MANAGING INTERACTIONS BETWEEN O-CLOUD RESOURCES MANAGEMENT AND ORCHESTRATION AND RADIO ACCESS NETWORK ORCHESTRATION ADMINISTRATION MAINTENANCE FUNCTIONS

Abstract

Provided are a method, system, and device for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function. The method may include receiving, by the ORMO, a service related to an SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

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Background/Summary

FIELD
[0001] Systems and methods consistent with example embodiments of the present disclosure relate to managing interactions between open radio access network (O-RAN) cloud (O-Cloud) resources management and orchestration (ORMO) and radio access network orchestration administration maintenance (RAN OAM) functions.
BACKGROUND
[0002] A radio access network (RAN) is an important component in a telecommunications system, as it connects end-user devices (or user equipment) to other parts of the network. The RAN includes a combination of various network elements (NEs) that connect the end-user devices to a core network. Traditionally, hardware and/or software of a particular RAN is vendor specific.
[0003] Open RAN (O-RAN) technology has emerged to enable multiple vendors to provide hardware and/or software to a telecommunications system. To this end, O-RAN disaggregates the RAN functions into a centralized unit (CU), a distributed unit (DU), and a radio unit (RU). The CU is a logical Node for hosting Radio Resource Control (RRC), Service Data Adaptation Protocol (SDAP), and/or Packet Data Convergence Protocol (PDCP) sublayers of the RAN. The DU is a logical Node hosting Radio Link Control (RLC), Media Access Control (MAC), and Physical (PHY) sublayers of the RAN. The RU is a physical Node that converts radio signals from antennas to digital signals that can be transmitted over the FrontHaul to a DU. Because these entities have open protocols and interfaces between them, they can be developed by different vendors.
[0004] FIG. **1** illustrates a related art O-RAN architecture. Referring to FIG. **1**, RAN functions in the O-RAN architecture are controlled and optimized by a RIC. The RIC is a software-defined component that implements modular applications to facilitate the multivendor operability required in the O-RAN system, as well as to automate and optimize RAN operations. The RIC is divided into two types: a non-real-time RIC (Non-RT RIC) and a near-real-time RIC (Near-RT RIC).
[0005] The Non-RT RIC is the control point of a non-real-time control loop and operates on a timescale greater than 1 second within the Service Management and Orchestration (SMO) framework. Its functionalities are implemented through modular applications called rApps (rApp 1, . . . , rApp N), and include: providing policy based guidance and enrichment across the A1 interface, which is the interface that enables communication between the Non-RT RIC and the Near-RT RIC; performing data analytics; Artificial Intelligence/Machine Learning (AI/ML) training and inference for RAN optimization; and/or recommending configuration management actions over the O1 interface, which is the interface that connects the SMO to RAN managed elements (e.g., Near-RT RIC, O-RAN centralized Unit (O-CU), O-RAN Distributed Unit (O-DU), etc.).
[0006] The Near-RT RIC operates on a timescale between 10 milliseconds and 1 second and connects to the O-DU, O-CU (disaggregated into the O-CU control plane (O-CU-CP) and the O-CU user plane (O-CU-UP)), and an open evolved NodeB (O-eNB) via the E2 interface. The Near-RT RIC uses the E2 interface to control the underlying RAN elements (E2 Nodes/network

functions (NFs)) over a near-real-time control loop. The Near-RT RIC monitors, suspends/stops, overrides, and controls the E2 Nodes (O-CU, O-DU, and O-eNB) via policies. For example, the Near-RT sets policy parameters on activated functions of the E2 Nodes. Further, the Near-RT RIC hosts xApps to implement functions such as quality of service (QOS) optimization, mobility optimization, slicing optimization, interference mitigation, load balancing, security, etc. The two types of RICs work together to optimize the O-RAN. For example, the Non-RT RIC provides, over the AI interface, the policies, data, and AI/ML models enforced and used by the Near-RT RIC for RAN optimization, and the Near-RT returns policy feedback (i.e., how the policy set by the NON-RT RIC works).

[0007] The SMO framework, within which the Non-RT RIC is located, manages and orchestrates RAN elements. Specifically, the SMO includes the Federated O-Cloud Orchestration and Management (FOCOM), a Network Function Orchestrator (NFO) that manages Virtual Machines (VM) based Virtual Network Functions (VNF) and container (i.e., instance) based VNF, and the OAM as a part of the SMO that manages and orchestrates what is referred to as the O-RAN Cloud (O-Cloud). The O-Cloud is a collection of physical RAN Nodes that host the RICs, O-CUs, and O-DUs, the supporting software components (e.g., the operating systems and runtime environments), and the SMO itself. In other words, the SMO manages the O-Cloud from within. The O2 interface is the interface between the SMO and the O-Cloud it resides in. Through the O2 interface, the SMO provides Infrastructure Management Services (IMS) and Deployment Management Services (DMS). The O2 interface may also send O2 telemetry data to the SMO, e.g., O-Cloud configuration or any logical function data, energy consumption, health status of Node, etc.

SUMMARY

[0008] In the related art, O-Cloud Resources Management and Orchestration (ORMO) (which may consist of both the NFO and FOCOM described above) may need to interact with other SMO functions (SMOF's) such as RAN Operations Administration Maintenance (RAN OAM), Topology Exposure and Inventory Management (TE & IV), and other Non-RT RIC SMOF's.

[0009] Network Functions (NF's) are typically orchestrated by NFO related capabilities of the ORMO, and these NF applications are configured through RAN OAM via the O1 interface. As an example, in the case of scaling of the NF, prior to terminating any active NF deployment, NF instance traffic associated with that NF deployment may need to be distributed amongst remaining active NF deployments. Accordingly, the NFO may need to instruct the RAN OAM to drain traffic of an NF deployment which is to be terminated. However, in this scenario, there is a need for the RAN OAM to be able to ascertain that policies are enforced as to how to distribute traffic amongst other NF deployment via interactions with other SMOF's such as the NFO, Non-RT RIC, TE &IV or RAN OAM.

[0010] Accordingly, there is a need for being able to seamlessly manage interactions between the ORMO and RAN OAM.

[0011] Example embodiments of the present disclosure provide a method and system for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function. The method may include receiving, by the ORMO, a service related to an SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

[0012] According to embodiments, a method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function may be provided. The method may include receiving, by the ORMO, a service related to a Service Orchestration (SO) SMOF from a Service Management and Exposure (SME); sending, by

the ORMO, a request to the SO SMOF to terminate and redeploy at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

[0013] According to embodiments, a method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function may be provided. The method may include: receiving, by the ORMO, a service related to a Service Orchestration and Assurance (SOA) SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SOA SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

[0014] Accordingly, it can be understood that since the ORMO can facilitate interactions with the RANOAM and other SMOF's, seamless interaction between different SMOF's can be achieved in order to facilitate managing NF instances.

[0015] Additional aspects will be set forth in part in the description that follows and, in part, will be apparent from the description, or may be realized by practice of the presented embodiments of the disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Features, aspects and advantages of certain exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like reference numerals denote like elements, and wherein:

[0017] FIG. **1** illustrates an O-RAN architecture according to the related art;

[0018] FIG. **2** illustrates a callflow diagram for an interaction between ORMO and RANOAM SMOF according to an embodiment;

[0019] FIG. **3** illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including a SO SMOF according to an embodiment;

[0020] FIG. **4** illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including an SOA SMOF according to an embodiment;

[0021] FIG. **5** illustrates a diagram of an example environment in which systems and/or methods, described herein, may be implemented;

[0022] FIG. **6** illustrates a diagram of example components of a device according to an embodiment;

[0023] FIG. **7**A-**7**C illustrates a callflow diagram for an interaction between ORMO and RANOAM SMOF according to an embodiment;

[0024] FIG. **8**A-**8**D illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including a SO SMOF according to an embodiment; and

[0025] FIG. **9**A-**9**C illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including an SOA SMOF according to an embodiment.

DETAILED DESCRIPTION

[0026] The following detailed description of example embodiments refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements.

[0027] The foregoing disclosure provides illustration and description, but is not intended to be exhaustive or to limit the implementations to the precise form disclosed. Modifications and variations are possible in light of the above disclosure or may be acquired from practice of the implementations. Further, one or more features or components of one embodiment may be

incorporated into or combined with another embodiment (or one or more features of another embodiment). Additionally, in the flowcharts and descriptions of operations provided below, it is understood that one or more operations may be omitted, one or more operations may be added, one or more operations may be performed simultaneously (at least in part), and the order of one or more operations may be switched.

[0028] It will be apparent that systems and/or methods, described herein, may be implemented in different forms of hardware, firmware, or a combination of hardware and software. The actual specialized control hardware or software code used to implement these systems and/or methods is not limiting of the implementations. Thus, the operation and behavior of the systems and/or methods were described herein without reference to specific software code. It is understood that software and hardware may be designed to implement the systems and/or methods based on the description herein.

[0029] Even though particular combinations of features are recited in the claims and/or disclosed in the specification, these combinations are not intended to limit the disclosure of possible implementations. In fact, many of these features may be combined in ways not specifically recited in the claims and/or disclosed in the specification. Although each dependent claim listed below may directly depend on only one claim, the disclosure of possible implementations includes each dependent claim in combination with every other claim in the claim set.

[0030] No element, act, or instruction used herein should be construed as critical or essential unless explicitly described as such. Also, as used herein, the articles "a" and "an" are intended to include one or more items, and may be used interchangeably with "one or more." Where only one item is intended, the term "one" or similar language is used. Also, as used herein, the terms "has," "have," "having," "include," "including," or the like are intended to be open-ended terms. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise. Furthermore, expressions such as "at least one of [A] and [B]" or "at least one of [A] or [B]" are to be understood as including only A, only B, or both A and B.

[0031] Example embodiments are directed to O-Cloud resource optimization, which is a process of utilizing O-Cloud resources in an efficient manner and eliminating waste of O-Cloud resources by selecting, provisioning, and rightsizing the resources within the O-Cloud. In accordance with example embodiments, Network Functions (NFs) within the O-Cloud are orchestrated as VNFs/CNFs. The SMO (NFO, FOCOM) handles the management and orchestration of VNFs/CNFs and underlying O-Cloud infrastructure. The SMO's management, orchestration, and optimization functionalities can be enhanced in accordance with example embodiments by intelligent observability analysis from VNFs/CNFs and O-Cloud.

[0032] The Non-RT RIC hosts third-party applications such as rApps in the SMO, which can collect and read various O1 and O2-related observability data and metrics through O1 and O2 related services. These third-party rApps can be leveraged in example embodiments to provide guidance and/or recommendations to the NFO and FOCOM for management, orchestration, and optimization of VNFs/CNFs and underlying O-Cloud infrastructure.

[0033] A service orchestrator (SO) and/or service assurance (SA) SMO function (SMOF) may also be provided according to embodiments. The SO SMOF and/or SA SMOF may support orchestrating various procedures which are required for interactions between the RANOAM related functions and providing NFO/FOCOM based services with service assurance. The SO SMOF may use a set of recipes to define steps which are involved in creating a service, and then execute such steps in a sequence in order to ensure that a service is created service. The SO SMOF and/or SA SMOF may accordingly work together to ensure that network services are created and maintained in a consistent and reliable manner. The SO SMOF ensures that services are created correctly, and the SA SMOF ensures that they are performing as expected. This may allow for improved overall quality of service for the network.

