O-RAN.WG1.Slicing-Architecture-v01.00

Technical Specification

O-RAN Working Group 1
Slicing Architecture

Revision History

Date	Revision	Author	Description
2019.11.13	01.00.00	Arda Akman (Netsia), Burcu Yargicoglu Sahin (Netsia)	Draft for template
2020.01.02	01.00.01	Arda Akman (Netsia), Burcu Yargicoglu Sahin (Netsia)	Addition of slicing overview, RAN slice SLA assurance use case, general principles
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2020.02.10	01.00.06	Arda Akman (Netsia), Burcu Yargicoglu Sahin (Netsia)	Updated reference slicing architecture based on feedback, added notes on 3GPP 28.526 VNF/PNF handling
2020.03.01	01.00.07	Arda Akman (Netsia), Burcu Yargicoglu Sahin (Netsia)	Updated architecture with SMO alignment discussion, ordered references, fixed table of contents issues, editorial updates
2020.03.11	01.00.08	Arda Akman (Netsia), Burcu Yargicoglu Sahin (Netsia)	Updates to various sections based on review feedback during WG1 approval process

Contents

Chapter 1. Introduction

1.1 Scope

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

The contents of the present document are subject to continuing work within O-RAN WG1 Slicing Task Group and may change following formal O-RAN approval. In the event that O-RAN Alliance decides to modify the contents of the present document, it will be re-released by O-RAN Alliance with an identifying change of release date and an increase in version number as follows:

Release x.y.z

where:

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

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

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

The current document describes the high level O-RAN slicing related use cases, requirements and architecture. While some of the requirements are derived from use cases, some of the relevant SDO requirements are captured as they have impact on O-RAN functions. Along with requirements and reference slicing architecture, slicing related impact to O-RAN functions and interfaces are captured as well.

1.2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document in Release 16.

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

[2] 3GPP TS 22.261: "Technical Specification Group Services and System Aspects; Service requirements for the 5G system; Stage 1", Release 16, December 2019.

[3] 3GPP TS 23.501: "Technical Specification Group Services and System Aspects; System Architecture for the 5G System; Stage 2", Release 16, December 2019.

[4] 3GPP TS 28.526: "Technical Specification Group Services and System Aspects; Telecommunication management; Life Cycle Management (LCM) for mobile networks that include virtualized network functions; Procedures", Release 15, December 2018.

[5] 3GPP TS 28.533: "Technical Specification Group Services and System Aspects; Management and orchestration; Architecture framework", Release 16, January 2020.

[6] 3GPP TS 28.541: "Management and orchestration; 5G Network Resource Model (NRM); Stage 2 and stage 3", Release 16, January 2020.

[7] 3GPP TS 28.552: "Technical Specification Group Services and System Aspects; Management and orchestration; 5G performance measurements", Release 16, January 2020.

[8] 3GPP TS 38.300: "NR and NG-RAN Overall Description", Release 16, January 2020

[9] O-RAN-WG1.OAM-Architecture-v02.00: "O-RAN WG1 Operations and Maintenance Architecture v02.00".

[10] ORAN-WG2.A1.GA&P-v01.00: "O-RAN Working Group 2; (A1 interface: General Aspects and Principles)".

[11] ORAN-WG3.E2GAP.0-v0.1: "O-RAN Working Group 3; Near-Real-time RAN Intelligent Controller Architecture & E2 General Aspects and Principles"

[12] O-RAN-WG6.CAD-V01.00.00: "Cloud Architecture and Deployment Scenarios for O-RAN Virtualized RAN".

[13] O-RAN_Study_ORAN_Slicing_Technical_Report.v01.00: "Study on O-RAN Slicing", Technical Report.

1.3 Definitions and Abbreviations

1.3.1 Definitions

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

A1: Interface between non-RT RIC and Near-RT RIC to enable policy-driven guidance of Near-RT RIC applications/functions, and support AI/ML workflow.

A1 policy: Type of declarative policies expressed using formal statements that enable the non-RT RIC function in the SMO to guide the near-RT RIC function, and hence the RAN, towards better fulfilment of the RAN intent.

A1 Enrichment information: Information utilized by near-RT RIC that is collected or derived at SMO/non-RT RIC either from non-network data sources or from network functions themselves.

E2: Interface connecting the Near-RT RIC and one or more O-CU-CPs, one or more O-CU-UPs, and one or more O-DUs.

E2 Node: a logical node terminating E2 interface. In this version of the specification, O-RAN nodes terminating E2 interface are:

- for NR access: O-CU-CP, O-CU-UP, O-DU or any combination;
- for E-UTRA access: O-eNB.

FCAPS: Fault, Configuration, Accounting, Performance, Security.

near-RT RIC: O-RAN near-real-time RAN Intelligent Controller: a logical function that enables near-real-time control and optimization of RAN elements and resources via fine-grained data collection and actions over E2 interface.

non-RT RIC: O-RAN non-real-time RAN Intelligent Controller: a logical function that enables non-real-time control and optimization of RAN elements and resources, AI/ML workflow including model training and updates, and policy-based guidance of applications/features in near-RT RIC.

NMS: A Network Management System.

O-CU: O-RAN Central Unit

O-CU-CP: O-RAN Central Unit – Control Plane: a logical node hosting the RRC and the control plane part of the PDCP protocol.

O-CU-UP: O-RAN Central Unit – User Plane: a logical node hosting the user plane part of the PDCP protocol and the SDAP protocol.

O-DU: O-RAN Distributed Unit: a logical node hosting RLC/MAC/High-PHY layers based on a lower layer functional split.

