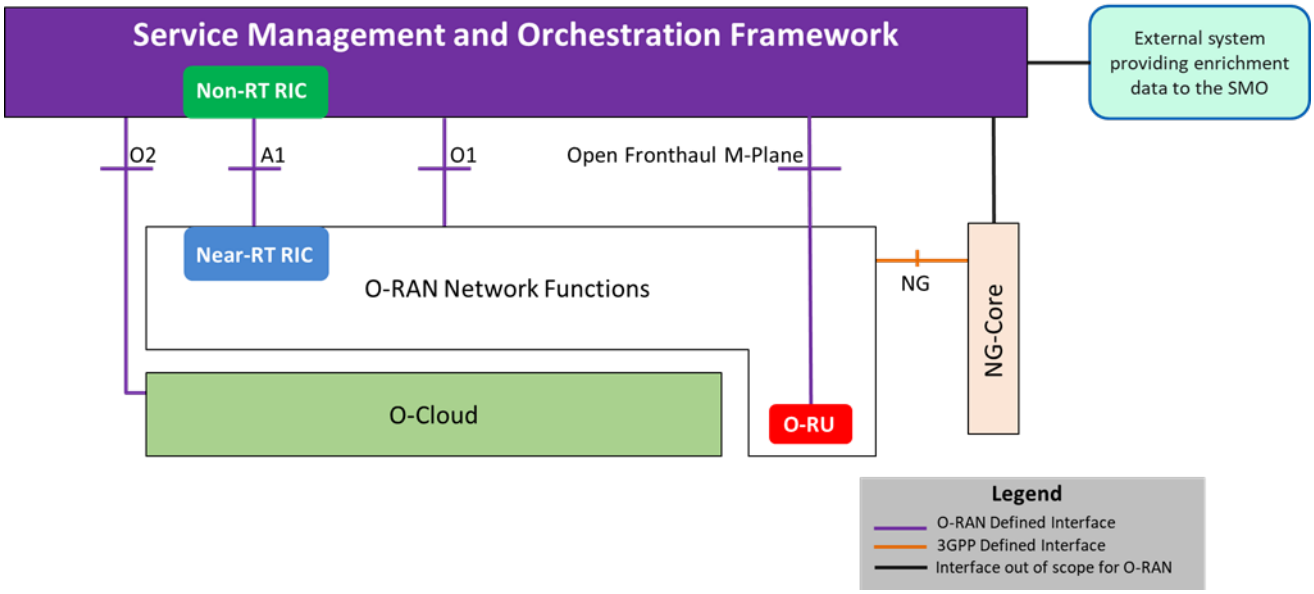


Figure 2: O-RAN Architecture and Management Interfaces

The Use Cases in this document describe the use of the O1 and O2 interfaces for orchestration within an O-RAN.

2.4 Functional Description of O-RAN Cloud Infrastructure

This document uses terminology for O-Cloud components taken from the Cloud Architecture and Deployment Scenarios for O-RAN virtualized RAN Specification [7], including the O-Cloud Node, O-Cloud Infrastructure Management Services, and O-Cloud Deployment Management Services .

3 Orchestration Use Cases

These Use Cases focus on the private cloud case where the cloud is managed by the operator. Applicability to the public cloud case is for further study.

3.1 O-Cloud Basic Use Cases

Cloud Platforms must be identified for the SMO to take advantage of them. In traditional data center clouds these have been manually or externally added to the SMO for homing of cloudified workloads since the numbers are typically low from hundreds of cloud regions to even several thousand. However, in the case of edge clouds the number of deployments scale into the 10K to 100K range, in which case this process needs to more closely resemble the way RAN elements are “discovered”. Even in this latter case, the rationale for edge clouds is for specific performance requirements, therefore not all edge clouds are equivalent. In this example we examine how the SMO will discover and manage a cloud implementation that meets the O-RAN specifications as described in the Cloud Architecture and Deployment Scenarios for O-RAN virtualized RAN [6]. Such a cloud instance is generally referred to as an O-Cloud which is comprised of Cloud Nodes (Compute, Storage, and Network), dedicated resources for the O-Cloud Management Software and the O-Cloud Management Software itself.

This group of Use Cases includes the following:

- Pre-processing where before the O-Cloud is activated the SMO is configured with the identity of the O-Cloud so that registration can be done
- Basic platform software installation by the SMO and O-Cloud Infrastructure Management Services
- O-Cloud deployment processing where the O-Cloud registers with SMO and has its identity and software version checked
- Capabilities Exchange where the SMO either queries for O-Cloud capabilities or is notified autonomously that there has been a change in O-Cloud capabilities
- O-Cloud hardware upgrade where a new O-Cloud Node is added
- O-Cloud software upgrade where new platform software is added to the O-Cloud

The end result of the group of use cases is an active O-Cloud registered with SMO and ready for the deployment of Network Functions.

Note: where Personnel are shown as part of the Use Case, the roles and terminology used are given for purposes of illustration only.

3.1.1 O-Cloud Pre-Deployment Processing Use Case

3.1.1.1 High Level Description

This Use Case describes the SMO being configured to add an O-Cloud into its inventory prior to the O-Cloud itself being activated and attempting to register with the SMO.

The Use Case assumes that this will be part of a sequence of “Service Requests” to the SMO, one for the deployment of the O-Cloud and one for the Network Function(s) that will run on that O-Cloud instance. In the latter request, information is assumed to be present on the NF Service Requests to identify the O-Cloud instance, as described in a later Use Case. Note: in some cases, there could potentially be a single “Service Request” to SMO containing information about both the O-Cloud and Network Function(s) that will run on that O-Cloud instance, but this is not covered in the Use Case.

206 ### 3.1.1.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	SMO is aware of the Correlation Id used to associate the information on the northbound request with the registration event that will be eventually received from the O-Cloud instance.	
Actors and Roles	RAN Planner: Cloud Planner: Cloud Installation Project Manager: O-Cloud Vendor SMO: O-Cloud M&O	
Assumptions	1) The “Service Request” to the SMO will capture the “Correlation id” that identifies the O-Cloud instance in a globally unique manner. (This will be used to correlate the “service request” with the registration event.)	
Pre conditions	1) SMO is available 2) RAN Planner creates RAN Buildout Plan of Record and sends to Cloud Planner; 3) Cloud Planner sends Cloud Blueprint to Cloud Install Project Manager; 4) Cloud Install Project Manager interacts with O-Cloud Vendor to identify the future O-Cloud instance and retrieve an Instance Correlation ID	
Begins when	Decision to deploy an O-Cloud to support RAN growth/coverage has been made.	
Step 1 (M)	Cloud Install Project Manager requests SMO to update its Inventory with a new O-Cloud instance and its associated Correlation ID	
Step 2 (M)	SMO updates its inventory with the Correlation ID and waits for Registration Event from the O-Cloud	
Ends when	SMO has updated inventory with the Correlation ID of the O-Cloud	
Exceptions	None identified	
Post Conditions	SMO is ready for O-Cloud registration	
Traceability	REQ-ORC-GEN1; REQ-ORC-GEN2	