[0034] It should be appreciated that while NF traffic draining is primarily discussed below as an

example of a possible interaction between the ORMO and RANOAM, and that other possible interactions can be achieved by the below embodiments and configurations. For example, configuration or reconfiguring a NF post NF-instantiation by the DMS is a possible interaction between a NFO and RANOAM which could be implemented. Querying operational, administrative, usage states of an NF can also be a possible request sent from a NFO to RANOAM. A notification related to NF state and health could also be sent from the NFO to RANOAM. The NFO can also send a response to actions which are initiated by the RANOAM to RANOAM. RANOAM can also send a notification to the NFO related to NF configuration, traffic draining, and fault reporting.

[0035] It should be appreciated that the ORMO (FOCOM/NFO) may support capabilities to receive notifications from RANOAM. The ORMO (FOCOM/NFO) may support capability to configure NF deployment through the RANOAM. The RANOAM may support capabilities to receive notifications from ORMO SMOF. The RANOAM may support capabilities to send notifications to other SMOF's.

[0036] Example embodiments of the present disclosure provide a method and system for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function. It may include receiving, by the ORMO, a service related to an SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory. Accordingly, it can be understood that since the ORMO can facilitate interactions with the RANOAM and other SMOF's, seamless interaction between different SMOF's can be achieved in order to facilitate managing NF instances.

[0037] Embodimetns of the present disclosure may be directed towards a use case for ORMO & RANOAM SMOF Interactions. Background and goals of the use case may be as follows.

[0038] O-Cloud orchestration and managements requires seamless interactions with other SMO functions such as RANOAM, TE & IV, Non-RT RIC SMOF. This use case may focus on interactions with RAN OAM SMOF.

[0039] Network functions are orchestrated by NFO related capabilities of ORMO, however those NF application are configured through RAN OAM via O1 interface. In case of Scale In of NF, before terminating any NF deployment i.e. NF instance traffic associated with that NF deployment needs to distribute amongst remaining NF deployment. Here, the NFO needs instruct RAN OAM to drain traffic of NF deployment which is to be terminated. RAN OAM to ascertain policy to distribute traffic among NF deployment through other SMOF such NFO, Non-RT RIC, TE &IV or RAN OAM.

[0040] NF traffic draining is example of interaction required between ORMO & RAN OAM, there could be more examples such as, but not necessarily limited to:

[0041] NFO.fwdarw.RANOAM: Configuring or Reconfiguring NF post NF instantiation by DMS.

[0042] NFO.fwdarw.RANOAM: Querying operational, administrative, usage state of NF.

[0043] NFO.fwdarw.RANOAM: Notification related to NF state & health.

[0044] NFO.fwdarw.RANOAM: Response to actions initiated by RANOAM.

[0045] RANOAM.fwdarw.NFO: Notification related to NF Configuration, Traffic draining, Fault reporting.

[0046] Below capabilities may be essential for O-Cloud Orchestration and Management in relation with interaction with other RAN OAM:

[0047] FOCOM/NFO to support for capabilities to receive notifications from RANOAM.

[0048] FOCOM/NFO to support for capability to configure NF deployment through RAN OAM

[0049] RAN OAM to support capabilities to receive notifications from ORMO SMOF.

[0050] RAN OAM to support capabilities to send notifications to other SMOF.

[0051] Entities/resources which may be involved in the use case are described as follows:

[0052] SME SMOF: In a decoupled service-based SMO architecture, the SME can be leveraged as a universal SMO service (SMOS), handling service management and exposure for any SMOS's within the SMO. To support functionality to discover the available services from SMOF and authorization of SMOF to determine which services an SMOF can discover. Support to retrieve the stored service information and performs filtering of available services based on selection criteria that may be provided by the SMOF.

[0053] Non-RT RIC SMOF: Support to monitor and evaluate NF PM/FM/CM data via O1 & O2 for NF traffic draining.

[0054] ORMO SMOF (NFO & FOCOM): Support registration of capabilities for NFO related services such as with SME. Support receiving and sending necessary notifications for RANOAM SMOF related to life cycle of NF deployment.

[0055] O-Cloud (IMS & DMS): Support to receive actions and feedback from ORMO SMOF (NFO & FOCOM) & implement on O-Cloud platform through IMS & DMS

[0056] Topology Exposure and Inventory Management (TE & IV) SMOF: Support updating Topology Exposure and Inventory based on request from other SMOF.

[0057] RAN OAM SMOF: Supports requests from other SMOF for services such as PM,FM, CM. Notifying other SMOF about mentioned changes in CM requests

[0058] Service Orchestrator (SO) and Service assurance (SA) SMOF: Support orchestrating various procedures required for interaction between RAN OAM related function and NFO/FOCOM based services assurance. The SO uses a set of recipes to define the steps involved in creating a service, and it then executes these steps in a sequence to ensure that the service is created correctly. The SO and SA may work together to ensure that network services are created and maintained in a consistent and reliable manner. The SO ensures that the services are created correctly, and the SA ensures that they are performing as expected. This may help to improve the overall quality of service for network customers.

[0059] It should be noted that the following requirements may be provided for component elements and SMOF's according to embodiments.

ORMO Function (ORMOF) Requirements

[0060] The ORMOF may support registration of NFO and/or FOCOM related services with SME SMOF. The ORMOF may support traffic draining request for cases such as NF termination towards Service Orchestrator and Assurance. The ORMOF may support invoking O2DMS/O2IMS actions based on SOA or SO recommendations. The ORMOF may support acknowledge notifications related to RAN OAM SMOF

Non-RT RIC Function (NRTRF) Requirements

[0061] The NRTRF may support role of assurance for SOF in cases such as NF traffic draining. The NRTRF may support discovery of SOF or SOAF related services over SMEs

SOA Function (SOAF) Requirements

[0062] The SOAF may support registration of SOA related services over SME. The SOAF may support discovery of SOA related services through SME. The SOAF may support role of services orchestrator to facilitate procedures between various SMOF within SMO. The SOAF may support role of services assurance to enable SLA based procedures within SMO. The SOAF may support ORMOF and RAN OAMF related data collection. TheSOAF may support storing relevant end to end NF application related, O-Cloud Infrastructure related, NF deployment related automation procedures and registering it over SME/DME for discovery purpose.

SO Function (SOF) Requirements

[0063] The SOF may support role of services orchestrator to facilitate procedures between various SMOF within SMO. The SOF may support registration of SO related services over SME. The SOF may support discovery of SO related services through SME. The SOF may support storing relevant end to end NF application related, O-Cloud Infrastructure related, NF deployment related

automation procedures and registering it over SME/DME for discovery purpose.

[0064] It should be appreciated that the above "requirements" do not necessarily limit the function of the elements thereto, and that the specific function may depend on the specific implementation.

[0065] FIG. **2** illustrates a callflow diagram for an interaction between ORMO and RANOAM SMOF according to an embodiment. In particular, the below use-case may be implemented in the case where an rApp and/or a machine learning (ML) model acts as the Service Assurance (SA). That is, the rApp and/or ML model may provide recommendations to perform an action on a particular NF (e.g., recommending to drain a particular NF instance or node). In this particular use-case, no SO is included.

[0066] DMS **200** and IMS **210** may operate within the O-Cloud. ORMO SMOF (which may include the NFO and FOCOM) **220**, RANOAM SMOF **230**, TE & IV SMOF **240**, Service Management and Exposure (SME) **250**, Data Management and Exposure (DME) **260**, Non-RT RIC SMOF **270** may operate within the SMO framework. E2 Nodes **280** may operate within the O-RAN nodes.

[0067] DMS **200** and IMS **210** are intended to provide support to receive actions and feedback from the ORMO SMOF **220**, and thereby implement actions onto the O-Cloud platform.

[0068] ORMO SMOF **220** may include the NFO and FOCOM functionalities. In particular, it may support registration capabilities for NFO related services, such as with SME **250**. ORMO SMOF **220** may also support receiving and sending necessary notifications to the RANOAM SMOF **230** which are related to the life-cycle of NF deployment.

[0069] RANOAM SMOF **230** supports request from other SMOF's for services related to performance management (PM), fault management (FM), and configuration management (CM). RANOAM SMOF may also be responsible for notifying other SMOF's about mentioned changes in CM requests.

[0070] TE & IV SMOF **240** may be responsible for providing support to update a Topology Exposure and Inventory based on requests from other SMOF's.

[0071] SME **250** may be leveraged in a decoupled service-based SMO architecture as a universal SMO service (SMOS), by handling service management and exposure for any SMOS within the SMO. SME **250** may also support functionality to discover available services from a particular SMOF and may provide authorization of an SMOF to determine which services an SMOF can discover. SME **250** may also support retrieving stored service information and provide filtering of available services based on selection criteria provided by an SMOF. Accordingly, it may be possible to discover services related to an SMOF using SME **250**, according to embodiments.

[0072] DME **260** may be used to provide PM data, according to embodiments.

[0073] Non-RT RIC SMOF **270** may be responsible for providing support to monitor NF PM/FM/CM data via O1 & O2 interface for the purpose of draining NF traffic.

[0074] The embodiment illustrated in FIG. **2** may allow for configuration management (CM) interactions between the ORMO SMOF and RANOAM SMOF. SME **250** may act as the service exposure entity, the Non-RT RIC SMOF **270** may act as an analytical function, ORMO SMOF **220** (which may include the NFO and FOCOM functionality) may act as the O-Cloud Orchestration and Management Function, and the RAN OAMF **230** may act as the CM enforcement entity.

[0075] It can be assumed that in the embodiment illustrated in FIG. **2**, O2 interface connectivity is established between the SMO and the O-Cloud, that O1 interface connectivity is enabled, and the network is operational.

[0076] The embodiment in FIG. **2** may be initiated when the ORMO SMOF **220** initiates a request to RANOAM SMOF **230**.

[0077] In step **1**, the RANOAM SMOF **230** may register its services related to performance management (PM), fault management (FM), and CM with the SME **250**.

[0078] In step **2**, the RANOAM SMOF **230** may receive a message from SME **250** indicating that the services were successfully registered. According to some embodiments, this may include

receiving a service profile ID.

[0079] In step **3**, the ORMO SMOF **220** may discover RANOAM related services with the SME **250**.

[0080] In step **4**, the ORMO SMOF **220** may receive the RANOAM related services from SME **250**.

[0081] There may arise a need to drain traffic from a particular NF instance (e.g., from a recommendation from an rApp, or due to performance issues).

[0082] In step **5**, the ORMO SMOF **220** may request RANOAM SMOF **230** to drain the traffic from a particular NF instance.

[0083] In step **6**, RANOAM SMOF **230** may notify the Non-RT RIC SMOF **270** about the traffic draining request for the particular NF instance. Specifically, this may be so that Non-RT RIC SMOF **270** may monitor PM and FM of the particular NF instance.

[0084] In step **7**, the Non-RT RIC SMOF **270** may query and collect PM data from DME **260**.

[0085] In step **8**, the Non-RT RIC SMOF **270** may query and collect FM and CM data from RANOAM SMOF **230**.

[0086] In step **9**, the RANOAM SMOF **230** may configure a NF traffic distribution in order to distribute traffic from the particular NF instance to other NF instance(s), and send the configuration to E2 Nodes **280**.

[0087] In step **10**, E2 nodes **280** may enforce the NF traffic distribution configuration received from the RANOAM SMOF **230**.

[0088] In step **11**, E2 nodes **280** may notify RANOAM SMOF **230** that the traffic distribution has been completed.

[0089] In step **12**, RANAOAM SMOF **230** may notify the Non-RT RIC SMOF **270** that the traffic distribution has been completed (e.g., it may forward the notification).