O-RU: O-RAN Radio Unit: a logical node hosting Low-PHY layer and RF processing based on a lower layer functional split. This is similar to 3GPP's "TRP" or "RRH" but more specific in including the Low-PHY layer (FFT/iFFT, PRACH extraction).

O1: Interface between management entities (NMS/EMS/MANO) and O-RAN managed elements, for operation and management, by which FCAPS management, Software management, File management shall be achieved.

RAN: Generally referred as Radio Access Network. In terms of this document, any component below near-RT RIC per O-RAN architecture, including O-CU/O-DU/O-RU.

1.3.2 Abbreviations

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

eNB	eNodeB (applies to LTE)
gNB	gNodeB (applies to NR)
KPI	Key Performance Indicator
KQI	Key Quality Indicator
Near-RT RIC	O-RAN Near-Real-Time RIC
NFMF	Network Function Management Function
Non-RT RIC	O-RAN Non-Real-Time RIC
NSMF	Network Slice Management Function
NSSMF	Network Slice Subnet Management Function
O-CU	O-RAN Central Unit
O-DU	O-RAN Distributed Unit
O-RU	O-RAN Radio Unit
PNF	Physical Network Function
PRB	Physical Resource Block

RIC	O-RAN RAN Intelligent Controller
RRM	Radio Resource Management
SDO	Standards Developing Organizations (For ex: 3GPP, ETSI, ONAP, O-RAN)
SMO	Service and Management Orchestration
VNF	Virtual Network Function

Chapter 2. Slicing Overview

Network Slicing is expected to play a critical role in 5G networks because of various use cases and services 5G will support. It allows a network operator to provide services tailored to customers' requirements. Network slice is defined as a logical network with a bundle of specified network services over a common network infrastructure. A single physical network is sliced into multiple virtual networks that can support different service types over a single RAN. 3GPP has standardized 4 different service types: eMBB, URLLC, MIoT and V2X [3].

3GPP defined 5G architecture and procedures containing network slicing and related concepts in Release 15. Furthermore, management and orchestration of 5G networks featuring slicing was defined in the 3GPP specifications. Other standard groups e.g. GSMA, ETSI NFV-MANO, ETSI ZSM and ONAP focus on the different aspects of network slicing. Further information regarding network slicing and other SDO's contributions was discussed in the Study on O-RAN Slicing Technical Report [13].

A sample RAN slicing deployment of O-RAN network functions based on the select initial deployment option, option B as described in [12], is shown in Figure 1, with some of the network functions shared between RAN slices (such as O-CU-CP, O-DU, O-RU) and some network functions dedicated to a particular RAN slice (such as O-CU-UP).

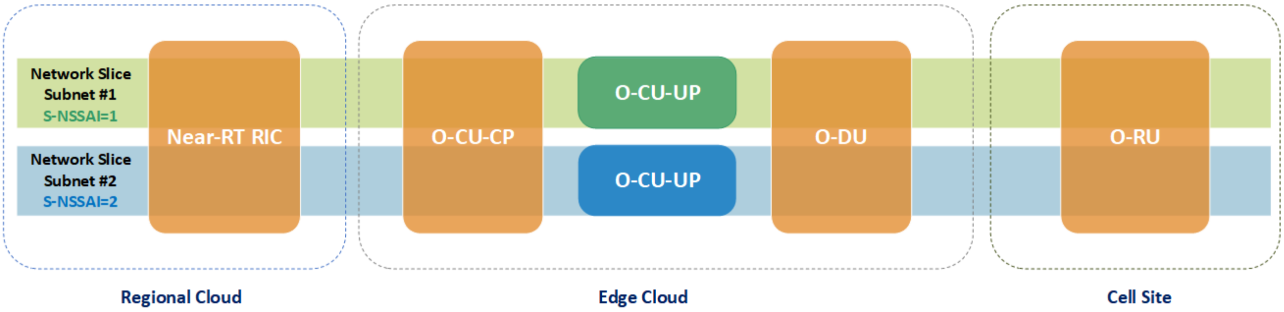

Figure 1: Example O-RAN Slicing Deployment

Chapter 3. High-Level O-RAN Slicing Use Cases

This section contains high-level O-RAN slicing use cases that O-RAN is expected to support. Slicing requirements will include the requirements derived from the specified use cases. The initial use case defined is RAN Slice SLA Assurance. Additional use cases will be added as prioritized by the O-RAN community in future versions of this document.

3.1 Use Case 1: RAN Slice SLA Assurance

In the 5G era, network slicing is a prominent feature which provides end-to-end connectivity and data processing tailored to specific business requirements. These requirements include customizable network capabilities such as the support of very high data rates, traffic densities, service availability and very low latency. According to 5G standardization efforts, the 5G system should support the needs of the business through the specification of several service needs such as data rate, traffic capacity, user density, latency, reliability, and availability. These capabilities are always provided based on a Service Level Agreement (SLA) between the mobile operator and the business customer, which brought up interest for mechanisms to ensure slice SLAs and prevent its possible violations. O-RAN's open interfaces and AI/ML based architecture will enable such challenging mechanisms to be implemented and help pave the way for operators to realize the opportunities of network slicing in an efficient manner.

