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# O-RAN WG1 Operations and Maintenance Architecture v02.00

# Contents

# Chapter 1. Introductory Material

## 1.1 Scope

This Technical Specification has been produced by the o-RAN.org.

The contents of the present document are subject to continuing work within o-RAN WG1 and may change following formal o-RAN approval. Should the o-RAN.org 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 present document studies O-RAN OAM architecture and interface functions. The OAM architecture supports a variety of management network deployment models, including the model of management entities (NMS/EMS/MANO) connecting directly to NEs, and the indirect connection (e.g., M-Plane involved) model. A separate OAM interface document provides details of the functions and protocols conveyed over the interface, that include management functions, procedures, operations and corresponding solutions.

## 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 15.


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

[2] 3GPP TS 38.401: NG-RAN; Architecture description.

[3] 3GPP TS 28.622: Telecommunication management; Generic Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS).

[4] 3GPP TS 32.101: Telecommunication management; Principles and high level requirements.

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

[6] O-RAN-WG4.MP.0-v01.00: O-RAN Alliance Working Group 4 Management Plane Specification

[7] O-RAN-WG1.OAM Interface Specification-v2.0, “O-RAN Operations and Maintenance Interface Specification”.

[8] O-RAN-WG6.CAD-V00.01, “Cloud Architecture and Deployment Scenarios for O-RAN Virtualized RAN”

## 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].

**near-RT RIC:** O-RAN near-real-time RAN Intelligent Controller: a logical function that enables near-real-time control and optimization of O-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: a logical node hosting RRC, SDAP and PDCP protocols

**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 in Service Management and Orchestration Framework and O-RAN managed elements, for operation and management, by which FCAPS management, Software management, File management shall be achieved.

**O1***: Interface between Service Management and Orchestration Framework and Infrastructure Management Framework supporting O-RAN virtual network functions.

**xAPP**: Independent software plug-in to the Near-RT RIC platform to provide functional extensibility to the RAN by third parties.

### 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].

| | |
|---|---|
| FCAPS | Fault, Configuration, Accounting, Performance, Security |
| IMF | Infrastructure Management Framework |
| ME | Managed Element |
| MF | Managed Function |
| NAT | Network Address Translation |
| Near-RT RIC | O-RAN near real time RAN Intelligent Controller |
| NFV | Network Function Virtualization |
| NFVI | Network Function Virtualization Infrastructure |
| NM | Network Manager |
| Non-RT RIC | O-RAN non-real time RAN Intelligent Controller |
| O-CU-CP | O-RAN Central Unit – Control Plane. |
| O-CU-UP | O-RAN Central Unit – User Plane |
| O-DU | O-RAN Distributed Unit |
| O-RU | O-RAN Radio Unit |
| PCP | Port Control Protocol |
| PNF | Physical Network Function |
| RAN | Radio Access Network |
| SMO | Service Management and Orchestration |

| | | |
|---|---|---|
| 1 | VNF | Virtualized Network Function |
| 2 | VPN | Virtual Private Network |
| 3 | UPNP | Universal Plug-N-Play |

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# Chapter 2. O-RAN Overview

## 2.1 Scope and Objectives

O-RAN activities are guided by the following objectives [5]:

- Leading the industry towards open, interoperable interfaces, RAN virtualization, and big data and AI enabled RAN intelligence.
- Maximizing the use of common-off-the-shelf hardware and merchant silicon and minimizing proprietary hardware
- Specifying APIs and interfaces, driving standards to adopt them as appropriate, and exploring open source where appropriate

The O-RAN OAM Architecture identifies management services, managed functions and managed elements supported in O-RAN, including the interworking between service management and orchestration and other O-RAN components such as infrastructure management. Requirements are derived from end-to-end OAM use cases, initially using the initial provisioning of O-RAN service across VNFs and PNFs as the primary use case. The architecture identifies the interfaces between O-RAN Service Management and Orchestration and Managed Elements for different models and example deployment options.