[0090] In step **13**, the Non-RT RIC SMOF **270** may evaluate the performance of the drained NF and decide whether to rollback or take any corrective action to recover the desired performance of the NF. This step may optionally be performed.

[0091] In step **14**, the Non-RT RIC SMOF **270** may send an evaluation report to RANOAM SMOF **230**. This may include an indication that rollback should be performed. This step may optionally be performed.

[0092] In step **15**, RANOAM SMOF **230** may send a notification to ORMO SMOF **220** that NF draining was completed.

[0093] In step **16**, ORMO SMOF **220** may send a request to DMS **200** to terminate the NF deployment based on receiving the notification from RANOAM SMOF **230** in step **15** above.

[0094] In step **17**, the ORMO SMOF **220** may update the inventory with TE & IV **240**.

[0095] The above use-case may end when the O-Cloud becomes non-operational or when the operator disables using the rApp as policy function and/or an ML model for the policy function (e.g., the rApp and/or ML model are no longer being used as an SA).

[0096] An example implementation of the steps in FIG. **2** for a use-case of a RAN OAM SMOF to NFO/FOCOM Interaction without SO and rApp as SA may be summarized per the table below. "(M)" may denote a mandatory step and "(O)" may denote an optional one, nevertheless, it should be appreciated that the specific steps used may depend on the specific implementation. TABLE-US-00001 Use Case Stage Evolution/Specification Goal Enabling CM interactions between ORAMF and RANOAMF Actors and SME: Service exposure Entity Roles Non-RT RIC: Analytical Function ORMO SMOF (Including NFO & FOCOM): O-Cloud Orchestration and Management function. RAN OAMF: CM Enforcement Entity Assumptions O2 interface connectivity is established between SMO and O- Cloud O1 interface connectivity is established. Network is operational. Pre-conditions ORMOF Initiated O2 procedures as mentioned O-RAN-WG6.ORCH-USE-CASES in Section 3.2 Begins when ORMOF initiates request to RAN OAMF. Step 1 (M) The RANOAM SMOF registers its services related to PM, FM, and CM with the SME.

Step 2 (M) The ORMO SMOF (NFO/FOCOM) discovers the RANOAM- related services with the SME. Step 3 (M) The ORMO SMOF initiates the traffic draining process by sending a request to the OAM. Step 4 (M) The OAM notifies the nRT about the traffic draining request. Step 5 (M) The nRT queries and collects the PM data from the DME. Step 6(M) The nRT queries and collects the FM/CM data from the OAM. Step 7 (M) The OAM configures the NF traffic distribution on the E2-Nodes. Step 8 (M) The E2-Nodes enforce the NF traffic distribution. Step 9 (M) The E2-Nodes notify the OAM about the completion of the NF traffic distribution. Step 10 (M) The OAM notifies the nRT about the completion of the NF traffic draining. Step 11 (O) The nRT evaluates the performance of the drained NF and decides whether to rollback or take any corrective action to recover the desired performance of the NF. Step 12 (O) If the nRT decides to rollback, it sends a report to the OAM. Step 13 (M) The OAM terminates the NF deployment by sending a request to the DMS. Step 14 (M) The ORMO SMOF updates the inventory with the TEIV. Ends when O-Cloud becomes non-operational or when the operator disables the rApp as policy function or ML model for policy function. Exceptions TBD Post End Conditions

[0097] FIG. **3** illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including a SO SMOF according to an embodiment. In particular, the below use-case introduces SO SMOF **350**, which may act as the service orchestration entity. The rApp and/or a machine learning (ML) model may act as the Service Assurance (SA).

[0098] DMS **300**, IMS **310**, ORMO SMOF **320**, RANOAM SMOF **330**, TE & IV SMOF **340**, SME **360**, DME **370**, Non-RT RIC SMOF **380**, and E2 Nodes **390** may be similar to DMS **200**, IMS **210**, ORMO SMOF **220**, RANOAM SMOF **230**, TE & IV SMOF **240**, SME **250**, DME **260**, Non-RT RIC SMOF **270**, E2 Nodes **280** described with reference to FIG. **2** above. Accordingly, redundant descriptions are omitted for the sake of improved readability.

[0099] The embodiment illustrated in FIG. **3** may allow for configuration management (CM) interactions between the ORMO SMOF and RANOAM SMOF. SME **360** may act as the service exposure entity, the Non-RT RIC SMOF **380** may act as an analytical function, ORMO SMOF **320** (which may include the NFO and FOCOM functionality) may act as the O-Cloud Orchestration and Management Function, the RAN OAMF **330** may act as the CM enforcement entity, and SO SMOF **350** may act as the service orchestration entity.

[0100] The embodiment in FIG. **3** may be initiated when the ORMO SMOF **320** initiates a request to SO SMOF **350**.

[0101] In step **1**, the RANOAM SMOF **330** may register its services related to performance management (PM), fault management (FM), and CM with the SME **350**.

[0102] In step **2**, the RANOAM SMOF **330** may receive a message from SME **360** indicating that the services were successfully registered. According to some embodiments, this may include receiving a service profile ID.

[0103] In step **3**, the ORMO SMOF **320** may discover SO related services with the SME **360**.

[0104] In step **4**, the ORMO SMOF **320** may receive the SO related services from SME **360**.

[0105] There may arise a need to drain traffic from a particular NF instance (e.g., from a recommendation from an rApp, or due to performance issues).

[0106] In step **5**, the ORMO SMOF **320** may request SO SMOF **350** to drain the traffic from a particular NF instance.

[0107] As an alternative to step **5**, in step **6**, the Non-RT RIC SMOF **380** may request SO SMOF **350** to drain the traffic from a particular NF instance. This is based on a case where the Non-RT RIC SMOF **380** can detect an issue with an NF deployment on the O-Cloud and request to terminate deployment.

[0108] In step **7**, SO SMOF **350** may query and collect topology details of the NF and allocated resources from TE&IV **340**.

[0109] In step **8**, SO SMOF **350** may send a request to ORMO SMOF **320** to redeploy the NF.

[0110] In step **9**, ORMO SMOF **320** may create an NF instance by sending a request to DMS **300**.

[0111] In step **10**, ORMO SMOF **320** may notify SO SMOF **350** that the instance of the NF was created.

[0112] In step **11**, SO SMOF **350** may send a request to RANOAM SMOF **330** to drain the NF and redistribute the traffic.

[0113] In step **12**, RANOAM SMOF **330** may notify the Non-RT RIC SMOF **380** about the traffic draining request for the particular NF instance. Specifically, this may be so that Non-RT RIC SMOF **370** may monitor PM and FM of the particular NF instance.

[0114] In step **13**, the Non-RT RIC SMOF **380** may query and collect PM data from DME **370**.

[0115] In step **14**, the Non-RT RIC SMOF **380** may query and collect FM and CM data from RANOAM SMOF **330**.

[0116] In step **15**, the RANOAM SMOF **330** may configure a NF traffic distribution in order to distribute traffic from the particular NF instance to other NF instance(s), and send the configuration to E2 Nodes **390**.

[0117] In step **16**, E2 nodes **390** may enforce the NF traffic distribution configuration received from the RANOAM SMOF **330**.

[0118] In step **17**, E2 nodes **390** may notify RANOAM SMOF **330** that the traffic distribution has been completed.

[0119] In step **18**, RANOAM SMOF **330** may notify SO SMOF **350** that traffic distribution has been completed (e.g., it may forward the notification).

[0120] In step **19**, RANAOAM SMOF **330** may notify the Non-RT RIC SMOF **380** that the traffic distribution has been completed (e.g., it may forward the notification).

[0121] In step **20**, the Non-RT RIC SMOF **380** may evaluate the performance of the drained NF and decide whether to rollback or take any corrective action to recover the desired performance of the NF. This step may optionally be performed.

[0122] In step **21**, the Non-RT RIC SMOF **380** may send an evaluation report to RANOAM SMOF **330**. This may indicate that there are no issues with the performance (e.g., it is successful). This step may optionally be performed.

[0123] As an alternative to step **21**, if there were issues with the performance, in step **22**, the Non-RT RIC SMOF **380** may send a failing evaluation report to RANOAM SMOF **330**, indicating that rollback or corrective actions should be performed. This step may optionally be performed. The SO SMOF **350** may choose to perform such corrective action based on receiving this evaluation report.

[0124] In step **23**, SO SMOF **350** may send a request to ORMO SMOF **320** to terminate the NF deployment.

[0125] In step **24**, ORMO SMOF **320** may send a request to DMS **300** to terminate the NF deployment based on receiving the request from SO SMOF **350** in step **23** above.

[0126] In step **25**, the ORMO SMOF **320** may update the inventory with TE & IV **340**.

[0127] In addition or as an alternative to step **25**, in step **26**, the SO SMOF **350** may update the inventory with TE & IV **340**.

[0128] The above use-case may end when the O-Cloud becomes non-operational or when the operator disables using the rApp as policy function and/or an ML model for the policy function (e.g., the rApp and/or ML model are no longer being used as an SA).

[0129] An example implementation of the steps in FIG. **3** for a use-case of a RAN OAM SMOF to NFO/FOCOM Interaction with SO and rApp as SA may be summarized per the table below. "(M)" may denote a mandatory step and "(O)" may denote an optional one, nevertheless, it should be appreciated that the specific steps used may depend on the specific implementation.

TABLE-US-00002 Use Case Stage Evolution/Specification Goal Enabling CM interactions between ORAMF and RANOAMF Actors and SME: Service exposure Entity Roles Non-RT RIC: Analytical Function ORMO SMOF (Including NFO & FOCOM): O-Cloud Orchestration and Management function. RAN OAMF: CM Enforcement Entity SO SMOF: Service orchestration entity Assumptions O2 interface connectivity is established between SMO and O-Cloud O1

interface connectivity is established. Network is operational. Pre-conditions ORMOF Initiated O2 procedures as mentioned O-RAN- WG6.ORCH-USE-CASES in Section 3.2 Begins when ORMOF initiates request to SO SMOF. Step 1 (M) The RANOAM SMOF registers its services related to PM, FM, and CM with the SME. Step 2 (M) The ORMO SMOF (NFO/FOCOM) discovers the SO related to services with the SME. Step 3 (M) The ORMO SMOF or the Non-RT RIC initiates the NF termination and redeployment process by sending a request to the SO. Step 4 (M) The SO queries the TEIV for the topology details of the NF and the allocated resources. Step 5 (M) The SO redeploys the NF by sending a request to the ORMO. Step 6(M) The ORMO creates an NF instance by sending a request to the DMS. Step 7 (M) The ORMO notifies the SO about the creation of the NF instance. Step 8 (M) The SO notifies the OAM to drain the NF and redistribute the traffic. Step 9 (M) The OAM notifies the nRT about the NF draining request. Step 10 (M) The nRT queries and collects the PM data from the DME. Step 11 (O) The nRT queries and collects the FM/CM data from the OAM. Step 12 (O) The OAM configures the NF traffic distribution on the E2-Nodes. Step 13 (M) The E2-Nodes enforce the NF traffic distribution. Step 14 (M) The E2-Nodes notify the OAM about the completion of the NF traffic distribution. Step 15 (M) The OAM notifies the nRT about the completion of the NF draining. Step 16 (M) The nRT evaluates the performance of the drained NF and decides whether to rollback or take any corrective action to recover the desired performance of the NF. Step 17 (M) If the nRT decides to rollback, it sends a report to the SO. Step 18 (M) The SO executes the revised policy or recommendation, which may involve re-draining the NF and redistributing the traffic. Step 19 (M) The SO terminates the NF deployment by sending a request to the ORMO. Step 20 (M) The ORMO terminates the NF deployment by sending a request to the DMS. Step 21 (M) The ORMO or the SO updates the inventory with the TEIV. Ends when O-Cloud becomes non-operational or when the operator disables the rApp as policy function or ML model for policy function. Exceptions TBD Post End Conditions

[0130] FIG. **4** illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including a Service Orchestration and Assurance (SOA) SMOF according to an embodiment. In particular, the below use-case introduces SOA SMOF **450**, which may provide both SO and SA functionality.