207

208 ### 3.1.1.3 UML sequence diagram

209

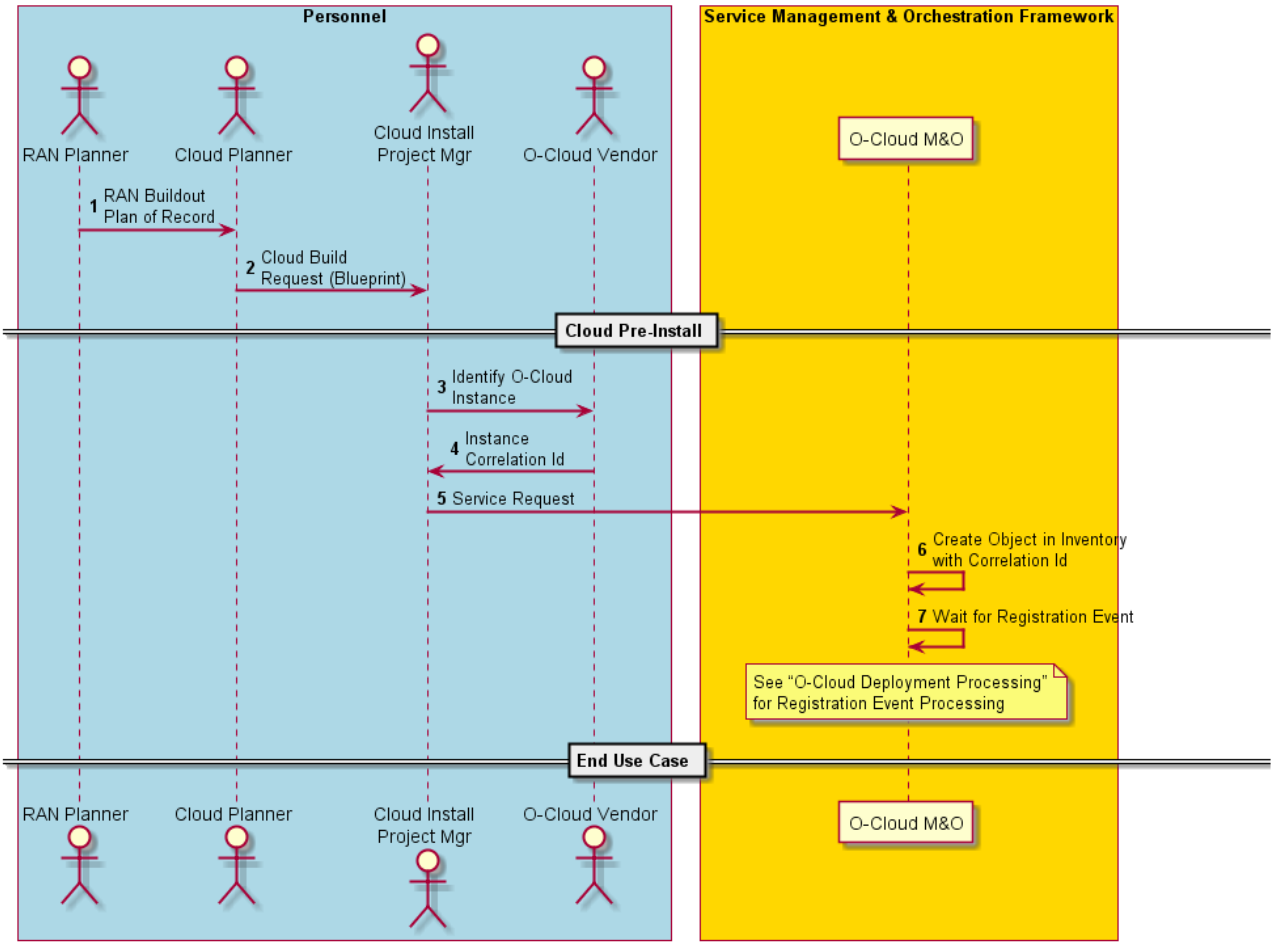


Figure 3-1:O-Cloud Pre-Deployment Processing

3.1.2 O-Cloud Infrastructure Software Installation Use Case

3.1.2.1 High Level Description

The Use Case describes the deployment of the O-Cloud and installation of basic Cloud Management Software on an O-Cloud Node. The Cloud Installer begins the installation by installing the new O-Cloud hardware and notifying SMO to begin Cloud Build. SMO then loads basic Cloud Management Software on a first server in the O-Cloud, which then brings up any additional servers in the O-Cloud.

During activation of other servers, the O-Cloud Management Plane activates O-Cloud Infrastructure Management Services (IMS), which then notifies the SMO of its availability. The SMO then sends IMS the required set of O-Cloud Node Roles and Personalities to support. The IMS loads necessary software onto the other O-Cloud Nodes and also configures and activates one or more O-Cloud Deployment Management Services (DMSs).

3.1.2.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Cloud Management Software on the O-Cloud is initialized and communicating with the SMO.	
Actors and Roles	Cloud Installation Project Manager: Cloud Installer: SMO: O-Cloud M&O O-Cloud/ Infrastructure Management Services (IMS) O-Cloud/Deployment Management Services (DMS) O-Cloud/Cloud Node:	
Assumptions	1) Through some means an application will be loaded to the O-Cloud, that application at minimum having the following abilities: a. Having knowledge of its own IP address, the IP address endpoint or url of the SMO and any necessary security keys or passwords for communication using O2. b. Being able to communicate at least the IMS Address endpoint and Correlation Id of this O-Cloud instance. c. Being able to generate a registration event to the SMO including its Correlation ID. d. Being able to process requests to load SW onto an O-Cloud Node in the Cloud Platform	
Pre conditions	1) SMO is available 2) Network connectivity exists between the O-Cloud and SMO 3) SMO has basic software for the O-Cloud available for download	
Begins when	Work order triggers O-Cloud installation processing.	
Step 1 (M)	Cloud Install Project Manager generates a work order to the Cloud Installer for the new O-Cloud; Cloud Installer installs the new O-Cloud servers and responds to Project Manager	
Step 2 (M)	Cloud Installer notifies SMO of the new O-Cloud Build Note: Cloud Installer must provide SMO with information to connect with the new O-Cloud Build, including the target server in the O-Cloud and identity of the basic software package to be loaded on the O-Cloud	
Step 3 (M)	SMO loads basic software on the first server in the O-Cloud; First server then brings up additional servers in the O-Cloud including O-Cloud Infrastructure Management Services (Note: details of how the IMS and other servers are brought up are specific to the O-Cloud implementation)	
Step 4 (M)	O-IMS brings up other O-Cloud Nodes and activates DMS.	
Ends when	O-Cloud is running with successfully installed IMS and DMS	
Exceptions	None identified	
Post Conditions	O-Cloud ready to register with SMO	
Traceability	REQ-ORC-GEN3; REQ-ORC-GEN4; REQ-ORC-GEN5; REQ-ORC-O2-1; REQ-ORC-O2-2	