Future versions of the architecture will address additional areas of O-RAN OAM functionality.

## 2.2 End to End OAM Use Case

This section contains end to end OAM use cases that O-RAN is expected to support. Requirements will be derived from the use cases.

The initial use case defined is O-RAN Service Provisioning. Additional Use Cases will be added as prioritized by the O-RAN community in future versions of this document

### 2.2.1 O-RAN Service Provisioning

#### 2.2.1.1 Basic Objective

In the O-RAN architecture, the radio side includes Near-RT RIC, O-CU-CP, O-CU-UP, O-DU, and O-RU Managed Functions, and the management side is comprised of the Service Management and Orchestration Framework (including the Non-RT RIC). In the NFV environment, O-RAN network elements can also be implemented in a virtualized form, and thus include an Infrastructure layer (e.g. COTS/White Box/Peripheral hardware and virtualization layer) and an Infrastructure Management Framework.

The current use case focuses on network/element deployment rather than physical construction. According to the radio coverage requirement, operators could deploy the O-RAN network/element on dedicated physical resources and/or virtualized resources in a specific area.

This use case assumes that the network elements are deployed based on an example Network Design using VNFs for centralized functions and PNFs for functions closer to the customer, so that the sequence calls for deployment of VNFs for the Near-RT RIC, O-CU-CP and O-CU-UP first followed by PNFs for the O-DU and O-RU. Note: RF functions must always be realized as PNFs but the O-DU can be realized as a PNF or VNF; this document uses PNF as an example to illustrate the associated OAM flows.

It is also assumed that secure network connectivity is already available between RAN components.

#### 2.2.1.2 Entities/Resources involved

To support the O-RAN network provisioning, the Service Management and Orchestration Framework needs to support the following capabilities:

- O-RAN network element deployed in selected area

a) For non-virtualized parts, the Service Management and Orchestration Framework supports the deployment of physical network elements on the target dedicated physical resources which satisfy the coverage requirements, with management through the O1 interface.

b) For virtualized network elements, the Service Management and Orchestration Framework has the capability to interact with the Infrastructure Management Framework to perform network element life cycle management, e.g. instantiate the virtualized network element on the target infrastructure through the O1* interface (e.g., indicate the selected geo-location for each VNF to be instantiated, where close to the PNFs).

c) The Service Management and Orchestration Framework has the capability to consume the provisioning management service through the O1 interface to manage the configuration of the network element, details are defined in O-RAN-WG1.OAM Interface Specification [7].

- O-RAN network provisioning

a) Based on the deployed network elements, the Service Management and Orchestration Framework configures the IP addressing, etc. in the PNFs and VNFs to support connectivity between them (this operation could also be performed during the instantiation steps).

b) Operators can operate and maintain the network dynamically through the O1 and/or O1* interface by means of:

i. Reconfiguration of the network elements

ii. System update (usually refers to software management, without adding network elements) and system upgrade (the network elements could be added/removed/modified)

According to above, the Service Management and Orchestration Framework together with the Infrastructure Management Framework implements the O-RAN network element deployment and provisioning, creating an O-RAN network to provide service to consumers.

*Note: The O1* interface will be defined in more detail in future O-RAN Orchestration specifications.

#### 2.2.1.3 Solutions

Table 1 shows the O-RAN service provisioning procedures.