[0131] DMS **400**, IMS **410**, ORMO SMOF **420**, RANOAM SMOF **430**, TE & IV SMOF **440**, SME **460**, DME **470**, Non-RT RIC SMOF **480**, and E2 Nodes **490** may be similar to DMS **200**, IMS **210**, ORMO SMOF **220**, RANOAM SMOF **230**, TE & IV SMOF **240**, SME **250**, DME **260**, Non-RT RIC SMOF **270**, E2 Nodes **280** described with reference to FIG. **2** above. Accordingly, redundant descriptions are omitted for the sake of improved readability.

[0132] The embodiment illustrated in FIG. **4** may allow for configuration management (CM) interactions between the ORMO SMOF and RANOAM SMOF. SME **460** may act as the service exposure entity, the Non-RT RIC SMOF **480** may act as an analytical function, ORMO SMOF **420** (which may include the NFO and FOCOM functionality) may act as the O-Cloud Orchestration and Management Function, the RAN OAMF **430** may act as the CM enforcement entity, and SOA SMOF **450** may act as the service orchestration entity.

[0133] The embodiment in FIG. **4** may be initiated when the ORMO SMOF **420** initiates a request to SOA SMOF **450**.

[0134] In step **1**, the RANOAM SMOF **430** may register its services related to performance management (PM), fault management (FM), and CM with the SME **450**.

[0135] In step **2**, the RANOAM SMOF **430** may receive a message from SME **460** indicating that the services were successfully registered. According to some embodiments, this may include receiving a service profile ID.

[0136] In step **3**, the ORMO SMOF **420** may discover SOA related services with the SME **460**.

[0137] In step **4**, the ORMO SMOF **420** may receive the SOA related services from SME **460**.

[0138] There may arise a need to drain traffic from a particular NF instance (e.g., from a

recommendation from an rApp, or due to performance issues). This may be detected by ORMO SMOF **420**. In this case, in step **5**, the ORMO SMOF **420** may request SOA SMOF **450** to terminate and redeploy a particular NF instance.

[0139] As an alternative to step **5**, the SOA may detect an issue with the NF deployment based on, for instance, an automation algorithm for SA. Accordingly, SOA SMOF **450** may also request and terminate the NF itself in step **6**.

[0140] In step **7**, SOA SMOF **450** may query and collect topology details of the NF and allocated resources from TE&IV **440**.

[0141] In step **8**, SOA SMOF **450** may send a request to ORMO SMOF **420** to redeploy the NF.

[0142] In step **9**, SOA SMOF **450** may send a request to RANOAM SMOF **430** to drain the NF and redistribute the traffic.

[0143] In step **10**, RANOAM SMOF **430** may notify the Non-RT RIC SMOF **480** about the traffic draining request for the particular NF instance. Specifically, this may be so that Non-RT RIC SMOF **470** may monitor PM and FM of the particular NF instance.

[0144] In step **11**, the Non-RT RIC SMOF **480** may query and collect PM data from DME **470**.

[0145] In step **12**, the Non-RT RIC SMOF **480** may query and collect FM and CM data from RANOAM SMOF **430**.

[0146] In step **13**, the RANOAM SMOF **430** may configure a NF traffic distribution in order to distribute traffic from the particular NF instance to other NF instance(s), and send the configuration to E2 Nodes **490**.

[0147] In step **14**, E2 nodes **490** may enforce the NF traffic distribution configuration received from the RANOAM SMOF **430**.

[0148] In step **15**, E2 nodes **490** may notify RANOAM SMOF **430** that the traffic distribution has been completed.

[0149] In step **16**, RANOAM SMOF **430** may notify SOA SMOF **450** that traffic distribution has been completed (e.g., it may forward the notification).

[0150] In step **17**, RANAOAM SMOF **430** may notify the Non-RT RIC SMOF **480** that the traffic distribution has been completed (e.g., it may forward the notification).

[0151] In step **18**, the Non-RT RIC SMOF **480** may evaluate the performance of the drained NF and decide whether to rollback or take any corrective action to recover the desired performance of the NF. This step may optionally be performed.

[0152] In step **19**, the Non-RT RIC SMOF **480** may send an evaluation report to SOA SMOF **450**. This may indicate that there are no issues with the performance (e.g., it is successful). This step may optionally be performed.

[0153] As an alternative to step **19**, if there were issues with the performance, in step **20**, the Non-RT RIC SMOF **480** may send a failing evaluation report to SOA SMOF **450**, indicating that rollback or corrective actions should be performed. This step may optionally be performed. The SOA SMOF **450** may choose to perform such corrective action based on receiving this evaluation report.

[0154] In step **21**, SOA SMOF **450** may send a request to ORMO SMOF **420** to terminate the NF deployment.

[0155] In step **22**, ORMO SMOF **420** may send a request to DMS **400** to terminate the NF deployment based on receiving the request from SOA SMOF **450** in step **21** above.

[0156] In step **23**, the ORMO SMOF **420** may update the inventory with TE & IV **440**.

[0157] In addition or as an alternative to step **23**, in step **24**, the SOA SMOF **450** may update the inventory with TE & IV **440**.

[0158] The above use-case may end when the O-Cloud becomes non-operational or when the operator disables using the rApp as policy function and/or an ML model for the policy function (e.g., the rApp and/or ML model are no longer being used as an SA).

[0159] An example implementation of the steps in FIG. **4** for a use-case of a RAN OAM SMOF to

NFO/FOCOM Interaction with SOA may be summarized per the table below. "(M)" may denote a mandatory step and "(O)" may denote an optional one, nevertheless, it should be appreciated that the specific steps used may depend on the specific implementation.

TABLE-US-00003 Use Case Stage Evolution/Specification Goal Enabling CM interactions between ORAMF and RANOAMF Actors and SME: Service exposure Entity Roles Non-RT RIC: Analytical Function ORMO SMOF (Including NFO & FOCOM): O-Cloud Orchestration and Management function. RAN OAMF: CM Enforcement Entity SOA SMOF: Service orchestration and assurance entity Assumptions O2 interface connectivity is established between SMO and O-Cloud O1 interface connectivity is established. Network is operational. Pre-conditions ORMOF Initiated O2 procedures as mentioned O-RAN- WG6.ORCH-USE-CASES in Section 3.2 Begins when ORMOF initiates request to SOA SMOF. Step 1 (M) The RANOAM SMOF registers its services related to PM, FM, and CM with the SME. Step 2 (M) The ORMO SMOF (NFO/FOCOM) discovers the SO&A related to services with the SME. Step 3 (M) The ORMO SMOF or the SOA SMOF initiates the NF termination and redeployment process by sending a request to the SOA. Step 4 (M) The SOA queries the TEIV for the resource details of the NF. Step 5 (M) The SOA redeploys the NF by sending a request to the ORMO. Step 6(M) The SOA distributes the traffic by sending a request to the OAM. Step 7 (M) The OAM notifies the nRT about the NF draining request. Step 8 (M) The nRT queries and collects the PM data from the DME. Step 9 (M) The nRT queries and collects the FM/CM data from the OAM. Step 10 (M) The OAM configures the NF traffic distribution on the E2-Nodes. Step 11 (O) The E2-Nodes enforce the NF traffic distribution. Step 12 (O) The E2-Nodes notify the OAM about the completion of the NF traffic distribution. Step 13 (M) The OAM notifies the nRT about the completion of the NF draining. Step 14 (M) The SOA evaluates the performance of the drained NF and decides whether to rollback or take any corrective action to recover the desired performance of the NF. Step 15 (M) If the SOA decides to rollback, it sends a report to itself. Step 16 (M) The SOA executes the revised policy or recommendation, which may involve re-draining the NF and redistributing the traffic. Step 17 (M) The SOA terminates the NF deployment by sending a request to the ORMO. Step 18 (M) The ORMO terminates the NF deployment by sending a request to the DMS. Step 19 (M) The ORMO or the SOA updates the inventory with the TEIV. Ends when O-Cloud becomes non-operational or when the operator disables the rApp as policy function or ML model for policy function. Exceptions TBD Post End Conditions

[0160] Based on the above embodiments, it can be understood that since the ORMO can facilitate interactions with the RANOAM and other SMOF's, seamless interaction between different SMOF's can be achieved in order to facilitate managing NF instances.

[0161] FIG. **5** is a diagram of an example environment **500** in which systems and/or methods, described herein, may be implemented. As shown in FIG. **5**, environment **500** may include a user device **510**, a platform **520**, and a network **530**. Devices of environment **500** may interconnect via wired connections, wireless connections, or a combination of wired and wireless connections. In embodiments, any of the functions and operations described with reference to FIGS. **2** through **4** above may be performed by any combination of elements illustrated in FIG. **5**.

[0162] User device **510** includes one or more devices capable of receiving, generating, storing, processing, and/or providing information associated with platform **520**. For example, user device **510** may include a computing device (e.g., a desktop computer, a laptop computer, a tablet computer, a handheld computer, a smart speaker, a server, etc.), a mobile phone (e.g., a smart phone, a radiotelephone, etc.), a wearable device (e.g., a pair of smart glasses or a smart watch), or a similar device. In some implementations, user device **510** may receive information from and/or transmit information to platform **520**.

[0163] Platform **520** includes one or more devices capable of receiving, generating, storing, processing, and/or providing information. In some implementations, platform **520** may include a cloud server or a group of cloud servers. In some implementations, platform **520** may be designed

to be modular such that certain software components may be swapped in or out depending on a particular need. As such, platform **520** may be easily and/or quickly reconfigured for different uses.

[0164] In some implementations, as shown, platform **520** may be hosted in cloud computing environment **522**. Notably, while implementations described herein describe platform **520** as being hosted in cloud computing environment **522**, in some implementations, platform **520** may not be cloud-based (i.e., may be implemented outside of a cloud computing environment) or may be partially cloud-based.

[0165] Cloud computing environment **522** includes an environment that hosts platform **520**. Cloud computing environment **522** may provide computation, software, data access, storage, etc., services that do not require end-user (e.g., user device **510**) knowledge of a physical location and configuration of system(s) and/or device(s) that hosts platform **520**. As shown, cloud computing environment **522** may include a group of computing resources **524** (referred to collectively as "computing resources **524**" and individually as "computing resource **524**").

[0166] Computing resource **524** includes one or more personal computers, a cluster of computing devices, workstation computers, server devices, or other types of computation and/or communication devices. In some implementations, computing resource **524** may host platform **520**. The cloud resources may include compute instances executing in computing resource **524**, storage devices provided in computing resource **524**, data transfer devices provided by computing resource **524**, etc. In some implementations, computing resource **524** may communicate with other computing resources **524** via wired connections, wireless connections, or a combination of wired and wireless connections.