3.1.2.3 UML sequence diagram

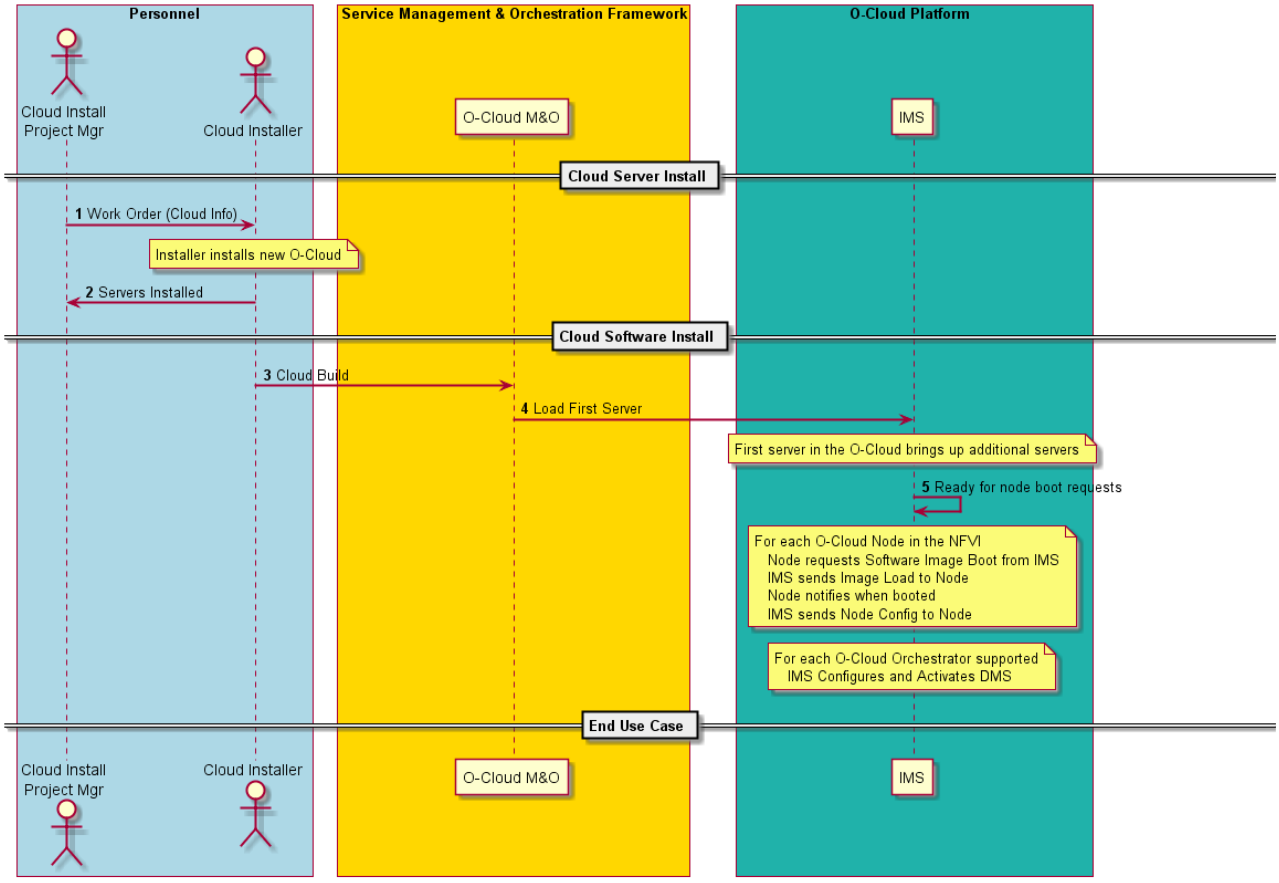


Figure 3-2: Infrastructure Software Installation

3.1.3 O-Cloud Deployment Processing Use Case

3.1.3.1 High Level Description

This Use Case describes the deployment of the O-Cloud.

3.1.3.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Cloud Management Software is initialized and registered with the SMO, ready for workloads to be deployed.	
Actors and Roles	SMO: O-Cloud M&O O-Cloud/ Infrastructure Management Services (IMS) O-Cloud/Deployment Management Services (DMS) O-Cloud/Cloud Node:	
Assumptions	SMO is ready for O-Cloud registration	
Pre conditions	1) SMO is available 2) Network connectivity exists between O-Cloud and SMO 3) SMO has been configured with O-Cloud ID in its inventory	
Begins when	IMS is ready to register O-Cloud to accept new workloads	
Step 1 (M)	O-Cloud Infrastructure Management Services notifies SMO that it is available and provides its Correlation ID; It may optionally provide more information such as flavors or SMO may determine this using the Capabilities Exchange procedure below.	
Step 2 (alt)	SMO checks to see if its Inventory has this Correlation ID. 1) If Correlation ID is not found in Inventory: a. SMO ignores Notification Event b. SMO may notify the Cloud Project Manager of an unexpected registration attempt 2) If Correlation ID is found in Inventory: a. SMO updates Inventory with O-Cloud Infrastructure Management Services' endpoint address b. SMO queries IMS for current software inventory	
Step 3 (alt)	SMO checks software inventory. 1) If SW inventory does not match required inventory: a. SMO downloads updated software inventory to IMS b. IMS installs new inventory, activates and notifies SMO it is available c. return to Step 2 2) If SW inventory is correct, continue to next Step	
Step 4 (M)	SMO configures O-Cloud	
Step 5 (M)	SMO queries O-Cloud to discover and Inventory new O-Cloud Deployment Management Services O-Cloud returns list of new O-Cloud Deployment Management Services end points	
Ends when	O-Cloud has registered with SMO and SMO has checked software version, configuration, and available DMS	
Exceptions	Correlation ID not found in inventory	
Post Conditions	O-Cloud ready to support new NF workloads	
Traceability	REQ-ORC-GEN6; REQ-ORC-GEN7; REQ-ORC-GEN8; REQ-ORC-GEN9; REQ-ORC-O2-3; REQ-ORC-O2-4; REQ-ORC-O2-5; REQ-ORC-O2-6	