RAN slice SLA assurance scenario involves Non-RT RIC, Near-RT RIC, E2 Nodes and SMO interaction. The scenario starts with the retrieval of RAN specific slice SLA/requirements (possibly within SMO or from NSSMF depending on Operator deployment options). Based on slice specific performance measurements from E2 Nodes, Non-RT RIC and Near-RT RIC can fine-tune RAN behavior aligned with O-RAN architectural roles to assure RAN slice SLAs. Non-RT RIC monitors long-term trends and patterns for RAN slice subnets' performance, and employs AI/ML methods to perform corrective actions through SMO (e.g. reconfiguration via O1) or via creation of A1 policies. Non-RT RIC can also construct/train relevant AI/ML models that will be deployed at Near-RT RIC. A1 policies possibly include scope identifiers (e.g. S-NSSAI) and statements such as KPI targets. On the other hand, Near-RT RIC enables optimized RAN actions through execution of deployed AI/ML models in near-real-time by considering both O1 configuration (e.g. static RRM policies) and received A1 policies, as well as received slice specific E2 measurements.

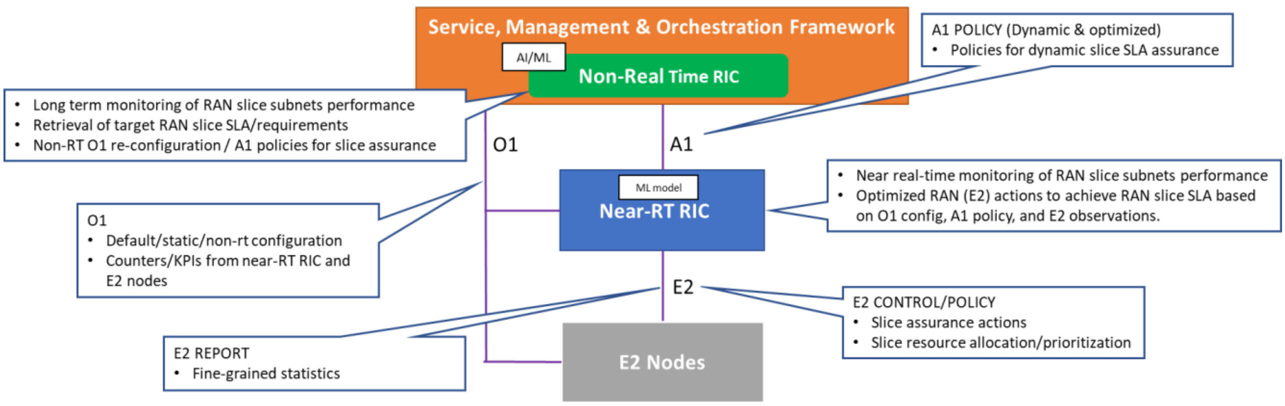

Figure 2: RAN Slice SLA Assurance use case overview

The more detailed functions provided by the entities for RAN slice SLA assurance are listed as below:

1) Non-RT RIC:
   a) Retrieve RAN slice SLA target from respective entities such as SMO, NSSMF
   b) Long term monitoring of RAN slice performance measurements

c) Training of potential ML models that will be deployed in Near-RT RIC for optimized slice assurance
d) Support deployment and update of AI/ML models into Near-RT RIC
e) Send A1 policies and enrichment information to Near-RT RIC to drive slice assurance
f) Send O1 reconfiguration requests to SMO for slow-loop slice assurance

2) Near-RT RIC:
   a) Near real-time monitoring of slice specific RAN performance measurements
   b) Support deployment and execution of the AI/ML models from Non-RT RIC
   c) Support interpretation and execution of policies from Non-RT RIC
   d) Perform optimized RAN (E2) actions to achieve RAN slice requirements based on O1 configuration, A1 policy, and E2 reports
3) RAN:
   a) Support slice assurance actions such as slice-aware resource allocation, prioritization, etc.
   b) Support slice specific performance measurements through O1
   c) Support slice specific performance reports through E2

Chapter 4. O-RAN Slicing Principles and Requirements

4.1 General Principles

This section contains the general O-RAN slicing architecture principles as described below:

- O-RAN slicing architecture and interface specifications shall be consistent with 3GPP architecture and interface specifications to the extent possible
- O-RAN slicing architecture shall provide standardized management service interfaces for RAN slicing management services
- O-RAN slicing architecture shall enable multi-vendor interoperability
- O-RAN slicing architecture shall support various Network Operator deployment options
- O-RAN slicing architecture shall support management of RAN slices in multi-operator scenarios

4.2 Slicing Requirements

4.2.1 Functional Requirements

Initial set of O-RAN slicing functional requirements based on the use cases defined in this version of the specification are captured in Table 4.2.1-1

Table 4.2.1-1: O-RAN Slicing Functional Requirements

REQ	Description	Note
[REQ-SL-FUN1]	O-RAN slicing architecture and interfaces must support network slicing, where an instance of O-RAN network function may be associated with one or more slices.	ORAN OAM Specification v02.00
[REQ-SL-FUN2]	O-RAN slicing architecture shall support differentiated handling of traffic for different RAN slices	3GPP TS 38.300
[REQ-SL-FUN3]	O-RAN slicing architecture shall support resource isolation between slices	3GPP TS 38.300
[REQ-SL-FUN4]	O-RAN slicing architecture shall enable traffic and services in one RAN slice having no impact on traffic and services in other RAN slices in the same network	3GPP TS 22.261
[REQ-SL-FUN5]	O-RAN slicing architecture shall enable mechanisms to avoid shortage of shared resources in one slice breaking the service level agreement for another slice	3GPP TS 38.300
[REQ-SL-FUN6]	O-RAN slicing architecture shall enable defining a priority order between different RAN slices in case multiple slices compete for resources on the same RAN	3GPP TS 22.261