[0167] As further shown in FIG. **5**, computing resource **524** includes a group of cloud resources, such as one or more applications ("APPs") **524-1**, one or more virtual machines ("VMs") **524-2**, virtualized storage ("VSs") **524-3**, one or more hypervisors ("HYPs") **524-4**, or the like. While the current example embodiment is with reference to virtualized network functions, it is understood that one or more other embodiments are not limited thereto, and may be implemented in at least one of containers, cloud-native services, one or more container platforms, etc. For example, in one or more other example embodiments, any of the above-described components (e.g., nodes, E2 nodes, SMO functions, RIC, system, apparatus, etc.) may be a software-based component deployed or hosted in, for example, a server cluster such as a hybrid cloud server, data center servers, and the like. The software-based component may be containerized and may be deployed and controlled by one or more machines, called "nodes", that run or execute the containerized network elements and are addressable. In this regard, a server cluster may contain at least one master node and a plurality of worker nodes, wherein the master node(s) controls and manages a set of associated worker nodes

[0168] Application **524-1** includes one or more software applications that may be provided to or accessed by user device **510**. Application **524-1** may eliminate a need to install and execute the software applications on user device **510**. For example, application **524-1** may include software associated with platform **520** and/or any other software capable of being provided via cloud computing environment **522**. In some implementations, one application **524-1** may send/receive information to/from one or more other applications **524-1**, via virtual machine **524-2**.

[0169] Virtual machine **524-2** includes a software implementation of a machine (e.g., a computer) that executes programs like a physical machine. Virtual machine **524-2** may be either a system virtual machine or a process virtual machine, depending upon use and degree of correspondence to any real machine by virtual machine **524-2**. A system virtual machine may provide a complete system platform that supports execution of a complete operating system ("OS"). A process virtual machine may execute a single program, and may support a single process. In some implementations, virtual machine **524-2** may execute on behalf of a user (e.g., user device **510**), and may manage infrastructure of cloud computing environment **522**, such as data management, synchronization, or long-duration data transfers.

[0170] Virtualized storage **524-3** includes one or more storage systems and/or one or more devices

that use virtualization techniques within the storage systems or devices of computing resource **524**. In some implementations, within the context of a storage system, types of virtualizations may include block virtualization and file virtualization. Block virtualization may refer to abstraction (or separation) of logical storage from physical storage so that the storage system may be accessed without regard to physical storage or heterogeneous structure. The separation may permit administrators of the storage system flexibility in how the administrators manage storage for end users. File virtualization may eliminate dependencies between data accessed at a file level and a location where files are physically stored. This may enable optimization of storage use, server consolidation, and/or performance of non-disruptive file migrations.

[0171] Hypervisor **524-4** may provide hardware virtualization techniques that allow multiple operating systems (e.g., "guest operating systems") to execute concurrently on a host computer, such as computing resource **524**. Hypervisor **524-4** may present a virtual operating platform to the guest operating systems, and may manage the execution of the guest operating systems. Multiple instances of a variety of operating systems may share virtualized hardware resources.

[0172] Network **530** includes one or more wired and/or wireless networks. For example, network **530** may include a cellular network (e.g., a fifth generation (5G) network, a long-term evolution (LTE) network, a third generation (3G) network, a code division multiple access (CDMA) network, etc.), a public land mobile network (PLMN), a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), a telephone network (e.g., the Public Switched Telephone Network (PSTN)), a private network, an ad hoc network, an intranet, the Internet, a fiber optic-based network, or the like, and/or a combination of these or other types of networks.

[0173] The number and arrangement of devices and networks shown in FIG. **5** are provided as an example. In practice, there may be additional devices and/or networks, fewer devices and/or networks, different devices and/or networks, or differently arranged devices and/or networks than those shown in FIG. **5**. Furthermore, two or more devices shown in FIG. **5** may be implemented within a single device, or a single device shown in FIG. **5** may be implemented as multiple, distributed devices. Additionally, or alternatively, a set of devices (e.g., one or more devices) of environment **500** may perform one or more functions described as being performed by another set of devices of environment **500**.

[0174] FIG. **6** is a diagram of example components of a device **600**. Device **600** may correspond to user device **510** and/or platform **520**. As shown in FIG. **6**, device **600** may include a bus **610**, a processor **620**, a memory **630**, a storage component **640**, an input component **650**, an output component **660**, and a communication interface **670**.

[0175] Bus **610** includes a component that permits communication among the components of device **600**. Processor **620** may be implemented in hardware, firmware, or a combination of hardware and software. Processor **620** may be a central processing unit (CPU), a graphics processing unit (GPU), an accelerated processing unit (APU), a microprocessor, a microcontroller, a digital signal processor (DSP), a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), or another type of processing component. In some implementations, processor **620** includes one or more processors capable of being programmed to perform a function. Memory **630** includes a random access memory (RAM), a read only memory (ROM), and/or another type of dynamic or static storage device (e.g., a flash memory, a magnetic memory, and/or an optical memory) that stores information and/or instructions for use by processor **620**.

[0176] Storage component **640** stores information and/or software related to the operation and use of device **600**. For example, storage component **640** may include a hard disk (e.g., a magnetic disk, an optical disk, a magneto-optic disk, and/or a solid state disk), a compact disc (CD), a digital versatile disc (DVD), a floppy disk, a cartridge, a magnetic tape, and/or another type of non-transitory computer-readable medium, along with a corresponding drive. Input component **650** includes a component that permits device **600** to receive information, such as via user input (e.g., a touch screen display, a keyboard, a keypad, a mouse, a button, a switch, and/or a microphone).

Additionally, or alternatively, input component **650** may include a sensor for sensing information (e.g., a global positioning system (GPS) component, an accelerometer, a gyroscope, and/or an actuator). Output component **660** includes a component that provides output information from device **600** (e.g., a display, a speaker, and/or one or more light-emitting diodes (LEDs)).

[0177] Communication interface **670** includes a transceiver-like component (e.g., a transceiver and/or a separate receiver and transmitter) that enables device **600** to communicate with other devices, such as via a wired connection, a wireless connection, or a combination of wired and wireless connections. Communication interface **670** may permit device **600** to receive information from another device and/or provide information to another device. For example, communication interface **670** may include an Ethernet interface, an optical interface, a coaxial interface, an infrared interface, a radio frequency (RF) interface, a universal serial bus (USB) interface, a Wi-Fi interface, a cellular network interface, or the like.

[0178] Device **600** may perform one or more processes described herein. Device **600** may perform these processes in response to processor **620** executing software instructions stored by a non-transitory computer-readable medium, such as memory **630** and/or storage component **640**. A computer-readable medium is defined herein as a non-transitory memory device. A memory device includes memory space within a single physical storage device or memory space spread across multiple physical storage devices.

[0179] Software instructions may be read into memory **630** and/or storage component **640** from another computer-readable medium or from another device via communication interface **670**. When executed, software instructions stored in memory **630** and/or storage component **640** may cause processor **620** to perform one or more processes described herein.

[0180] Additionally, or alternatively, hardwired circuitry may be used in place of or in combination with software instructions to perform one or more processes described herein. Thus, implementations described herein are not limited to any specific combination of hardware circuitry and software.

[0181] The number and arrangement of components shown in FIG. **6** are provided as an example. In practice, device **600** may include additional components, fewer components, different components, or differently arranged components than those shown in FIG. **6**. Additionally, or alternatively, a set of components (e.g., one or more components) of device **600** may perform one or more functions described as being performed by another set of components of device **600**.

[0182] In embodiments, any of the operations or processes of FIGS. **2-4** may be implemented by or using any one of the elements illustrated in FIGS. **5** and **6**. It is understood that other embodiments are not limited thereto, and may be implemented in a variety of different architectures (e.g., bare metal architecture, any cloud-based architecture or deployment architecture such as Kubernetes, Docker, OpenStack, etc.).

[0183] A use case in accordance with one or more example embodiments is described further herein below.

[0184] Use Case: ORMO & RANOAM SMOF Interactions

Background and Goal of the Use Case

[0185] O-Cloud orchestration and managements require seamless interactions with other

[0186] SMO functions such as RANOAM, TE & IV, Non-RT RIC SMOF. This use case focuses on interactions with RAN OAM SMOF.

[0187] Network functions are orchestrated by NFO related capabilities of ORMO; however those NF application are configured through RAN OAM via O1 interface. In case of Scale In of NF, before terminating any NF deployment, i.e., NF instance traffic associated with that NF deployment needs to distribute amongst remaining NF deployment. Here NFO needs to instruct RAN OAM to drain traffic of NF deployment which is to be terminated. RAN OAM to ascertain policy to distribute traffic among NF deployment through other SMOF such NFO, Non-RT RIC, TE &IV or RAN OAM.

[0188] NF traffic draining is an example of interaction required between ORMO & RAN OAM, there could be more examples such as:

[0189] NFO.fwdarw.RANOAM: Configuring or Reconfiguring NF post NF instantiation by DMS.

[0190] NFO.fwdarw.RANOAM: Querying operational, administrative, usage state of NF.

[0191] NFO.fwdarw.RANOAM: Notification related to NF state & health.

[0192] NFO.fwdarw.RANOAM: Response to actions initiated by RANOAM.

[0193] RANOAM.fwdarw.NFO: Notification related to NF Configuration, Traffic draining, Fault reporting.

[0194] Below capabilities are essential for O-Cloud Orchestration and Management in relation with interaction with other RAN OAM:

[0195] FOCOM/NFO to support for capabilities to receive notifications from RANOAM.

[0196] FOCOM/NFO to support for capability to configure NF deployment through RAN OAM.

[0197] RAN OAM to support capabilities to receive notifications from ORMO SMOF.

[0198] RAN OAM to support capabilities to send notifications to other SMOF.

Entities/Resources Involved in the Use Case

1) SME SMOF:

[0199] a) In a decoupled service-based SMO architecture, the SME can be leveraged as a universal SMOS, handling service management and exposure for any SMOSs within SMO. [0200] b) To support functionality to discover the available services from SMOF and authorization of SMOF to determine which services an SMOF can discover, [0201] c) Support to retrieve the stored service information and performs filtering of available services based on selection criteria that may be provided by the SMOF.

2) Non-RT RIC SMOF

[0202] a) Support to monitor and evaluate NF PM/FM/CM data via O1 & O2 for NF traffic draining.

3) ORMO SMOF (NFO & FOCOM)

[0203] a) Support registration of capabilities for NFO related services such as with SME. [0204] b) Support receiving and sending necessary notifications for RANOAM SMOF related to life cycle of NF deployment.

4) O-Cloud (IMS & DMS)

[0205] a) Support to receive actions and feedback from ORMO SMOF (NFO & FOCOM) & implement on O-Cloud platform through IMS & DMS

5) Topology Exposure and Inventory Management (TE & IV) SMOF

[0206] a) Support updating Topology Exposure and Inventory based on request from other SMOF.

6) RAN OAM SMOF

[0207] a) Supports requests from other SMOF for services such as PM, FM, CM. [0208] b) Notifying other SMOF about mentioned changes in CM requests

7) Service Orchestrator (SO) and Service assurance (SA) SMOF [0209] a) Support orchestrating various procedures required for interaction between RAN OAM related function and NFO/FOCOM based services assurance. [0210] b) The SO uses a set of recipes to define the steps involved in creating a service, and it then executes these steps in a sequence to ensure that the service is created correctly. [0211] c) The SO and SA work together to ensure that network services are created and maintained in a consistent and reliable manner. The SO ensures that the services are created correctly, and the SA ensures that they are performing as expected. This helps to improve the overall quality of service for network customers.