3.1.3.3 UML sequence diagram

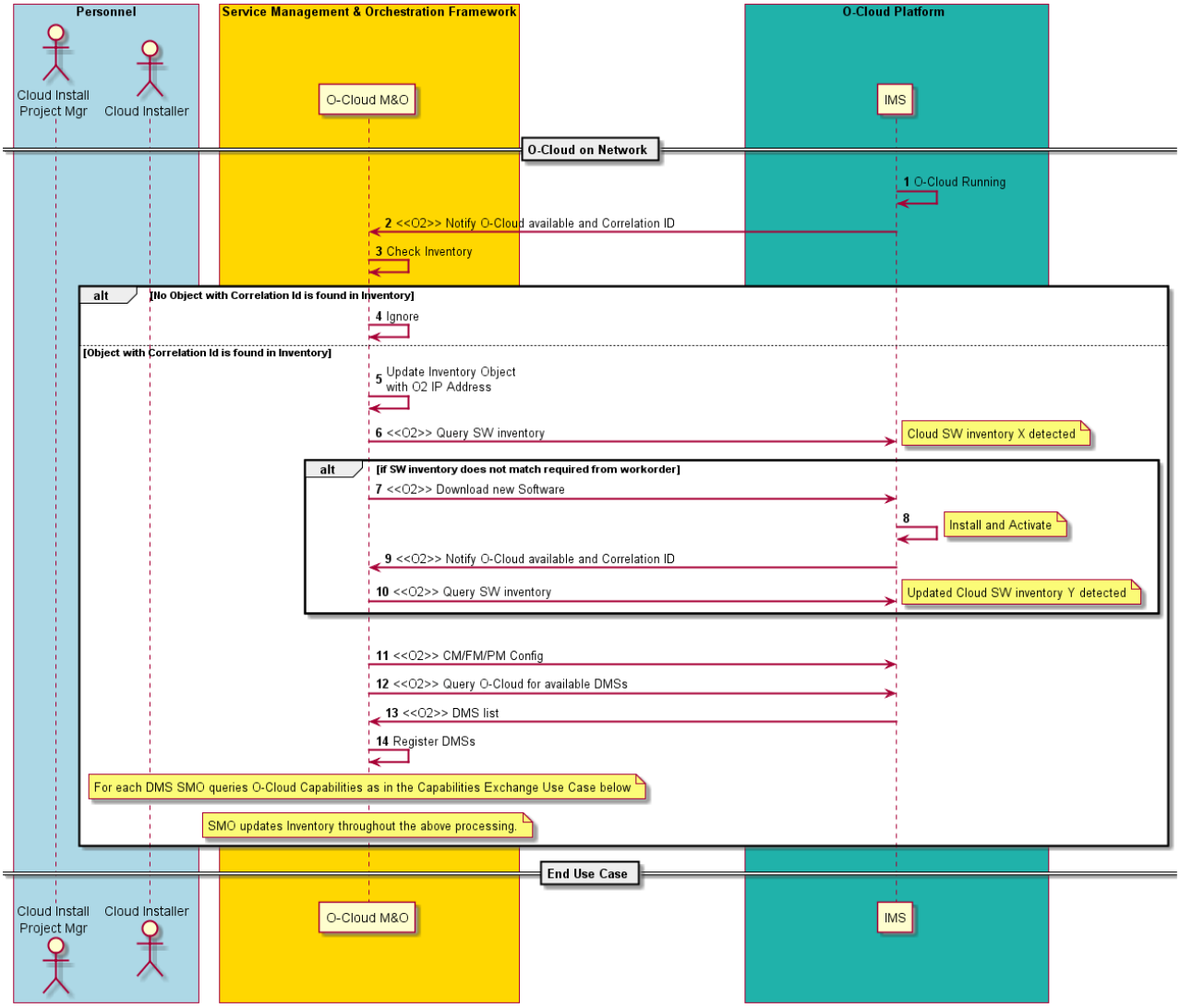


Figure 3-3: Deployment Processing

3.1.4 O-Cloud Capabilities Exchange Use Case

3.1.4.1 High Level Description

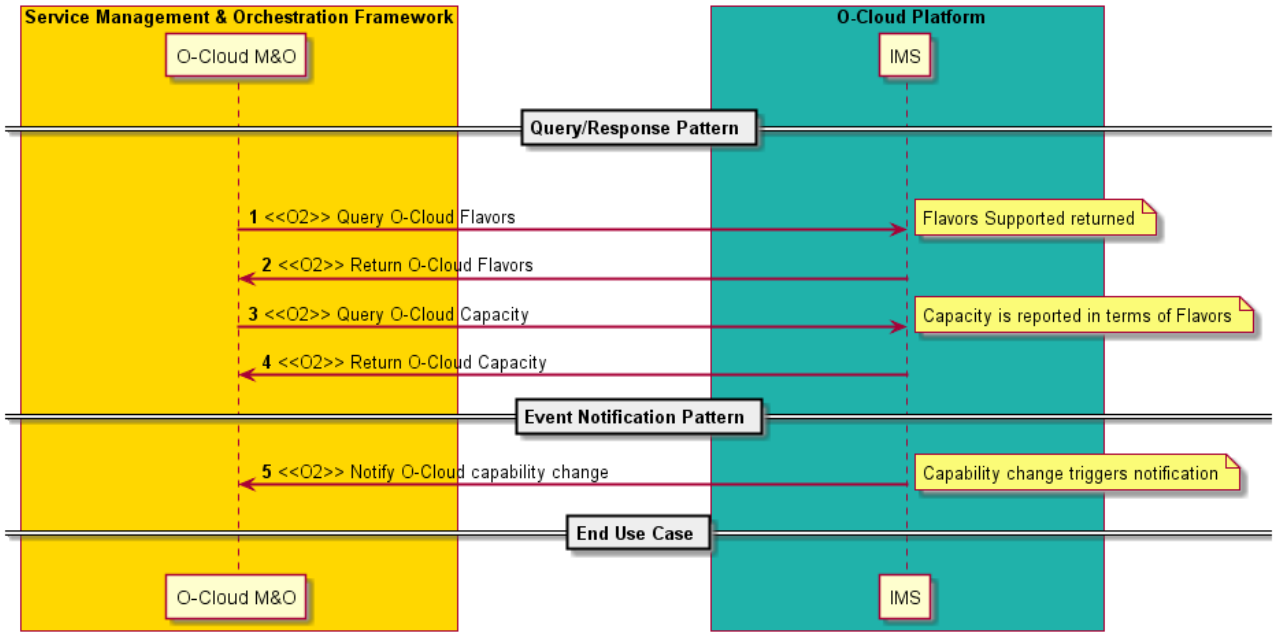
This Use Case describes the procedure for the SMO and O-Cloud to exchange information about its type and current capabilities, including resource build configurations (aka "flavors"). This procedure is invoked initially at deployment of the O-Cloud and can be invoked at later times to identify changes in the capabilities of the O-Cloud. Two patterns are possible, one using query/response from the SMO in order to get current capability status, e.g., before deploying a new workload and one using autonomous indications from the O-Cloud when there has been a change in capability status.

246 ### 3.1.4.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Cloud Platforms are powered on, Cloud Management Software is initialized and communicating with the SMO, ready for workloads to be deployed.	
Actors and Roles	Cloud Installation Project Manager Cloud Installer SMO: O-Cloud M&O O-Cloud/O-Cloud Infrastructure Management Services (IMS) O-Cloud/O-Cloud Node	
Assumptions	1) Notification Event has been configured into the O-Cloud Infrastructure Management Services by the SMO 2) SMO may invoke query/response for current O-Cloud capabilities as triggered by, for example, need to determine if the O-Cloud has capacity to support a new workload deployment.	
Pre conditions	1) SMO is available 2) O-Cloud has been installed and activated 3) SMO has registered O-Cloud and software version in its inventory	
Begins when	1) SMO is deploying or scaling up a new O-cloud or 2) SMO determines that it needs to query O-cloud to determine if O-cloud can support a new workload or 3) Capabilities change has occurred in the O-cloud and SMO has previously subscribed to notification of capability changes.	
Step 1 (alt)	In the Query/Response pattern, the SMO sends query to IMS to determine O-Cloud Flavors/Types IMS responds with what it supports	
Step 2 (O)	SMO sends query to IMS to determine capacity and/or other characteristics of the O-Cloud IMS responds with capacity per flavor	
Step 3 (alt)	In the Event Notification pattern, IMS sends notification event to the SMO due to a change in capabilities, where SMO has previously configured IMS to send a notification when such a change occurs	
Ends when	SMO is notified of O-Cloud capabilities status	
Exceptions	None identified	
Post Conditions		
Traceability	REQ-ORC-GEN10; REQ-ORC-GEN11; REQ-ORC-GEN12; REQ-ORC-GEN13; REQ-ORC-O2-7; REQ-ORC-O2-8	

247

248 ### 3.1.4.3 UML sequence diagram



249

Figure 3-4: Capabilities Exchange

3.1.5 Hardware Infrastructure Scaling of O-Cloud Post Deployment

3.1.5.1 High Level Description

After the initial deployment of an O-Cloud, it may be necessary to scale up resources at a site. In this example, we examine how the SMO will discover and manage a new cloud node that has been cabled and powered up to be part of an existing cloud.

3.1.5.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Additional cloud nodes are powered on for an existing cloud; Cloud Management Software initializes new cloud platforms and communicates the presence of additional resources to SMO.	
Actors and Roles	Cloud Planner Cloud Installer SMO/ O-Cloud M&O O-Cloud/O-Cloud Infrastructure Management Services O-Cloud/O-Cloud Node	
Assumptions	1) The additional O-Cloud Node is cabled to be part of the existing O-Cloud at the site	
Pre conditions	1) SMO is available 2) O-Cloud is operational and known to SMO 3) Network connectivity exists between the O-Cloud and the SMO	
Begins when	Decision to add additional resources to an existing O-Cloud has been made.	
Step 1 (M)	Cloud Planner notifies Cloud Installer of the need to add node(s) to the existing O-Cloud deployment	
Step 2 (M)	New O-Cloud Node is deployed and interacts with its IMS to get software load and configuration	
Step 3 (M)	IMS notifies SMO that new node is now available	
Ends when	O-Cloud has added new O-Cloud Node	
Exceptions	None identified	
Post Conditions	SMO may follow with a Query Capabilities procedure	
Traceability	REQ-ORC-GEN14; REQ-ORC-GEN15; REQ-ORC-O2-8	

3.1.5.3 UML sequence diagram

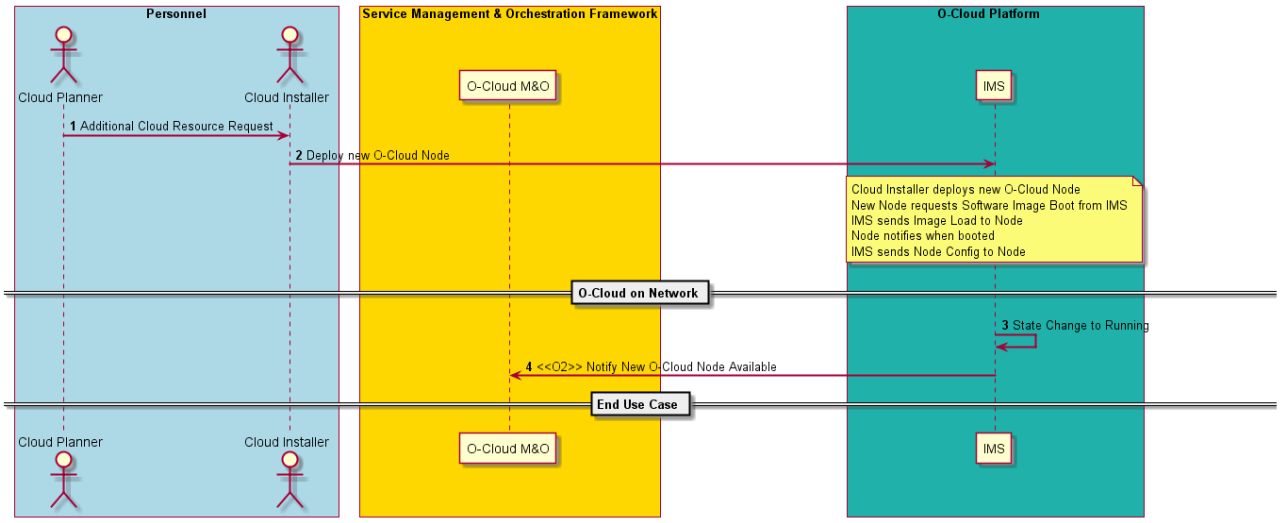


Figure 3-5: Hardware Infrastructure Scaling

3.1.6 O-Cloud Platform Software Upgrade Use Case

3.1.6.1 High Level Description

Edge clouds deployments can range in the 10K to 100K range across an operator network. Rolling edge cloud infrastructure software upgrades need to be performed without service disruption for both VM and container based workloads. Across a region, it may be necessary to upgrade all edge clouds in a serial fashion in order to minimize potential disruptions or in a parallel fashion where a set amount of edge clouds in a region are simultaneously upgraded. Compute and storage nodes of individual edge clouds can also be upgraded in a serial or parallel hitless fashion. Within an individual O-Cloud, the IMS migrates Network Function workloads from the affected Cloud Nodes before the software upgrade in order to avoid service disruption. From an SMO perspective, offloading the upgrade strategy of an edge cloud to a regional and local controller substantially reduces the upgrade complexity.