[REQ-SL-FUN7]	O-RAN slicing architecture shall apply policies at S-NSSAI level according to the SLA required by the network slice	-
[REQ-SL-FUN8]	O-RAN slicing architecture shall support means by which the operator can differentiate policy control, functionality and performance provided in different RAN slices	3GPP TS 22.261
[REQ-SL-FUN9]	O-RAN slicing architecture shall support QoS differentiation within a slice	3GPP TS 38.300
[REQ-SL-FUN10]	O-RAN slicing architecture shall enable slice aware radio resource management strategies (such as admission control, congestion control, handover preparation)	3GPP TS 38.300
[REQ-SL-FUN11]	O-RAN slicing architecture shall allow creation, modification, and deletion of a RAN slice subnet	3GPP TS 22.261
[REQ-SL-FUN12]	O-RAN slicing architecture shall support interaction with the SMO Framework to consume provisioning management services exposed by each O-RAN managed element to configure RAN slices through the O1 interface	RAN Slice SLA Assurance use case
[REQ-SL-FUN13]	O-RAN slicing architecture shall support the interaction with the SMO Framework to consume management of slice specific PM jobs, PM data collection/storage/query/statistical reports from O-RAN network functions through the O1 interface	RAN Slice SLA Assurance use case
[REQ-SL-FUN14]	O-RAN slicing architecture shall support interaction with the SMO Framework to retrieve RAN slice SLA target from respective entities such as NSSMF	RAN Slice SLA Assurance use case
[REQ-SL-FUN15]	O-RAN slicing architecture shall support long term provisioning, generation and monitoring of slice specific RAN performance metrics	RAN Slice SLA Assurance use case
[REQ-SL-FUN16]	O-RAN slicing architecture shall support training, deployment and execution of AI/ML models for slice SLA assurance	RAN Slice SLA Assurance use case
[REQ-SL-FUN17]	O-RAN slicing architecture shall support slice specific policy guidance, enrichment information and policy feedback	RAN Slice SLA Assurance use case
[REQ-SL-FUN18]	O-RAN slicing architecture shall support near real-time provisioning, generation and monitoring of slice specific RAN performance data	RAN Slice SLA Assurance use case
[REQ-SL-FUN19]	O-RAN slicing architecture shall support reconfiguration of slice specific RAN parameters and resources for slice SLA assurance	RAN Slice SLA Assurance use case

4.2.2 Non-Functional Requirements

Initial set of O-RAN slicing non-functional requirements based on the use cases defined in this version of the specification are captured in Table 4.2.2-1

Table 4.2.2-1: O-RAN Slicing Non-Functional Requirements

REQ	Description	Note
[REQ-SL-NFUN1]	O-RAN slicing architecture shall support use of AI/ML to support RAN slicing use cases	

Chapter 5. O-RAN Reference Slicing Architecture

This section provides O-RAN reference slicing architecture along with the high level roles and responsibilities of O-RAN network functions.

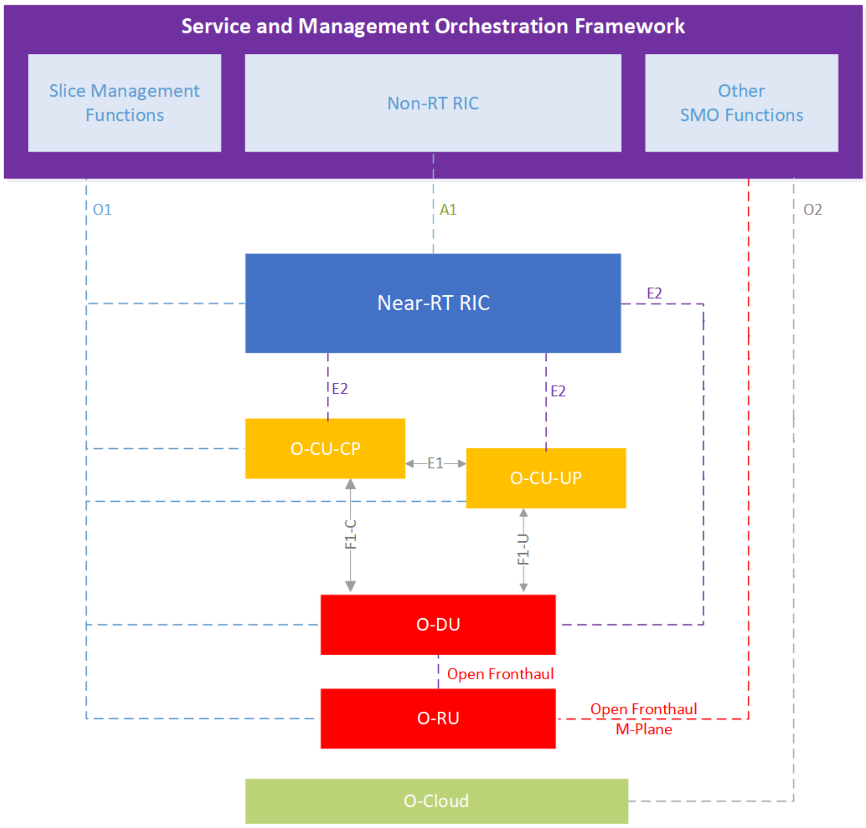

Figure 3: O-RAN Reference Slicing Architecture

O-RAN reference slicing architecture includes slice management functions along with O-RAN architectural components. As O-RAN's general principle is to be as compliant as possible with 3GPP architecture, these slice management functions are 3GPP defined NSMF and NSSMF with extensions for O-RAN network functions. Various deployment options of the location of NSMF and NSSMF have been presented in [13] and more detailed architectural implementation options for SMOs including NFV-MANO and ONAP are being presented in Appendix A.