TABLE-US-00004 Scenario 1: RAN OAM SMOF to NFO/FOCOM Interaction without SO and rApp as SA Use Case Stage Evolution/Specification Goal Enabling CM interactions between ORAMF and RANOAMF Actors and SME: Service exposure Entity Roles Non-RT RIC: Analytical Function ORMO SMOF (Including NFO & FOCOM): O-Cloud Orchestration and Management function. RAN OAMF: CM Enforcement Entity Assumptions O2 interface

connectivity is established between SMO and O- Cloud O1 interface connectivity is established. Network is operational. Pre-conditions ORMOF Initiated O2 procedures as mentioned O-RAN-WG6.ORCH-USE-CASES in Section 3.2 Begins when ORMOF initiates request to RAN OAMF. Step 1 (M) The RANOAM SMOF registers its services related to PM, FM, and CM with the SME. Step 2 (M) The ORMO SMOF (NFO/FOCOM) discovers the RANOAM- related services with the SME. Step 3 (M) The ORMO SMOF initiates the traffic draining process by sending a request to the OAM. Step 4 (M) The OAM notifies the nRT about the traffic draining request. Step 5 (M) The nRT queries and collects the PM data from the DME. Step 6(M) The nRT queries and collects the FM/CM data from the OAM. Step 7 (M) The OAM configures the NF traffic distribution on the E2-Nodes. Step 8 (M) The E2-Nodes enforce the NF traffic distribution. Step 9 (M) The E2-Nodes notify the OAM about the completion of the NF traffic distribution. Step 10 (M) The OAM notifies the nRT about the completion of the NF traffic draining. Step 11 (O) The nRT evaluates the performance of the drained NF and decides whether to rollback or take any corrective action to recover the desired performance of the NF. Step 12 (O) If the nRT decides to rollback, it sends a report to the OAM. Step 13 (M) The OAM terminates the NF deployment by sending a request to the DMS. Step 14 (M) The ORMO SMOF updates the inventory with the TEIV. Ends when O-Cloud becomes non-operational or when the operator disables the rApp as policy function or ML model for policy function. Exceptions TBD Post End Conditions

TABLE-US-00005 @startuml 'https://plantuml.com/sequence-diagram !pragma teoz true skinparam ParticipantPadding 5 skinparam BoxPadding 10 skinparam defaultFontSize 12 skinparam lifelineStrategy solid autonumber Box "O-Cloud" #lightseagreen participant "DMS" as DMS participant "IMS" as IMS End box Box "Service Management and Orchestration Framework" #gold Participant "ORMO SMOF\n(NFO & FOCOM)" as ORMO Participant "RANOAM SMOF" as OAM Participant "TE & IV SMOF" as TEIV Participant "SME" as SME Participant "DME" as DME Participant "Non-RT RIC SMOF" as nRT End box Box " O-RAN Nodes" #lightpink Participant "E2-Node(s)" as E2NODES End box group Service registeration Note over OAM RANOAM SMOF to register services Related to PM, FM ,CM with SME End note OAM −> SME : Register services SME −> OAM : Success (Service Profile ID) end group Service discovery Note over ORMO , SME ORMO SMOF i.e. NFO /FOCOM tp discover RANOAM related to services with SME . End note ORMO −> SME : <<R1>> Discover RANOAM SMOF Related services SME −> ORMO : <<R1>> Discovery Result end group ORMO to OAM Interaction for Traffic Draining Note over ORMO, OAM There are possible interactions such as there is need to to drain traffic from perticular instace of NF application End note Alt ORMO Initiates ORMO −> OAM : Drain NF traffic Else Non-RT RIC Initiates OAM −> nRT : Notify Drain NF traffic Note over OAM, nRT RANAOM receives request to drain traffic for particular instance of NF application RANOAM Notifies nRT about same in order to monitor PM/FM of respective NF application End note nRT <−> DME : Query & collect PM Data nRT <−> OAM : Query & collect FM/CM Data Note over OAM, E2NODES RANOAM to distribute traffic from target NF instance to be drained to other instances of NF instances End Note OAM −> E2NODES : <<O1>> Configure NF Traffic Distribution E2NODES −> E2NODES : Enforce NF\nTraffic Distribution E2NODES −> OAM : <<O1>> Completion of NF Traffic Distribution OAM −> nRT : Notify Completion of Drain NF traffic Note Over nRT , OAM Monitor performance of drained NF & evaluate Decision to rollback or any corrective action to recover desired performance of NF end note nRT −> nRT : Evaluate\nPerformance of NF nRT −> OAM : Successful Evaluation Report OAM −> ORMO : Completion of NF traffic draining ORMO −> DMS : Terminate NF Deployement end group Inventory Update ORMO <−> TEIV : Update Inventory End @enduml

[0212] FIG. **7**A-FIG. **7**C illustrates a callflow diagram for an interaction between ORMO and

RANOAM SMOF according to an embodiment. FIG. **7**A-FIG. **7**C may illustrate a use case for scenario 1.

TABLE-US-00006 Scenario 2: RAN OAM SMOF to NFO/FOCOM Interaction with SO and rApp as SA Use Case Stage Evolution/Specification Goal Enabling CM interactions between ORAMF and RANOAMF Actors and SME: Service exposure Entity Roles Non-RT RIC: Analytical Function ORMO SMOF (Including NFO & FOCOM): O-Cloud Orchestration and Management function. RAN OAMF: CM Enforcement Entity SO SMOF: Service orchestration entity Assumptions O2 interface connectivity is established between SMO and O- Cloud O1 interface connectivity is established. Network is operational. Pre-conditions ORMOF Initiated O2 procedures as mentioned O-RAN- WG6.ORCH-USE-CASES in Section 3.2 Begins when ORMOF initiates request to SO SMOF. Step 1 (M) The RANOAM SMOF registers its services related to PM, FM, and CM with the SME. Step 2 (M) The ORMO SMOF (NFO/FOCOM) discovers the SO related to services with the SME. Step 3 (M) The ORMO SMOF or the Non-RT RIC initiates the NF termination and redeployment process by sending a request to the SO. Step 4 (M) The SO queries the TEIV for the topology details of the NF and the allocated resources. Step 5 (M) The SO redeploys the NF by sending a request to the ORMO. Step 6(M) The ORMO creates an NF instance by sending a request to the DMS. Step 7 (M) The ORMO notifies the SO about the creation of the NF instance. Step 8 (M) The SO notifies the OAM to drain the NF and redistribute the traffic. Step 9 (M) The OAM notifies the nRT about the NF draining request. Step 10 (M) The nRT queries and collects the PM data from the DME. Step 11 (O) The nRT queries and collects the FM/CM data from the OAM. Step 12 (O) The OAM configures the NF traffic distribution on the E2-Nodes. Step 13 (M) The E2-Nodes enforce the NF traffic distribution. Step 14 (M) The E2-Nodes notify the OAM about the completion of the NF traffic distribution. Step 15 (M) The OAM notifies the nRT about the completion of the NF draining. Step 16 (M) The nRT evaluates the performance of the drained NF and decides whether to rollback or take any corrective action to recover the desired performance of the NF. Step 17 (M) If the nRT decides to rollback, it sends a report to the SO. Step 18 (M) The SO executes the revised policy or recommendation, which may involve re-draining the NF and redistributing the traffic. Step 19 (M) The SO terminates the NF deployment by sending a request to the ORMO. Step 20 (M) The ORMO terminates the NF deployment by sending a request to the DMS. Step 21 (M) The ORMO or the SO updates the inventory with the TEIV. Ends when O-Cloud becomes non-operational or when the operator disables the rApp as policy function or ML model for policy function. Exceptions TBD Post End Conditions

TABLE-US-00007 @startuml ′https://plantuml.com/sequence-diagram !pragma teoz true skinparam ParticipantPadding 5 skinparam BoxPadding 10 skinparam defaultFontSize 12 skinparam lifelineStrategy solid autonumber Box "O-Cloud" #lightseagreen participant "DMS" as DMS participant "IMS" as IMS End box Box ′Service Management and Orchestration Framework′ #gold Participant "ORMO SMOF\n(NFO & FOCOM)" as ORMO Participant "RANOAM SMOF" as OAM Participant "TE & IV SMOF" as TEIV Participant "SO SMOF" as SO Participant "SME" as SME Participant "DME" as DME Participant "Non-RT RIC SMOF" as nRT End box Box ′ O- RAN Nodes′ #lightpink Participant ′E2-Node(s)′ as E2NODES End box group Service registeration Note over OAM RANOAM SMOF to register services Related to PM, FM ,CM with SME End note OAM −> SME : Register services SME −> OAM : Success (Service Profile ID) end group Service discovery Note over ORMO , SME ORMO SMOF i.e. NFO /FOCOM to discover SO&A related to services with SME . End note ORMO −> SME : <<R1>> Discover SOA SMOF Related services SME −> ORMO : <<R1>> Discovery Result end Note over ORMO, OAM There are possible interactions such as there is need to to drain traffic from particular instance of NF application End note Alt ORMO Initiates ORMO −> SO : Terminating & Redeploy NF Else Non-RT RIC Initiates Note

over nRT, SO   Non-RT RIC can detect issue with NF deployment   or O-Cloud and requesting to terminate and redeploy NF   End note   nRT −> SO : Terminating & redeploy NF   end   Note over SO, TEIV   SO can query details of NF traffic policy , IP details, etc. to provide   details about traffic redistribution . Non-RT RIC can provide traffic   redistribution policy.   End note   SO <-> TEIV : Query Topology details of NF & allocated resources   SO <-> ORMO : Redeploy NF   ORMO <-> DMS : Create NF Instance   ORMO <-> SO : Notify Creation of NF Instance   SO <-> OAM : Drain NF and Redistribute Traffic   Group Non-RT RIC Data collection   SO −> nRT : Notify Drain NF traffic   Note Left   RANAOM receives request to drain traffic for particular instance   of NF application RANOAM   SO Notifies nRT about same in order to monitor PM/FM of respective   NF application   End note   nRT <-> DME : Query & collect PM Data   nRT <-> OAM : Query & collect FM/CM Data   Note over OAM, E2NODES   RANOAM to distribute traffic from target NF instance to be drained   to other instances of NF   End Note   End   Group RAN OAM executes traffic draining   OAM −> E2NODES : <<O1>> Configure NF Traffic Distribution   E2NODES −> E2NODES : Enforce NF\nTraffic Distribution   E2NODES −> OAM : <<O1>> Completion of NF Traffic Distribution   OAM −> SO : Notify Completion of Drain NF traffic   OAM −> nRT : Notify Completion of Drain NF traffic   End   Group Non-RT RIC as Assurance   nRT −> nRT : Evaluate\nPerformance of NF   Note left   Monitor performace of drained NF & evaluate Decision to rollback or any corrective action   to recover desired performance of NF   end note   Alt Successful   nRT −> SO : Successful Evaluation Report   Else Failed   nRT −> SO : Failed Evaluation Report & revised policy or   recommendation   Note Over SO, nRT   SO to execute revised policy or recommendation in similar manner   as mentioned on previous steps end note   End   End   SO <-> ORMO : Terminate NF Deployment   ORMO <-> DMS : Terminate NF Deployment   alt Inventory Update   ORMO <-> TEIV : Update Inventory   Else   SO <-> TEIV : Update Inventory   @enduml

[0213] FIG. **8**A-FIG. **8**D illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including a SO SMOF according to an embodiment. FIG. **8**A-FIG. **8**D may illustrate a use case for scenario 2.