Fault handling of an O-Cloud upgrade is critical. Individual nodes can fail during the upgrade process and may need to be replaced. Rolling back of the upgrade prior to a successful completion must also be supported.

In this example, we examine how the SMO will upgrade a single O-Cloud. It is assumed that the software upgrade does not affect the IMS itself, and that the IMS is capable of performing the software upgrade and migrating NF workloads from the affected O-Cloud Nodes without affecting active services.

3.1.6.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Upgrade the infrastructure software of an existing O-Cloud	
Actors and Roles	Cloud Maintainer SMO/O-Cloud M&O O-Cloud/O-Cloud Infrastructure Management Services O-Cloud/O-Cloud Node	
Assumptions	Software update to cloud platform software is available IMS supports software upgrade and workload migration	
Pre conditions	1) SMO is available 2) O-Cloud is operational and known to SMO 3) Compute resources are available at the edge cloud in order to support workload migration during the upgrade process. 4) All O-Cloud infrastructure software is patch current 5) The O-Cloud is healthy with no unexpected alarms	
Begins when	Decision to upgrade the cloud platform software infrastructure is made.	
Step 1 (M)	Operator Cloud Maintainer requests that SMO upgrade platform software on an existing O-Cloud instance.	
Step 2 (M)	SMO starts platform software download and validate procedure at the O-Cloud	
Step 3 (M)	IMS gets new software package from SMO and validates internally; IMS notifies SMO that software download is complete	
Step 4 (M)	SMO requests pre-check procedure be done by IMS to determine if software update is acceptable or will cause reset; IMS responds with pre-check response	
Step 5 (M)	If the pre-check indicates update is acceptable: 1) SMO directs IMS to activate the software update; 2) IMS migrates workloads from affected O-Cloud Nodes - note original requirements for these workloads must continue to be met; 3) IMS upgrades software image on the affected O-Cloud Nodes; 4) The request from SMO must indicate if restart is required, if so perform restart. If the pre-check indicates update is not acceptable, complete procedure	
Step 6 (M)	IMS determines that O-Cloud Node has upgraded software and is in running state; IMS notifies SMO that O-Cloud software has been upgraded and SMO updates its inventory.	
Ends when	O-Cloud Node has upgraded software successfully	
Exceptions	Software update is not acceptable, in which case upgrade does not proceed	
Post Conditions		
Traceability	REQ-ORC-GEN16; REQ-ORC-GEN17; REQ-ORC-O2-11	

3.1.6.3 UML sequence diagram

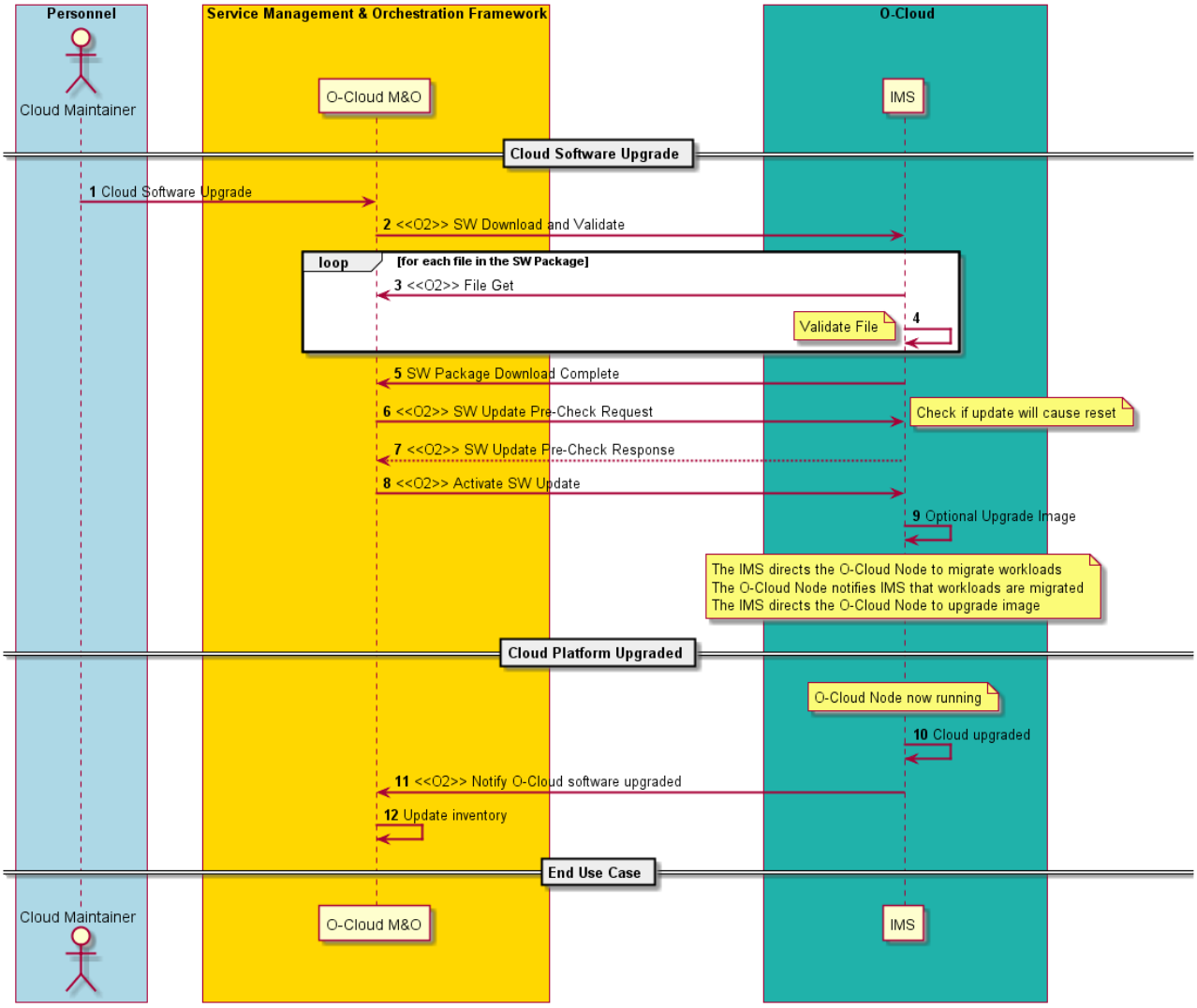


Figure 3-6: Platform Software Upgrade

3.2 Network Function Basic Use Cases

3.2.1 Instantiate Network Function on O-Cloud

3.2.1.1 High Level Description

This Use Case describes the instantiation of a Network Function as a new deployment on an O-Cloud Node, and notification to the SMO of the activation of the Network Function.

Note: the instantiation on the O-Cloud Node may be part of a larger procedure instantiating multiple connected Network Functions, in which case the SMO will coordinate the timing of instantiation across O-Clouds and O-Cloud Nodes, the configuration of transport needed between O-Cloud Nodes and other requirements such as addressing and security used for connecting the Network Functions as below.