5.1 Non-RT RIC

The fundamental role of the Non-RT RIC in O-RAN slicing architecture is to gather long term slice related data through interaction with the SMO framework and apply AI/ML based approaches interworking with the Near-RT RIC to provide innovative RAN slicing use cases. For this purpose, Non-RT RIC should be aware of RAN slices and their respective SLAs through SMO. In addition, Non-RT RIC may retrieve enrichment information from 3rd party applications enabling advanced RAN slicing technology to be applied in O-RAN framework.

In order to construct AI/ML models to be deployed in the Near-RT RIC, Non-RT RIC retrieves slice specific performance metrics, configuration parameters and required attributes of the RAN slices from the SMO framework. Complex problems for Near-RT RIC e.g. applying RRM policies can be tackled by learning capabilities of AI/ML. The output of these algorithms can lead non-real-time optimization of the slice specific parameters of Near-RT RIC, O-CU and O-DU over O1 interface through SMO interaction. Moreover, these performance, configuration and other slice related data are used to generate policy guidance and assist Near-RT RIC over A1 to provide closed loop slice optimization. Applying such slice optimizations in the Near-RT RIC can be used for SLA assurance and prevent SLA violations between the slices as well.

5.2 Near-RT RIC

Near-RT RIC is the component which enables near-real-time RAN slice optimization through execution of slicing related xApps and communicating necessary parameters to O-CU and O-DU through E2 interface. Deployed xApps may utilize either AI/ML based models or other control schemes which can further be guided by A1 policies that are generated by Non-RT RIC.

In order to drive sliced RAN resources properly, Near-RT RIC should have the knowledge of existing RAN slices as well as their requirements. This information will be received through O1 interface during provisioning of RAN slices. Therefore similar to Non-RT RIC, Near-RT RIC will be aware of RAN slices through O-RAN specific information models and provisioning procedures.

In O-RAN slicing architecture, configuration of slice resources on E2 nodes can be achieved through slow loop with O1 configuration and through fast loop with E2 configuration. This architecture enables advanced slicing use cases such as RAN slice SLA assurance and further enhances 3GPP slicing capability without mis-alignment. While Near-RT RIC is capable for fast-loop configuration, slicing related O1 configuration, such as RRM policy information sent to O-CU, configured by the SMO framework will be taken into account. Moreover, slice specific near-RT performance data will be monitored through E2 interface which needs proper PM mechanisms between E2 nodes and Near-RT RIC as well.

5.3 O-RAN Central Unit (O-CU)

O-CU, which includes a single O-CU-CP and possibly multiple O-CU-UP(s), which are communicating through E1 interface, needs to support slicing features as defined by 3GPP. Depending on slice requirements, O-CU-UP can be shared across slices or a specific instance of O-CU-UP can be instantiated per slice. On top of 3GPP slicing features, O-RAN further enhances slicing through the utilization of E2 interface and the assistance of Near-RT RIC dynamic slice optimizations along with the enhanced O1 interface to support additional slice configuration parameters.

O-CU stacks, which are the upper layer protocols of the RAN stack, should be slice aware and execute slice specific resource allocation and isolation strategies. These stacks are initially configured through O1 interface based on the slice specific requirements and then dynamically updated through E2 interface via Near-RT RIC for various slicing use cases.

Based on the PM requests from SMO and Near-RT RIC, O-CU may need to generate and send specific PMs through O1 and E2 interfaces respectively, where the PMs can be used for slice performance monitoring and slice SLA assurance purposes.

5.4 O-RAN Distributed Unit (O-DU)

O-DU, which runs the lower layer protocols of RAN stack, should support slice specific resource allocation strategies as well. Based on the initial O1 configuration of PRB allocation levels along with O-CU directives over F1 interface and the dynamic guidance received from Near-RT RIC over E2 interface, MAC layer needs to allocate and isolate relevant PRBs to specific slices.

Based on the PM requests from SMO and Near-RT RIC, O-DU may need to generate and send specific PMs through O1 and E2 interfaces respectively, where the PMs can be used for slice performance monitoring and slice SLA assurance purposes.

5.5 A1 Interface

A1, which is the interface between the Non-RT RIC and the Near-RT RIC, supports policy management, ML model management and enrichment information services [10]. These three services will be utilized for various slicing use cases, such as slice SLA assurance. Policy management will be used by Non-RT RIC to send slice specific (e.g. S-NSSAI based) policies to guide Near-RT RIC with slice resource allocations and slice specific control activities, as well as to receive slice specific policy feedback for the policies deployed on the Near-RT RIC.

For the use cases that make use of external enrichment data or where Non-RT RIC produces enrichment information, A1 enrichment interface will be used to send slice specific enrichment data to Near-RT RIC.

It should be noted that slice specific A1 policies are not persistent (do not survive the restart of Near-RT RIC) and while they may take precedence over O1 slice specific configurations, they should be aligned and not deviate significantly from O1 configurations.

Note: It is intended to add examples for the usage of A1 services for slicing use cases in the next version of this document.

5.6 E2 Interface

E2, which is the interface between the Near-RT RIC and the E2 nodes, supports E2 primitives (Report, Insert, Control and Policy) to control the services exposed by E2 nodes [11]. These primitives will be used by slice specific applications (xApps) to drive E2 nodes' slice configurations and slice specific behaviour, such as slice based radio resource management, radio resource allocations, MAC scheduling policies and other configuration parameters used by various RAN protocol stacks.

E2 will be used to configure and receive slice specific reports and performance data from E2 nodes. These reports may include 3GPP defined slice specific PMs (such as PRB utilization, average delay, etc. [4]) and new PMs that can be defined by O-RAN to support various slicing use cases.

Note: It is intended to add examples for the usage of E2 primitives for slicing use cases in the next version of this document.