**Table 1: O-RAN service provisioning**

| Use Case Stage | Evolution / Specification | <<Uses>> Related use |
|---|---|---|
| Goal | O-RAN service provisioning | |
| Actors and Roles | [1]. Service Management and Orchestration Framework<br>[2]. Infrastructure Management Framework<br>[3]. Infrastructure layer<br>[4]. PNF<br>[5]. VNF | |
| Assumptions | | |
| Pre-conditions | [1]. The Service Management and Orchestration Framework and Infrastructure Management Framework are connected and interact normally<br>[2]. The Infrastructure Management Framework and the Infrastructure layer are connected and interact normally<br>[3]. The PNF was constructed/installed but not activated<br>[4]. The VNF Software Package has been uploaded to the Infrastructure Management Framework<br>[5]. Secure network connectivity is already available between RAN components<br>- Note: security related procedure is FFS | |
| Begins when | The network operator/manager decides to deploy an O-RAN network in specific geo-location | |
| Step 1 (M) | The service designer deploys Service Model and Artifacts to SMO | |
| Step 2 (M) | SMO on boarding the VNF Descriptors for the service to the IMF | |
| Step 3 (M) | The radio planner orders RAN Service Deployment | |
| Step 4 (M) | The SMO initiates the O-RAN Service instantiation | |
| Step 5 (M) | The SMO interacts with IMF to instantiate Near-RT RIC based on Near-RT RIC VNFD | |
| Step 6 (M) | the IMF creates VNF of Near-RT RIC | |
| Step 7 (M) | The IMF notifies the SMO the Near-RT RIC has been instantiated | |
| Step 8 (M) | The SMO configures the Near-RT RIC | |
| Step 9 (M) | the IMF creates VNF of O-CU-CP | |
| Step 10 (M) | The IMF notifies the SMO the O-CU-CP has been instantiated | |
| Step 11 (M) | The SMO prepares configuration, e.g. Near-RT RIC related | |
| Step 12 (M) | The SMO configures the O-CU-CP | |
| Step 13 (M) | The SMO interacts with IMF to instantiate O-CU-UP, for multiple O-CU-UP VNF, the step 13 to 17 is circulated | |
| Step 14 (M) | the IMF creates VNF of O-CU-UP | |
| Step 15 (M) | The IMF notifies the SMO the O-CU-UP has been instantiated | |
| Step 16 (M) | The SMO prepares configuration, e.g. Near-RT RIC, O-CU-CP related | |
| Step 17 (M) | The SMO configures the O-CU-UP | |
| Step 18 (O) | The SMO deploys xAPP to Near-RT RIC | |
| Step 19 (O) | After the above steps the Near-RT RIC could interact with O-CU-CP via E2 interface | |
| Step 20 (O) | After the above steps the Near-RT RIC could interact with O-CU-UP via E2 interface | |
| Step 21 (M) | SMO adds O-DU into inventory, e.g. with an O-DU.ID for each O-DU. For multiple O-DU this step is circulated | |
| Step 22 (M) | SMO add O-RU into inventory in the O-DU record, e.g. with an O-RU.ID for each O-RU. For multiple O-DU this step is circulated | |
| Step 23 (M) | The field technician powers on the O-DU | |
| Step 24 (M) | The O-DU sends Registration to the Collector<br>Note: controller address determined as per O-RAN-WG1.O1 Interface Specification | |
| Step 25 (M) | The Collector notifies the SMO the O-DU is on-line | |
| Step 26 (M) | The SMO prepares O-DU configuration, e.g. related information from Near-RT RIC and O-CU-CP, O-CU-UP | |

| Use Case Stage | Evolution / Specification | <<Uses>> Related use |
|---|---|---|
| Step 27 (M) | The SMO configures the O-DU<br>Note: includes NETCONF configuration as per O-RAN WG4.MP.0-v01.00 | |
| Step 28 (O) | The SMO could deploy xAPP to O-DU | |
| Step 29 (O) | After the above steps the Near-RT RIC could interact with O-DU via E2 interface | |
| Step 30 (M) | The field technician powers on the O-RU | |
| Step 31 (M) | The O-RU registers to the O-DU<br>Note: detailed procedures as per O-RAN WG4.MP.0-v01.00 – additional actions for hybrid case not shown | |
| Step 32 (M) | The O-DU sends Config Change Notification to the Collector indicating O-RU on-line | |
| Step 33 (M) | The Collector notifies the SMO the O-RU is on-line | |
| Step 34 (M) | The SMO configures the O-RU via O-DU | |
| Step 35 (M) | The O-DU gets O-RU configuration information from the SMO | |
| Step 36 (M) | The O-DU configures the O-RU | |
| Step 37 (M) | O-RU sends Registration to the Collector<br>Note: procedure not currently supported in WG4.MP.0-v01.00 but details assumed as per O-RAN-WG1.O1 Interface Specification | |
| Step 38 (M) | The Collector notifies the SMO the O-RU is on-line | |
| Step 39 (M) | The SMO prepares O-RU configuration, e.g. include co-related O-DU, etc. | |
| Step 40 (M) | The SMO configures the O-RU | |
| a) Ends when | FFS | |
| b) Exceptions | FFS | |
| c) Post Conditions | The O-RAN network has been established and can provide service to customers | |
| Traceability | FFS | |