3.2.1.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Network Function workloads are deployed resulting in live Network Function instances that are configured and communicating with the SMO.	
Actors and Roles	Cloud Installation Project Manager SMO:O-Cloud M&O SMO:OAM Functions O-Cloud/O-Cloud Deployment Management Services Network Function (Application)	
Assumptions	1) The "Service Request" to the SMO for the new Network Function will capture at a minimum: a. The desired "Network Function" (NF) or type(s) associated with the O-Cloud (e.g., RIC, CU-CP, SEBA) b. Other NF type-specific information (e.g., for a RAN NF type, the "parent" instance in the NF hierarchy) 2) Note: as noted in a previous use case, this may be triggered by a separate request for the new Network Function or the original request for the O-Cloud deployment	
Pre conditions	1) SMO is available 2) The O-Cloud instance has been installed successfully as per "O-Cloud Deployment Processing" use case. 3) NF package has been onboarded onto the SMO containing a descriptor that provides the deployment requirements for the NF.	
Begins when	New Network Function is to be deployed as a workload on an O-Cloud	
Step 1 (M)	Network Function Install Project Manager makes request to SMO to deploy new Network Function(s) on the O-Cloud	
Step 2 (alt)	Request from the Install Project Manager does not specify where the Network Function needs to be deployed, and SMO selects an O-Cloud to use to deploy the new Network Function. Note: This can range from a trivial exercise (e.g., the Service Request identifies the target O-Cloud by Correlation Id) to a highly complex exercise (if the SMO were to determine an appropriate vacant O-Cloud instance based on homing policies such as latency tolerance, NF requirements to cloud capability matching, etc.).	
Step 3 (alt)	Alternatively, the request from the Network Function Install Project Manager may specify information about where the Network Function needs to be deployed	
Step 4 (M)	For each Network Function in the request: - NF is to be assigned to a specific O-Cloud - SMO tells the DMS on that O-Cloud to create the new workload - DMS notifies SMO that the workload creation is complete and SMO updates its inventory accordingly - Note: the NF must be configured by DMS with the SMO's O1 address and security key information to support connectivity for Step 5	
Step 5 (O)	For each newly deployed NF (now using O1) as needed: - SMO configures the NF using the O-RAN Provisioning Management Services [6] - SMO may optionally configure the NF in a single step or in multiple steps as desired. For example, SMO may choose to configure separately basic telecom, optional features, FM, PM, etc. - SMO also updates addressing, security and transport in other RAN NFs to support connectivity to the new NF - Note: if multiple NFs are being deployed, the order in which SMO configures them and activates them may depend on their relationship, also addressing requirements include other O-RAN interfaces required for the NF beyond the O1 interface	
Ends when	Network Function(s) have been deployed as workload(s) on the O-Cloud and configured by the SMO	
Exceptions	None identified	
Post Conditions		
Traceability	REQ-ORC-GEN18; REQ-ORC-GEN19; REQ-ORC-GEN20; REQ-ORC-O1-1; REQ-ORC-O2-11	

3.2.1.3 UML sequence diagram

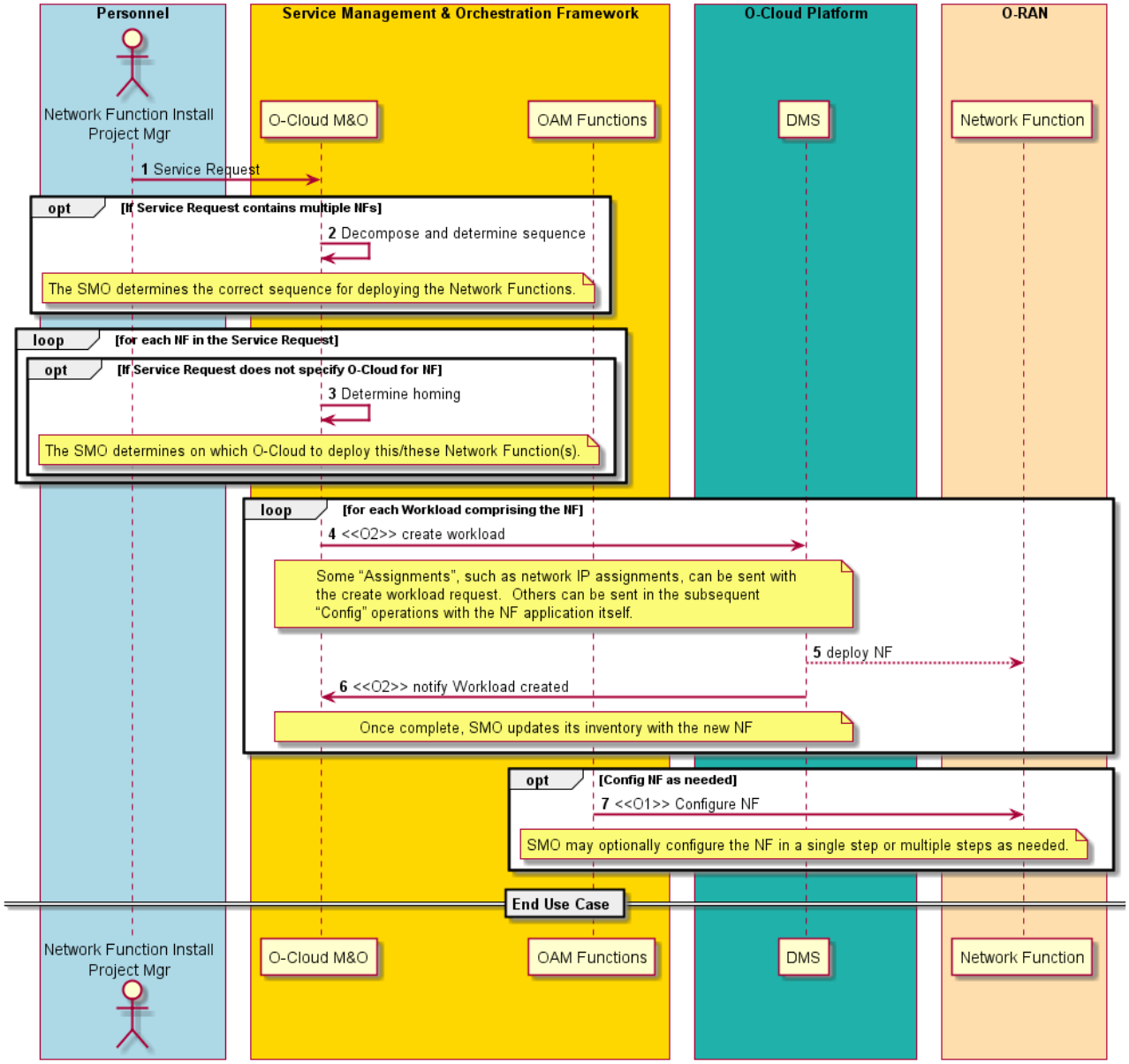


Figure 3-7: Instantiate Network Function

3.2.2 Scale Out/Scale In of NF

3.2.2.1 High Level Description

This Use Case describes how to deploy additional workloads to expand the capacity of the NF or to reduce the number of workloads deployed when the capacity is no longer needed. This allows the NF to only consume the resources it needs based on the level of demand based on network traffic.

3.2.2.2 Sequence Description

The Sequence Description and UML Sequence Diagram for this Use Case are for further study.

3.2.3 Software Upgrade of NF

3.2.3.1 High Level Description

This Use Case describes how to upgrade the software used to create a cloud native implementation of the Network Function. This covers the software deployment and its activation. Once activated the NF must be configured by SMO similar to the NF deployment use case.

This use case will illustrate the cloud native approach of build-and-replace. Other approaches could be developed specific to containerization such as break-fix, or the PNF form of Upgrade-in-place. More complex scenarios such as support of zero traffic loss may be explored in future versions.

3.2.3.2 Sequence Description

The Sequence Description and UML Sequence Diagram for this Use Case are for further study.

3.3 Multi-vendor network provisioning in a mixed PNF/VNF environment

A Use Case description of multi-vendor provisioning of an O-RAN service can be found in the O-RAN OAM Architecture specification [5].

3.4 Reconfiguration of O-RAN Virtual Network Function(s)

3.4.1 High Level Description

A common orchestration request is the reconfiguration of one or a set of cloud-based O-RAN Virtual Network Functions in order to affect the behavior of the RAN. The action taken could be, for example, to re-optimize network traffic patterns or update the load balancing of traffic across the RAN network. The trigger for this action could be any number of events such as non-real time traffic analysis by the Non-RT RIC, or input from non-RAN sources such as upcoming natural events or scheduled human events.