5.7 O1 Interface

O1, which is the interface between O-RAN managed elements and the management entity as defined in [9], will be used to configure slice specific parameters of O-RAN nodes based on the service requirements of the slice. 3GPP have defined some of the slice specific information models in TS 28.541 [6], including the RRM policy attributes to provide the ratio of PRBs and the split of these PRBs among slices. To support O-RAN slicing use cases and their requirements, 3GPP information models may be extended and additional information models may be defined to capture slice profiles and slice specific configuration parameters, which will be carried over O1 interface as well.

O1 will also be used to configure and gather slice specific performance metrics and slice specific faults from O-RAN nodes.

Note: It is intended to add examples for the usage of O1 for the configuration, performance and fault management of slicing use cases in the next version of this document.

5.8 O2 Interface

O2, which is the interface between the SMO and O-Cloud as introduced in [12], will be used for life cycle management of virtual O-RAN network functions. As part of RAN NSSI creation and provisioning, RAN NSSMF, in interaction with SMO, triggers the instantiation of necessary O-RAN functions (such as Near-RT RIC, O-CU-CP, O-CU-UP and O-DU) based on slice requirements. After the creation of RAN NSSI, NSSMF in interaction with SMO can execute NSSI modification and NSSI deletion procedures.

Since Non-RT is part of SMO and would be instantiated along with other SMO functions, O2 is not expected to be used for lifecycle management of Non-RT RIC.

Note: It is intended to add examples for the usage of O2 for slice lifecycle management of O-RAN network functions in the next version of this document.

Annex A (informative): Additional Information

A.1 Implemtation Options

This section presents example deployment options for various SMO options.

A.1.1 3GPP and ETSI NFV-MANO based O-RAN Slicing Architecture Implementation Option

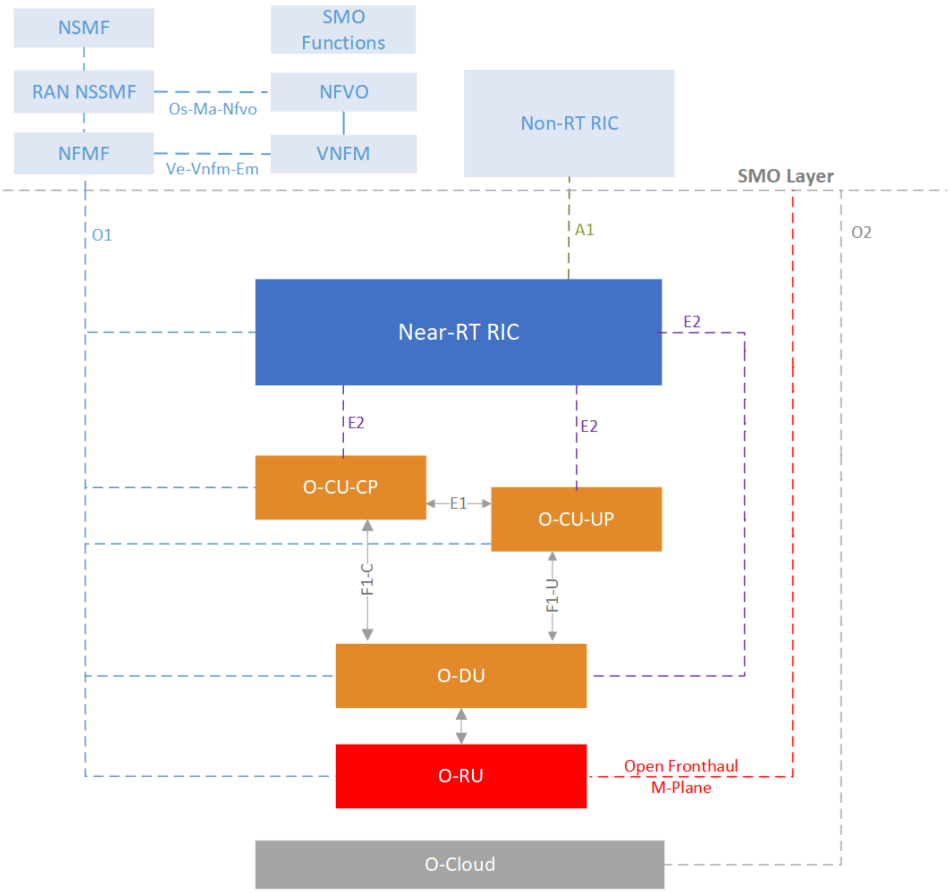

Figure 4: O-RAN Slicing Reference Architecture (ETSI NFV-MANO based example)

In Figure 4, a 3GPP - ETSI NFV-MANO based example of O-RAN slicing reference architecture and interfaces is shown to describe the relationship between 3GPP defined slice management functions (NSMF, NSSMF), 3GPP defined management functions (Network Function Management Function, NFMF [5]) and O-RAN network functions in terms of slice lifecycle management and slice configuration procedures. Life Cycle Management (LCM) procedures for mobile networks that include virtualized network functions (VNFs) as well as addition of physical network functions (PNFs) to network service (NS) instances are described in 3GPP TS28.526 [4].

A.2.1 ONAP based O-RAN Slicing Architecture Implementation Option

Note: It is intended to add ONAP based reference architecture as ONAP makes progress with RAN slicing.

Annex ZZZ O-RAN Adopter License Agreement

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SECTION 1: DEFINITIONS

1.1 "Affiliate" means an entity that directly or indirectly controls, is controlled by, or is under common control with another entity, so long as such control exists. For the purpose of this Section, "Control" means beneficial ownership of fifty (50%) percent or more of the voting stock or equity in an entity.