TABLE-US-00008 Scenario 3: RAN OAM SMOF to NFO/FOCOM Interaction with SOA Use Case Stage Evolution/Specification Goal Enabling CM interactions between ORAMF and RANOAMF Actors and Roles SME: Service exposure Entity Non-RT RIC: Analytical Function ORMO SMOF (Including NFO & FOCOM): O-Cloud Orchestration and Management function. RAN OAMF: CM Enforcement Entity SOA SMOF: Service orchestration and assurance entity Assumptions O2 interface connectivity is established between SMO and O- Cloud O1 interface connectivity is established. Network is operational. Pre-conditions ORMOF Initiated O2 procedures as mentioned O-RAN- WG6.ORCH-USE-CASES in Section 3.2 Begins when ORMOF initiates request to SOA SMOF. Step 1 (M) The RANOAM SMOF registers its services related to PM, FM, and CM with the SME. Step 2 (M) The ORMO SMOF (NFO/FOCOM) discovers the SO&A related to services with the SME. Step 3 (M) The ORMO SMOF or the SOA SMOF initiates the NF termination and redeployment process by sending a request to the SOA. Step 4 (M) The SOA queries the TEIV for the resource details of the NF. Step 5 (M) The SOA redeploys the NF by sending a request to the ORMO. Step 6(M) The SOA distributes the traffic by sending a request to the OAM. Step 7 (M) The OAM notifies the nRT about the NF draining request. Step 8 (M) The nRT queries and collects the PM data from the DME. Step 9 (M) The nRT queries and collects the FM/CM data from the OAM. Step 10 (M) The OAM configures the NF traffic distribution on the E2- Nodes. Step 11 (O) The E2-Nodes enforce the NF traffic distribution. Step 12 (O) The E2-Nodes notify the OAM about the completion of the NF traffic distribution. Step 13 (M) The OAM notifies the nRT about the completion of the NF draining. Step 14 (M) The SOA evaluates the performance of the drained NF and decides whether to rollback or take any corrective action to recover the desired performance of the NF. Step 15 (M) If the SOA decides to rollback, it

sends a report to itself. Step 16 (M) The SOA executes the revised policy or recommendation, which may involve re-draining the NF and redistributing the traffic. Step 17 (M) The SOA terminates the NF deployment by sending a request to the ORMO. Step 18 (M) The ORMO terminates the NF deployment by sending a request to the DMS. Step 19 (M) The ORMO or the SOA updates the inventory with the TEIV. Ends when O-Cloud becomes non-operational or when the operator disables the rApp as policy function or ML model for policy function. Exceptions TBD Post Conditions End

TABLE-US-00009 @startuml ′https://plantuml.com/sequence-diagram !pragma teoz true skinparam ParticipantPadding 5 skinparam BoxPadding 10 skinparam defaultFontSize 12 skinparam lifelineStrategy solid autonumber Box "O-Cloud" #lightseagreen participant "DMS" as DMS participant "IMS" as IMS End box Box ″Service Management and Orchestration Framework″ #gold Participant "ORMO SMOF\n(NFO & FOCOM)" as ORMO Participant "RANOAM SMOF" as OAM Participant "TE & IV SMOF" as TEIV Participant "SOA SMOF" as SOA Participant "SME" as SME Participant "DME" as DME Participant "Non-RT RIC SMOF" as nRT End box Box ″O-RAN Nodes″ #lightpink Participant ″E2-Node(s)″ as E2NODES End box group Service registeration Note over OAM RANOAM SMOF to register services Related to PM, FM ,CM with SME End note OAM −> SME : Register services SME −> OAM : Success (Service Profile ID) end group Service discovery Note over ORMO , SME ORMO SMOF i.e. NFO /FOCOM to discover SO&A related to services with SME . End note ORMO −> SME : <<R1>> Discover SOA SMOF Related services SME −> ORMO : <<R1>> Discovery Result end Alt ORMO Initiates Note over ORMO, SOA ORMO detect issue and there is need to drain traffic from particular instance of NF application End note ORMO −> SOA : Need to Terminate & Redeploy NF Else SOA Initiates Note over ORMO, SOA SO can detect issue with NF deployment based on automation algorithm For service assurance ,then requesting to terminate and redeploy NF End note SOA −> SOA : Terminating & redeploy NF end Note over TEIV, SOA SO to query details of NF traffic policy , IP details, etc., to provide details about traffic redistribution . Create traffic redistribution policy. End note SOA <-> TEIV : Query Resource details of NF SOA <-> ORMO : Redeploy NF SOA <-> OAM : Distribute Traffic SOA −> nRT : Notify Drain NF traffic Note over OAM, nRT RANAOM receives request to drain traffic for particular instance of NF application RANOAM Notifies nRT about same in order to monitor PM/FM of respective NF application End note Group SOA Data collection SOA <-> DME : Query & collect PM Data SOA <-> OAM : Query & collect FM/CM Data End Group RAN OAM Executes traffic draining Note over OAM, E2NODES RANOAM to distributes traffic from target NF instance to be drained to other instances of NF instances End Note OAM −> E2NODES : <<O1>> Configure NF Traffic Distribution E2NODES −> E2NODES : Enforce NF\nTraffic Distribution E2NODES −> OAM : <<O1>> Completion of NF Traffic Distribution OAM −> SOA : Notify Completion of Drain NF traffic OAM −> nRT : Notify Completion of Drain NF traffic End Alt Successful Note Over SOA Monitor performance of drained NF & evaluate Decision to rollback or any corrective action to recover desired performance of NF end note SOA −> SOA : Successful Evaluation Report Else Failed SOA −> SOA : Failed Evaluation Report &\n revised policy or recommendation End SOA <-> ORMO : Terminate NF Deployment ORMO <-> DMS : Terminate NF Deployment alt Inventory Update ORMO <-> TEIV : Update Inventory Else SOA <-> TEIV : Update Inventory End @enduml

[0214] FIG. **9**A-FIG. **9**C illustrates a callflow diagram for an interaction between ORMO, RANOAM SMOF, including an SOA SMOF according to an embodiment. FIG. **9**A-FIG. **9**C may illustrate a use case for scenario 3.

7 Recommended Functional Requirements

TABLE-US-00010 7.x ORMOF Requirements REQ Description Note [REQ- ORMOF -001] ORMOF shall support registration of NFO and/or FOCOM related services with SME SMOF. [REQ- ORMOF -002] ORMOF shall support traffic draining request for cases such as NF termination towards Service Orchestrator and Assurance. [REQ- ORMOF -003] ORMOF shall support invoking O2DMS/O2IMS actions based on SOA or SO recommendations. [REQ- ORMOF -004] ORMOF shall support acknowledge notifications related to RAN OAM SMOF

TABLE-US-00011 7.x NRTRF Requirements REQ Description Note [REQ- NRTF -001] NRTRF shall support role of assurance for SOF in cases such as NF traffic draining. [REQ- NRTF -002] NRTRF shall support discovery of SOF or SOAF related services over SME

TABLE-US-00012 7.x SOAF Requirements REQ Description Note [REQ- SOAF -001] SOAF shall support registration of SOA related services over SME. [REQ- SOAF -002] SOAF shall support discovery of SOA related services through SME. [REQ- SOAF -003] SOAF shall support role of services orchestrator to facilitate procedures between various SMOF within SMO. [REQ- SOAF -004] SOAF shall support role of services assurance to enable SLA based procedures within SMO. [REQ- SOAF -005] SOAF shall support ORMOF and RAN OAMF related data collection. [REQ- SOAF -006] SOAF shall support storing relevant end to end NF application related, O-Cloud Infrastructure related, NF deployment related automation procedures and registering it over SME/DME for discovery purpose.

TABLE-US-00013 7.x SOF Requirements REQ Description Note [REQ- SOAF -001] SOF shall support role of services orchestrator to facilitate procedures between various SMOF within SMO. [REQ- SOAF -002] SOF shall support registration of SO related services over SME. [REQ- SOAF -003] SOF shall support discovery of SO related services through SME. [REQ- SOAF -004] SOF shall support storing relevant end to end NF application related, O-Cloud Infrastructure related, NF deployment related automation procedures and registering it over SME/DME for discovery purpose.

[0215] The foregoing disclosure provides illustration and description, but is not intended to be exhaustive or to limit the implementations to the precise form disclosed. Modifications and variations are possible in light of the above disclosure or may be acquired from practice of the implementations.

[0216] Some embodiments may relate to a system, a method, and/or a computer readable medium at any possible technical detail level of integration. Further, one or more of the above components described above may be implemented as instructions stored on a computer readable medium and executable by at least one processor (and/or may include at least one processor). The computer readable medium may include a computer-readable non-transitory storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out operations.

[0217] The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light

pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

[0218] Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network may include copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

[0219] Computer readable program code/instructions for carrying out operations may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, configuration data for integrated circuitry, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Smalltalk, C++, or the like, and procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects or operations.

[0220] These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein includes an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

[0221] These computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0222] The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer readable media according to various embodiments. In this regard, each block in the flowchart or block diagrams may represent a microservice(s), module, segment, or portion of instructions, which includes one or more executable instructions for implementing the specified logical function(s). The method, computer system, and computer readable medium may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in the Figures. In some

alternative implementations, the functions noted in the blocks may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed concurrently or substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

[0223] It will be apparent that systems and/or methods, described herein, may be implemented in different forms of hardware, firmware, or a combination of hardware and software. The actual specialized control hardware or software code used to implement these systems and/or methods is not limiting of the implementations. Thus, the operation and behavior of the systems and/or methods were described herein without reference to specific software code. It is understood that software and hardware may be designed to implement the systems and/or methods based on the description herein.

Various Aspects of Embodiments

[0224] Various further respective aspects and features of embodiments of the present disclosure may be defined by the following items:

[0225] Item [1]; A method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function, the method including: receiving, by the ORMO, related services to the an SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

[0226] Item [2]: The method according to item [1], wherein the SMOF is the RANOAM SMOF, and wherein upon receiving the request from the ORMO, the RANOAM SMOF is configured to notify a non Real-Time (nRT) RIC SMOF about the request to drain traffic of the at least one NF, wherein the nRT RIC SMOF is configured to query and collect Performance Management (PM) data from a Data Management Entity (DME) and Fault Management (FM) and Configuration Management (CM) data from the RANOAM SMOF upon being notified about the request to drain traffic of the at least one NF.

[0227] Item [3]: The method according to item [2], wherein upon receiving the FM and CM data, the RANOAM SMOF is configured to send a NF traffic distribution configuration to E2 nodes, wherein the E2 nodes are configured to enforce NF traffic distribution based on the NF traffic distribution configuration to drain the at least one NF and send a notification of completing enforcing the NF traffic distribution to the RANOAM SMOF.

[0228] Item [4]: The method according to item [3], wherein upon receiving the notification of completing the NF traffic distribution, the RANOAM SMOF is configured to forward the notification of completing the NF traffic distribution to the nRT RIC SMOF.

[0229] Item [5]: The method according to item [4], wherein upon receiving the notification of completing the NF traffic distribution from the RANOAM SMOF, the nRT RIC SMOF is configured to evaluate the performance of the drained at least one NF, and based on the evaluated performance, send a report to the RANOAM SMOF recommending whether or not to rollback the NF traffic distribution configuration.

[0230] Item [6]: The method according to item [5], wherein upon receiving the report, the RANOAM SMOF is configured to send a notification to the ORMO indicating traffic draining was completed.

[0231] Item [7]: The method according to item [6], wherein upon receiving the notification from the RANOAM SMOF, the method further includes: sending, by the ORMO, a request to the DMS

to terminate a deployment of the at least one NF.