In such cases the SMO will either be told or determine by its own analysis which Virtual Network Functions need reconfiguration and in which order this is done if multiple Virtual Network Functions are involved. If a problem develops during reconfiguration then SMO may optionally invoke a fallback procedure to revert the Virtual Network Functions to their original configuration. As in reconfiguration of PNFs, O1 Interface [6] Provisioning Management is used.

Note: there may be a need for SMO to initially reroute traffic away from the affected Virtual Network Functions and subsequently revert traffic to the original patterns. This could be done by using Network Function Reconfiguration on adjacent Network Functions that send or receive information from the affected Network Functions.

3.4.2 Sequence Description

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Reconfigure O-RAN Virtual Network Functions based on the need to modify RAN network behavior, for example re-optimize traffic patterns or load balance traffic in response to new conditions.	
Actors and Roles	SMO:OAM Functions SMO/Non-RT RIC: source point for RAN policy control function Other RAN Elements: O-CU, O-DU	
Assumptions	1) All relevant functions and components are instantiated. 2) O1 interface connectivity is established with RAN elements. 3) SMO will reconfigure transport as needed to accommodate traffic rerouting, reconfigured network functions and traffic reversion	
Pre conditions	1) Network is operational. 2) SMO has established the data collection and sharing process, and SMO/Non-RT RIC has access to this data. 3) SMO/Non-RT RIC analyses performance data or other inputs and determines that reconfiguration of RAN network functions is required 4) SMO/Non-RT RIC determines an order of reconfiguration across affected RAN network functions	
Begins when	Operator specified trigger condition or event is detected	
Step 1 (M)	SMO performs relevant configuration updates in RAN over O1 interface for each network function that needs to be reconfigured, in an order determined by SMO or specified to SMO. Detailed procedures for O1 provisioning follow [6] section 2.1.	
Step 2 (M)	SMO determines from responses from the affected network functions that reconfiguration has been successful	
Step 3 (M)	SMO/Non-RT RIC monitors the performance of the RAN following reconfiguration by collecting and monitoring the relevant performance KPIs and counters using O1	
Step 4 (O)	If a fallback procedure has been identified by SMO and it determines that reconfiguration has not been successful, SMO initiates fallback by configuring the affected network functions back to their original configuration.	
Ends when	Operator specified trigger condition or event is satisfied	
Exceptions	None identified	
Post Conditions	SMO/Non-RT RIC continues to monitor the performance of the RAN by collecting and monitoring the relevant performance KPIs and counters using O1	
Traceability	REQ-ORC-GEN21; REQ-ORC-O1-2	

3.4.3 UML sequence diagram

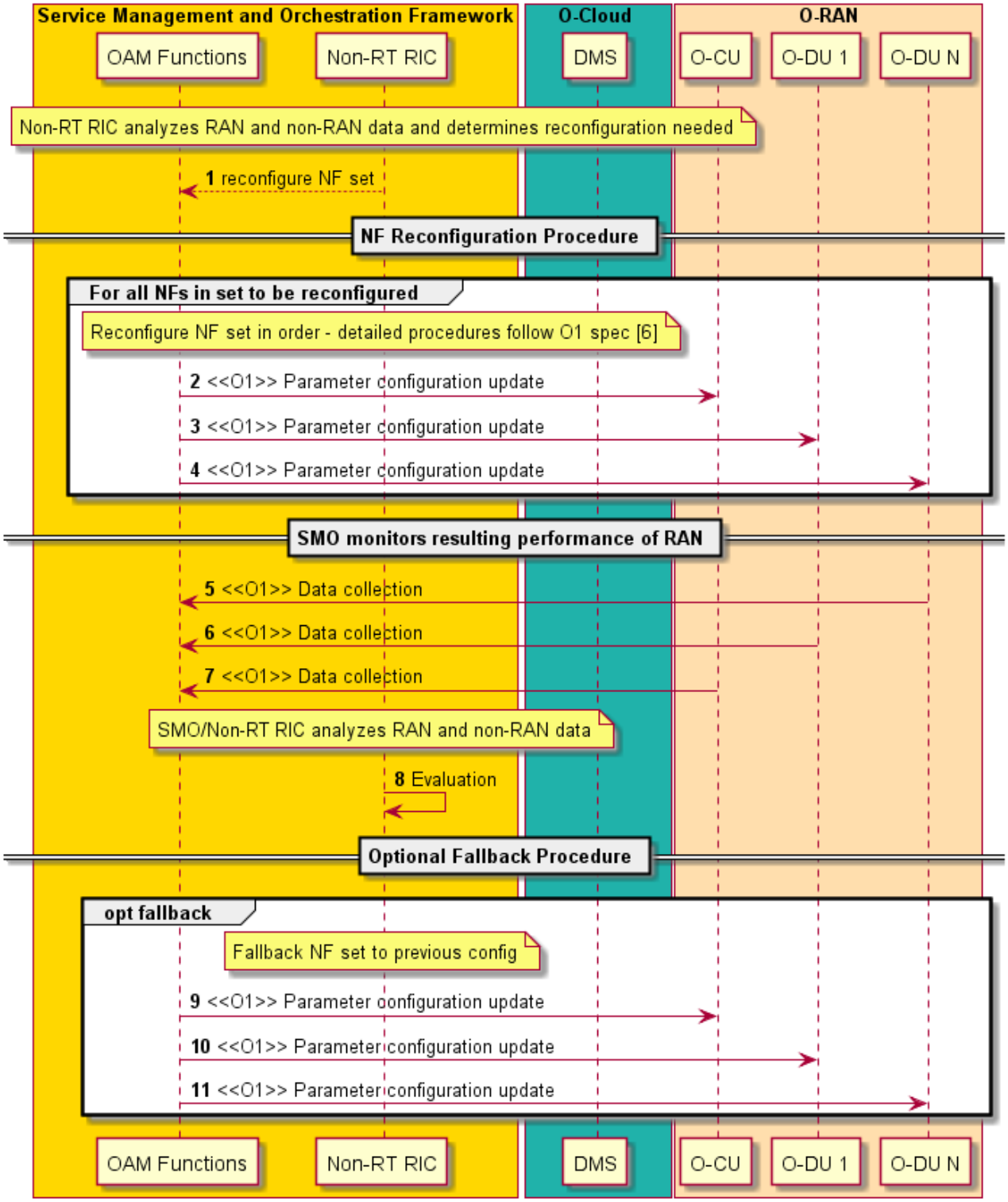


Figure 3-8: Reconfiguration

4 Orchestration Requirements

The following section contains requirements on the O-Cloud, SMO, O1 and O2 based on the Orchestration Use Cases above.