1.2 "Compliant Portion" means only those specific portions of products (hardware, software or combinations thereof) that implement any O-RAN Specification.

1.3 "Adopter(s)" means all entities, who are not Members, Contributors or Academic Contributors, including their Affiliates, who wish to download, use or otherwise access O-RAN Specifications.

1.4 "Minor Update" means an update or revision to an O-RAN Specification published by O-RAN Alliance that does not add any significant new features or functionality and remains interoperable with the prior version of an O-RAN Specification. The term "O-RAN Specifications" includes Minor Updates.

1.5 "Necessary Claims" means those claims of all present and future patents and patent applications, other than design patents and design registrations, throughout the world, which (i) are owned or otherwise licensable by a Member, Contributor or Academic Contributor during the term of its Member, Contributor or Academic Contributorship; (ii) such Member, Contributor or Academic Contributor has the right to grant a license without the payment of consideration to a third party; and (iii) are necessarily infringed by implementation of a Final Specification (without considering any Contributions not included in the Final Specification). A claim is necessarily infringed only when it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of the art generally available at the date any Final Specification was published by the O-RAN Alliance or the date the patent claim first came into existence, whichever last occurred, to make, sell, lease, otherwise dispose of, repair, use or operate an implementation which complies with a Final Specification without infringing that claim. For the avoidance of doubt in exceptional cases where a Final Specification can only be implemented by technical solutions, all of which infringe patent claims, all such patent claims shall be considered Necessary Claims.

1.6 "Defensive Suspension" means for the purposes of any license grant pursuant to Section 3, Member, Contributor, Academic Contributor, Adopter, or any of their Affiliates, may have the discretion to include in their license a term allowing the licensor to suspend the license against a licensee who brings a patent infringement suit against the licensing Member, Contributor, Academic Contributor, Adopter, or any of their Affiliates.

SECTION 2: COPYRIGHT LICENSE

2.1 Subject to the terms and conditions of this Agreement, O-RAN Alliance hereby grants to Adopter a nonexclusive, nontransferable, irrevocable, non-sublicensable, worldwide copyright license to obtain, use and modify O-RAN Specifications, but not to further distribute such O-RAN Specification in any modified or unmodified way, solely in furtherance of implementations of an O-RAN Specification.

2.2 Adopter shall not use O-RAN Specifications except as expressly set forth in this Agreement or in a separate written agreement with O-RAN Alliance.

SECTION 3: FRAND LICENSE

3.1 Members, Contributors and Academic Contributors and their Affiliates are prepared to grant based on a separate Patent License Agreement to each Adopter under Fair, Reasonable And Non-Discriminatory (FRAND) terms and conditions with or without compensation (royalties) a nonexclusive, non-transferable, irrevocable (but subject to Defensive Suspension), non-sublicensable, worldwide license under their Necessary Claims to make, have made, use, import, offer to sell, lease, sell and otherwise distribute Compliant Portions; provided, however, that such license shall not extend: (a) to any part or function of a product in which a Compliant Portion is incorporated that is not itself part of the Compliant Portion; or (b) to any Adopter if that Adopter is not making a reciprocal grant to Members, Contributors and Academic Contributors, as set forth in Section 3.3. For the avoidance of doubt, the foregoing license includes the distribution by the Adopter's distributors and the use by the Adopter's customers of such licensed Compliant Portions.

3.2 Notwithstanding the above, if any Member, Contributor or Academic Contributor, Adopter or their Affiliates has reserved the right to charge a FRAND royalty or other fee for its license of Necessary Claims to Adopter, then Adopter is entitled to charge a FRAND royalty or other fee to such Member, Contributor or Academic Contributor, Adopter and its Affiliates for its license of Necessary Claims to its licensees.

3.3 Adopter, on behalf of itself and its Affiliates, shall be prepared to grant based on a separate Patent License Agreement to each Members, Contributors, Academic Contributors, Adopters and their Affiliates under FRAND terms and conditions with or without compensation (royalties) a nonexclusive, non-transferable, irrevocable (but subject to Defensive Suspension), non-sublicensable, worldwide license under their Necessary Claims to make, have made, use, import, offer to sell, lease, sell and otherwise distribute Compliant Portions; provided, however, that such license will not extend: (a) to any part or function of a product in which a Compliant Portion is incorporated that is not itself part of the Compliant Portion; or (b) to any Members, Contributors, Academic Contributors, Adopters and their Affiliates that is not making a reciprocal grant to Adopter, as set forth in Section 3.1. For the avoidance of doubt, the foregoing license includes the distribution by the Members', Contributors', Academic Contributors', Adopters' and their Affiliates' distributors and the use by the Members', Contributors', Academic Contributors', Adopters' and their Affiliates' customers of such licensed Compliant Portions.

SECTION 4: TERM AND TERMINATION

4.1 This Agreement shall remain in force, unless early terminated according to this Section 4.

4.2 O-RAN Alliance on behalf of its Members, Contributors and Academic Contributors may terminate this Agreement if Adopter materially breaches this Agreement and does not cure or is not capable of curing such breach within thirty (30) days after being given notice specifying the breach.

4.3 Sections 1, 3, 5 - 11 of this Agreement shall survive any termination of this Agreement. Under surviving Section 3, after termination of this Agreement, Adopter will continue to grant licenses (a) to entities who become Adopters after the date of termination; and (b) for future versions of O-RAN Specifications that are backwards compatible with the version that was current as of the date of termination.