[0232] Item [8]: A method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function, the method including: receiving, by the ORMO, a service related to a Service Orchestration (SO) SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SO SMOF to terminate and redeploy at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

[0233] Item [9]: The method according to item [8]. wherein upon receiving the request from the ORMO, the SO SMOF is configured to query topology details of the at least one NF and allocated resources from the TE/IV and send a request to the ORMO to redeploy the at least one NF.

[0234] Item [10]: The method according to item [9], wherein upon receiving the request from the SO SMOF to redeploy the at least one NF, the method further includes: sending, by the ORMO, a request to a Deployment Management Services (DMS) to create a new NF instance; and sending, by the ORMO, a notification to the SO SMOF that the new NF instance was created.

[0235] Item [11]. The method according to item [10], wherein upon receiving the notification from the ORMO that the new NF instance was created, the SO SMOF is configured to send a request to a RANOAM SMOF to drain the at least one NF, wherein upon receiving the request from the SO SMOF to drain the at least one NF, the RANOAM SMOF is configured to notify a non Real-Time (nRT) RIC SMOF about the request to drain traffic of the at least one NF, wherein the nRT RIC SMOF is configured to query and collect Performance Management (PM) data from a Data Management Entity (DME) and Fault Management (FM) and Configuration Management (CM) data from the RANOAM SMOF upon being notified about the request to drain traffic of the at least one NF.

[0236] Item [12]: The method according to item [11], wherein upon receiving the FM and CM data, the RANOAM SMOF is configured to send a NF traffic distribution configuration to E2 nodes, wherein the E2 nodes are configured to enforce NF traffic distribution based on the NF traffic distribution configuration to drain the at least one NF and send a notification of completing enforcing the NF traffic distribution to the RANOAM SMOF, wherein upon receiving the notification of completing the NF traffic distribution, the RANOAM SMOF is configured to forward the notification of completing the NF traffic distribution to the SO SMOF and/or the nRT RIC SMOF.

[0237] Item [13]: The method according to item [12], wherein upon receiving the notification of completing the NF traffic distribution from the RANOAM SMOF, the nRT RIC SMOF is configured to evaluate the performance of the drained at least one NF, and based on the evaluated performance, send a report to the SO SMOF recommending whether or not to rollback the NF traffic distribution configuration, wherein upon receiving the report, the SO SMOF is configured to send a request to the ORMO to terminate a deployment of the at least one NF.

[0238] Item [14]: The method according to item [13], wherein upon receiving the request from the SO SMOF to terminate the deployment of the at least one NF, the method further includes: sending, by the ORMO, a request to the DMS to terminate the deployment of the at least one NF.

[0239] Item [15]: A method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function, the method including: receiving, by the ORMO, a service related to a Service Orchestration and Assurance (SOA) SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SOA SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

[0240] Item [16]: The method according to item [15], wherein upon receiving the request from the

ORMO, the SOA SMOF is configured to query topology details of the at least one NF and allocated resources from the TE/IV, send a request to the ORMO to redeploy the at least one NF, and send a request to a RANOAM SMOF to distribute the traffic.

[0241] Item [17]: The method according to item [16], wherein upon receiving the request from the SOA SMOF to distribute the traffic, the RANOAM SMOF is configured to notify a non Real-Time (nRT) RIC SMOF about the request to drain traffic of the at least one NF, wherein the nRT RIC SMOF is configured to query and collect Performance Management (PM) data from a Data Management Entity (DME) and Fault Management (FM) and Configuration Management (CM) data from the RANOAM SMOF upon being notified about the request to drain traffic of the at least one NF.

[0242] Item [18]: The method according to item [17], wherein upon receiving the FM and CM data, the RANOAM SMOF is configured to send a NF traffic distribution configuration to E2 nodes, wherein the E2 nodes are configured to enforce NF traffic distribution based on the NF traffic distribution configuration to drain the at least one NF and send a notification of completing enforcing the NF traffic distribution to the RANOAM SMOF, wherein upon receiving the notification of completing the NF traffic distribution, the RANOAM SMOF is configured to forward the notification of completing the NF traffic distribution to the SOA SMOF and/or the nRT RIC SMOF.

[0243] Item [19]: The method according to item [18], wherein upon receiving the notification of completing the NF traffic distribution from the RANOAM SMOF, the nRT RIC SMOF is configured to evaluate the performance of the drained at least one NF, and based on the evaluated performance, send a report to the SOA SMOF recommending whether or not to rollback the NF traffic distribution configuration.

[0244] Item [20]. The method according to item [19], wherein upon receiving the report, the SOA SMOF is configured to send a request to the ORMO to terminate a deployment of the at least one NF.

[0245] It can be understood that numerous modifications and variations of the present disclosure are possible in light of the above teachings. It will be apparent that within the scope of the appended clauses, the present disclosures may be practiced otherwise than as specifically described herein.

Claims

1. A method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function, the method comprising: receiving, by the ORMO, a service related to an SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

2. The method as claimed in claim 1, wherein the SMOF is the RANOAM SMOF, and wherein upon receiving the request from the ORMO, the RANOAM SMOF is configured to notify a non Real-Time (nRT) RIC SMOF about the request to drain traffic of the at least one NF, wherein the nRT RIC SMOF is configured to query and collect Performance Management (PM) data from a Data Management Entity (DME) and Fault Management (FM) and Configuration Management (CM) data from the RANOAM SMOF upon being notified about the request to drain traffic of the at least one NF.

3. The method as claimed in claim 2, wherein upon receiving the FM and CM data, the RANOAM SMOF is configured to send a NF traffic distribution configuration to E2 nodes, wherein the E2 nodes are configured to enforce NF traffic distribution based on the NF traffic distribution

configuration to drain the at least one NF and send a notification of completing enforcing the NF traffic distribution to the RANOAM SMOF.

4. The method as claimed in claim 3, wherein upon receiving the notification of completing the NF traffic distribution, the RANOAM SMOF is configured to forward the notification of completing the NF traffic distribution to the nRT RIC SMOF.

5. The method as claimed in claim 4, wherein upon receiving the notification of completing the NF traffic distribution from the RANOAM SMOF, the nRT RIC SMOF is configured to evaluate the performance of the drained at least one NF, and based on the evaluated performance, send a report to the RANOAM SMOF recommending whether or not to rollback the NF traffic distribution configuration.

6. The method as claimed in claim 5, wherein upon receiving the report, the RANOAM SMOF is configured to send a notification to the ORMO indicating traffic draining was completed.

7. The method as claimed in claim 6, wherein upon receiving the notification from the RANOAM SMOF, the method further comprises: sending, by the ORMO, a request to a Deployment Management Service (DMS) to terminate a deployment of the at least one NF.

8. A method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function, the method comprising: receiving, by the ORMO, a service related to a Service Orchestration (SO) SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SO SMOF to terminate and redeploy at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

9. The method as claimed in claim 8. wherein upon receiving the request from the ORMO, the SO SMOF is configured to query topology details of the at least one NF and allocated resources from the TE/IV and send a request to the ORMO to redeploy the at least one NF.

10. The method as claimed in claim 9, wherein upon receiving the request from the SO SMOF to redeploy the at least one NF, the method further comprises: sending, by the ORMO, a request to a Deployment Management Services (DMS) to create a new NF instance; and sending, by the ORMO, a notification to the SO SMOF that the new NF instance was created.

11. The method as claimed in claim 10, wherein upon receiving the notification from the ORMO that the new NF instance was created, the SO SMOF is configured to send a request to a RANOAM SMOF to drain the at least one NF, wherein upon receiving the request from the SO SMOF to drain the at least one NF, the RANOAM SMOF is configured to notify a non Real-Time (nRT) RIC SMOF about the request to drain traffic of the at least one NF, wherein the nRT RIC SMOF is configured to query and collect Performance Management (PM) data from a Data Management Entity (DME) and Fault Management (FM) and Configuration Management (CM) data from the RANOAM SMOF upon being notified about the request to drain traffic of the at least one NF.

12. The method as claimed in claim 11, wherein upon receiving the FM and CM data, the RANOAM SMOF is configured to send a NF traffic distribution configuration to E2 nodes, wherein the E2 nodes are configured to enforce NF traffic distribution based on the NF traffic distribution configuration to drain the at least one NF and send a notification of completing enforcing the NF traffic distribution to the RANOAM SMOF, wherein upon receiving the notification of completing the NF traffic distribution, the RANOAM SMOF is configured to forward the notification of completing the NF traffic distribution to the SO SMOF and/or the nRT RIC SMOF.

13. The method as claimed in claim 12, wherein upon receiving the notification of completing the NF traffic distribution from the RANOAM SMOF, the nRT RIC SMOF is configured to evaluate the performance of the drained at least one NF, and based on the evaluated performance, send a report to the SO SMOF recommending whether or not to rollback the NF traffic distribution

configuration, wherein upon receiving the report, the SO SMOF is configured to send a request to the ORMO to terminate a deployment of the at least one NF.

14. The method as claimed in claim 13, wherein upon receiving the request from the SO SMOF to terminate the deployment of the at least one NF, the method further comprises: sending, by the ORMO, a request to the DMS to terminate the deployment of the at least one NF.

15. A method for managing interactions between an O-Cloud Resources Management and Orchestration (ORMO) Service Management Orchestration Function (SMOF) and a Radio Access Network Operations Administration Maintenance (RANOAM) function, the method comprising: receiving, by the ORMO, a service related to a Service Orchestration and Assurance (SOA) SMOF from a Service Management and Exposure (SME); sending, by the ORMO, a request to the SOA SMOF to drain traffic of at least one network function (NF); and sending, by the ORMO, a request to a Topology Exposure and Inventory Management (TE/IV) to update an inventory.

16. The method as claimed in claim 15, wherein upon receiving the request from the ORMO, the SOA SMOF is configured to query topology details of the at least one NF and allocated resources from the TE/IV, send a request to the ORMO to redeploy the at least one NF, and send a request to a RANOAM SMOF to distribute the traffic.

17. The method as claimed in claim 16, wherein upon receiving the request from the SOA SMOF to distribute the traffic, the RANOAM SMOF is configured to notify a non Real-Time (nRT) RIC SMOF about the request to drain traffic of the at least one NF, wherein the nRT RIC SMOF is configured to query and collect Performance Management (PM) data from a Data Management Entity (DME) and Fault Management (FM) and Configuration Management (CM) data from the RANOAM SMOF upon being notified about the request to drain traffic of the at least one NF.

18. The method as claimed in claim 17, wherein upon receiving the FM and CM data, the RANOAM SMOF is configured to send a NF traffic distribution configuration to E2 nodes, wherein the E2 nodes are configured to enforce NF traffic distribution based on the NF traffic distribution configuration to drain the at least one NF and send a notification of completing enforcing the NF traffic distribution to the RANOAM SMOF, wherein upon receiving the notification of completing the NF traffic distribution, the RANOAM SMOF is configured to forward the notification of completing the NF traffic distribution to the SOA SMOF and/or the nRT RIC SMOF.

19. The method as claimed in claim 18, wherein upon receiving the notification of completing the NF traffic distribution from the RANOAM SMOF, the nRT RIC SMOF is configured to evaluate the performance of the drained at least one NF, and based on the evaluated performance, send a report to the SOA SMOF recommending whether or not to rollback the NF traffic distribution configuration.

20. The method as claimed in claim 19, wherein upon receiving the report, the SOA SMOF is configured to send a request to the ORMO to terminate a deployment of the at least one NF.