4.1 General Requirements

[REQ-ORC-GEN1]	The O-RAN SMO shall support the creation of a globally unique identifier (correlation ID) which can uniquely identify an O-Cloud instance in a provider's network.	Use Case 3.1.1
[REQ-ORC-GEN2]	The O-RAN SMO shall be able to create an inventory placeholder based on a correlation ID for an O-Cloud expected to be managed by the SMO	Use Case 3.1.1
[REQ-ORC-GEN3]	The O-RAN SMO shall be able to initiate an O-Cloud build out by loading the first O-Cloud server and providing a “blueprint” of the functionality and resources needed.	Use Case 3.1.2
[REQ-ORC-GEN4]	The O-RAN O-Cloud Infrastructure Management Services shall be able to orchestrate the control plane and resource nodes from O-Cloud Nodes as they are detected.	Use Case 3.1.2
[REQ-ORC-GEN5]	The O-RAN O-Cloud Infrastructure Management Services shall be able to notify the SMO when it has completed the O-Cloud build and is ready to be integrated to the SMO.	Use Case 3.1.2
[REQ-ORC-GEN6]	The O-RAN O-Cloud Infrastructure Management Services shall be able to identify a SW inventory or build id for its platform software	Use Case 3.1.3
[REQ-ORC-GEN7]	The O-RAN SMO shall be able to verify an O-Cloud instance is at the SW inventory or build expected for platform software for given deployment	Use Case 3.1.3
[REQ-ORC-GEN8]	The SMO shall be able to configure an O-Cloud to notify the SMO of O-Cloud Configuration Changes, Faults detected within, and performance of O-Cloud Nodes.	Use Case 3.1.3
[REQ-ORC-GEN9]	The O-RAN O-Cloud Infrastructure Management Services shall be able to provide on demand a list of its DMS with the resource locations that each can support and information linking the orchestrator with the deployment descriptor model types that each support.	Use Case 3.1.3
[REQ-ORC-GEN10]	The O-RAN O-Cloud Infrastructure Management Services shall be able to provide on demand a list of resource build configurations (aka "flavors") that it can currently support.	Use Case 3.1.4
[REQ-ORC-GEN11]	The O-RAN O-Cloud Infrastructure Management Services shall be able to provide on demand a report of capacity that it could support based on the "flavors" it has defined.	Use Case 3.1.4
[REQ-ORC-GEN12]	The O-RAN O-Cloud Infrastructure Management Services shall be able to provide on demand a report of availability that it can still support based on the "flavors" is has defined.	Use Case 3.1.4
[REQ-ORC-GEN13]	The O-RAN O-Cloud Infrastructure Management Services shall be able to notify the SMO when new "flavors" are configured within the O-Cloud.	Use Case 3.1.4
[REQ-ORC-GEN14]	The O-RAN O-Cloud Infrastructure Management Services shall be able to detect, configure and incorporate new O-Cloud Nodes into the O-Cloud instance according to the rules identified in the O-Cloud blueprint.	Use Case 3.1.5
[REQ-ORC-GEN15]	The O-RAN O-Cloud Infrastructure Management Services shall be able to notify the SMO when resources which can affect the total capacity of the O-Cloud are changed.	Use Case 3.1.5
[REQ-ORC-GEN16]	The O-RAN O-Cloud Infrastructure Management Services shall be able to support secure get of software packages from a server within the SMO for the purpose of upgrading the O-Cloud software build.	Use Case 3.1.6
[REQ-ORC-GEN17]	The O-RAN O-Cloud Infrastructure Management Services shall be able to evaluate a downloaded software package and verify that it can be activated	Use Case 3.1.6

	without impacting applications or networks executing on the affected O-Cloud resources.	
[REQ-ORC-GEN18]	The O-RAN SMO shall be able to separate requests for managing an O-Cloud and managing O-RAN Network Functions on the O-Cloud.	Use Case 3.2.1
[REQ-ORC-GEN19]	The O-RAN SMO shall determine which locations within the O-Cloud that should be used for implementing an end-to-end service if these are not specified in the service request	Use Case 3.2.1
[REQ-ORC-GEN20]	The O-Cloud shall be able to use a descriptor to orchestrate the creation and management of cloud based deployments.	Use Case 3.2.1
[REQ-ORC-GEN21]	The O-RAN SMO shall be able to restore a NF to a previous configuration as needed for network recovery.	Use Case 3.4, see also [8]

4.2 Orchestration Requirements Relating to O1

Defines requirements for O-RAN managed function IM elements and FM/PM elements needed for orchestration using the O1 interface.

[REQ-ORC-O1-1]	The O-RAN SMO shall support the ability to subscribe to notification of configuration events, fault events and performance metrics using the O1 interface.	Use Case 3.2.1
[REQ-ORC-O1-2]	The NF workload executing on O-Cloud shall support the ability to send notification of configuration changes to the SMO using the O1 interface.	Use Case 3.4

Note: These requirements are addressed in [6].

4.3 Orchestration Requirements Relating to O2

[REQ-ORC-O2-1]	The O-RAN SMO shall be able to provide a boot image for a remote node that it has a trusted connection to using the O2 interface.	Use Case 3.1.2
[REQ-ORC-O2-2]	The O-RAN SMO shall be able to send a cloud descriptor, (i.e., cloud deployment and configuration files) for initial cloud startup using the O2 interface.	Use Case 3.1.2
[REQ-ORC-O2-3]	The O-RAN SMO shall be able to query the O-Cloud for attributes such as SW inventory using the O2 interface.	Use Case 3.1.3
[REQ-ORC-O2-4]	The O-Cloud shall be able to receive a request to download software sent to it from the SMO using the O2 interface.	Use Case 3.1.3
[REQ-ORC-O2-5]	The O-RAN SMO shall be able to subscribe to notification of configuration events, fault events and performance metrics from the O-Cloud using the O2 interface.	Use Case 3.1.3
[REQ-ORC-O2-6]	The O-RAN SMO shall be able to query the O-Cloud for the DMS end points it supports using the O2 interface.	Use Case 3.1.3
[REQ-ORC-O2-7]	The O-RAN SMO shall be able to query the O-Cloud for attributes such as capabilities and capacities using the O2 interface.	Use Case 3.1.4
[REQ-ORC-O2-8]	The O-Cloud shall be able to send asynchronous events to the SMO when available capabilities or capacities are changed, including when new hardware is added, using the O2 interface.	Use Case 3.1.4, 3.1.5

[REQ-ORC-O2-9]	The O-Cloud shall be able to asynchronously notify the SMO when a software upgrade completes, using the O2 interface.	Use Case 3.1.6
[REQ-ORC-O2-10]	The O-RAN SMO shall be able to request the O-Cloud to create a Network Function deployment using cloud resources through the O2 interface, and subsequently manage the Network Function using the O1 interface.	Use Case 3.2.1

347

Annex A: Terminology Used in O-Cloud Requirements

The following terms and definitions are used in the O-Cloud requirements.

Requirements Term	Description
deployment descriptor	Deployment descriptor is a completed data model which provides an O-Cloud the necessary information to create a deployment.
deployment descriptor model type	Deployment descriptors use a model type such as TOSCA, HELM, or HOT Templates to describe the deployment to be performed. The type of model used by the descriptor should be included in its metadata.
flavor	In the case of O-Clouds the deployment units are in defined patterns known as [deployment] flavors [2]. The flavors are part of the deployment descriptor.
capacity	This is the capacity that an entity is designed for. For each flavor defined the maximum that could be deployed should be reported to the SMO. Cloud Scale Up and Scale Down would affect these values and cause the change to be reported to the SMO.
utilization	This is the count that is currently allocated from the O-Cloud capacity, for each flavor.
availability	This is the count that could be allocated based on the capacity minus the utilization, for each flavor.
cloud descriptor	This is the outlined plan for the O-Cloud. From this plan the O-Cloud Infrastructure Management Services knows which pools are expected to be available as resources are discovered and what version of software is required for O-Cloud Nodes in each pool.

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Specifications that are backwards compatible with the version that was current as of the date of termination.

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501
502
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505 Adopter acknowledges and agrees that Members, Contributors and Academic Contributors (including
506 future Members, Contributors and Academic Contributors) are entitled to rights as a third-party
507 beneficiary under this Agreement, including as licensees under Section 3.
508
509 **SECTION 10: BINDING ON AFFILIATES**
510
511 Execution of this Agreement by Adopter in its capacity as a legal entity or association constitutes that legal
512 entity's or association's agreement that its Affiliates are likewise bound to the obligations that are
513 applicable to Adopter hereunder and are also entitled to the benefits of the rights of Adopter hereunder.
514
515 **SECTION 11: GENERAL**
516
517 This Agreement is governed by the laws of Germany without regard to its conflict or choice of law
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519
520 This Agreement constitutes the entire agreement between the parties as to its express subject matter and
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524 Adopter, on behalf of itself and its Affiliates, agrees to comply at all times with all applicable laws, rules
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533
534 In the event that any provision of this Agreement conflicts with governing law or if any provision is held
535 to be null, void or otherwise ineffective or invalid by a court of competent jurisdiction, (i) such provisions
536 will be deemed stricken from the contract, and (ii) the remaining terms, provisions, covenants and
537 restrictions of this Agreement will remain in full force and effect.
538
539 Any failure by a party or third party beneficiary to insist upon or enforce performance by another party of
540 any of the provisions of this Agreement or to exercise any rights or remedies under this Agreement or
541 otherwise by law shall not be construed as a waiver or relinquishment to any extent of the other parties'
542 or third party beneficiary's right to assert or rely upon any such provision, right or remedy in that or any
543 other instance; rather the same shall be and remain in full force and effect.
544