SECTION 5: CONFIDENTIALITY

Adopter will use the same care and discretion to avoid disclosure, publication, and dissemination of O-RAN Specifications to third parties, as Adopter employs with its own confidential information, but no less than reasonable care. Any disclosure by Adopter to its Affiliates, contractors and consultants should be subject to an obligation of confidentiality at least as restrictive as those contained in this Section. The foregoing obligation shall not apply to any information which is: (1) rightfully known by Adopter without any limitation on use or disclosure prior to disclosure; (2) publicly available through no fault of Adopter; (3) rightfully received without a duty of confidentiality; (4) disclosed by O-RAN Alliance or a Member, Contributor or Academic Contributor to a third party without a duty of confidentiality on such third party; (5) independently developed by Adopter; (6) disclosed pursuant to the order of a court or other authorized governmental body, or as required by law, provided that Adopter provides reasonable prior written notice to O-RAN Alliance, and cooperates with O-RAN Alliance and/or the applicable Member, Contributor or Academic Contributor to have the opportunity to oppose any such order; or (7) disclosed by Adopter with O-RAN Alliance's prior written approval.

SECTION 6: INDEMNIFICATION

Adopter shall indemnify, defend, and hold harmless the O-RAN Alliance, its Members, Contributors or Academic Contributors, and their employees, and agents and their respective successors, heirs and assigns (the "Indemnitees"), against any liability, damage, loss, or expense (including reasonable attorneys' fees and expenses) incurred by or imposed upon any of the Indemnitees in connection with any claims, suits, investigations, actions, demands or judgments arising out of Adopter's use of the licensed O-RAN Specifications or Adopter's commercialization of products that comply with O-RAN Specifications.

SECTION 7: LIMITATIONS ON LIABILITY; NO WARRANTY

EXCEPT FOR BREACH OF CONFIDENTIALITY, ADOPTER'S BREACH OF SECTION 3, AND ADOPTER'S INDEMNIFICATION OBLIGATIONS, IN NO EVENT SHALL ANY PARTY BE LIABLE TO ANY OTHER PARTY OR THIRD PARTY FOR ANY INDIRECT, SPECIAL, INCIDENTAL, PUNITIVE OR CONSEQUENTIAL DAMAGES RESULTING FROM ITS PERFORMANCE OR NON-PERFORMANCE UNDER THIS AGREEMENT, IN EACH CASE WHETHER UNDER CONTRACT, TORT, WARRANTY, OR OTHERWISE, AND WHETHER OR NOT SUCH PARTY HAD ADVANCE NOTICE OF THE POSSIBILITY OF SUCH DAMAGES.

O-RAN SPECIFICATIONS ARE PROVIDED "AS IS" WITH NO WARRANTIES OR CONDITIONS WHATSOEVER, WHETHER EXPRESS, IMPLIED, STATUTORY, OR OTHERWISE. THE O-RAN ALLIANCE AND THE MEMBERS, CONTRIBUTORS OR ACADEMIC CONTRIBUTORS EXPRESSLY DISCLAIM ANY WARRANTY OR CONDITION OF MERCHANTABILITY, SECURITY, SATISFACTORY QUALITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, ERROR-FREE OPERATION, OR ANY WARRANTY OR CONDITION FOR O-RAN SPECIFICATIONS.

SECTION 8: ASSIGNMENT

Adopter may not assign the Agreement or any of its rights or obligations under this Agreement or make any grants or other sublicenses to this Agreement, except as expressly authorized hereunder, without having first received the prior, written consent of the O-RAN Alliance, which consent may be withheld in O-RAN Alliance's sole discretion. O-RAN Alliance may freely assign this Agreement.

SECTION 9: THIRD-PARTY BENEFICIARY RIGHTS

Adopter acknowledges and agrees that Members, Contributors and Academic Contributors (including future Members, Contributors and Academic Contributors) are entitled to rights as a third-party beneficiary under this Agreement, including as licensees under Section 3.

SECTION 10: BINDING ON AFFILIATES

Execution of this Agreement by Adopter in its capacity as a legal entity or association constitutes that legal entity's or association's agreement that its Affiliates are likewise bound to the obligations that are applicable to Adopter hereunder and are also entitled to the benefits of the rights of Adopter hereunder.

SECTION 11: GENERAL

This Agreement is governed by the laws of Germany without regard to its conflict or choice of law provisions.

This Agreement constitutes the entire agreement between the parties as to its express subject matter and expressly supersedes and replaces any prior or contemporaneous agreements between the parties, whether written or oral, relating to the subject matter of this Agreement.

Adopter, on behalf of itself and its Affiliates, agrees to comply at all times with all applicable laws, rules and regulations with respect to its and its Affiliates' performance under this Agreement, including without limitation, export control and antitrust laws. Without limiting the generality of the foregoing, Adopter acknowledges that this Agreement prohibits any communication that would violate the antitrust laws.

By execution hereof, no form of any partnership, joint venture or other special relationship is created between Adopter, or O-RAN Alliance or its Members, Contributors or Academic Contributors. Except as expressly set forth in this Agreement, no party is authorized to make any commitment on behalf of Adopter, or O-RAN Alliance or its Members, Contributors or Academic Contributors.

In the event that any provision of this Agreement conflicts with governing law or if any provision is held to be null, void or otherwise ineffective or invalid by a court of competent jurisdiction, (i) such provisions will be deemed stricken from the contract, and (ii) the remaining terms, provisions, covenants and restrictions of this Agreement will remain in full force and effect.

Any failure by a party or third party beneficiary to insist upon or enforce performance by another party of any of the provisions of this Agreement or to exercise any rights or remedies under this Agreement or otherwise by law shall not be construed as a waiver or relinquishment to any extent of the other parties' or third party beneficiary's right to assert or rely upon any such provision, right or remedy in that or any other instance; rather the same shall be and remain in full force and effect.

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