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```
@startuml
skinparam sequenceArrowThickness 2
skinparam ParticipantPadding 5
skinparam BoxPadding 10
autonumber
Box “Personnel” #lightblue
  Actor “Service \nDesigner” as SD
  Actor “Radio \nPlanner” as RP
  Actor “Field \nTechnician” as Tech
End box
box “Service Management & \nOrchestration Framework” #gold
  Participant SMO
  Collections “Non-RT RIC”
  Boundary Collector
end box
Box “Cloud Platform \nInfrastructure” #lightseagreen
  participant IMF
End box

box "O-RAN Components"#lightpink
  Participant “Near-RT RIC” as NearRTRIC <<(z,lime)>>
  collections “O-CU-CP” as OCUCP <<(z,lime)>>
  collections “O-CU-UP” as OCUUP <<(z,lime)>>
```

```
  collections "O-DU" as ODU <<(p,aqua)>>
  collections "O-RU" as ORU <<(p,aqua)>>
end box

== O-RAN Service Design ==
SD -> SMO: Deploy Service Model and Artifacts
SMO -> IMF: On boarding the VNF Descriptors for the service
== O-RAN Service Deploy ==
RP -> SMO: Order RAN Service Deployment
SMO --> SMO : Instantiate (\n\tO-RAN Service)
|||
== O-RAN Service Resource VNF Deploy ==
group O-RAN Virtualized Part Instantiation and Configuration
  SMO -> IMF: Instantiate (Near-RT RIC_VNFD)
  'SMO -> IMF: Instantiate (O-RAN Service NSD)
  rnote left IMF
Details of VNF creation omitted
  endnote
  IMF -> NearRTRIC **: Create VNF
  IMF -> SMO: Notify Near-RT RIC instantiated
  SMO -> NearRTRIC : Configure (Near-RT RIC_Config)
|||
  'SMO -> IMF: Instantiate (O-CU-CP_VNFD)
  IMF -> OCUCP **: Create VNF
  IMF -> SMO: Notify O-CU-CP instantiated
  SMO -> SMO: CP_Cfg = Build (\n\tNear-RT RIC_Cfg)
  SMO -> OCUCP : Configure (O-CU-CP_Config)
|||
  rnote over SMO, OCUUP
 Instantiate all req'd O-CU-UP for this O-CU-CP
  endrnote
  Loop foreach O-CU-UP associated with the O-CU-CP
    SMO -> IMF: Instantiate (O-CU-UP_VNFD)
    IMF -> OCUUP **: Create VNF
    IMF -> SMO: Notify O-CU-UP instantiated
    SMO -> SMO: UP_Cfg = Build (\nt\tNear-RT RIC_cfg,\n\tO-CU-CP_Cfg)
    SMO -> OCUUP: Configure (O-CU-UP_Cfg)
  End
|||
  SMO -> NearRTRIC : deploy xAPPs
  rnote over SMO,OCUUP
    Near-RT RIC can't subscribe to O-CU-CP/UP msgs until they exist
  endrnote

  Alt Near-RT RIC subscribes to O-CU-CP
    NearRTRIC -> OCUCP : <<E2>> Subscribe
|||
  End
  Alt Near-RT RIC subscribes to O-CU-UP
    NearRTRIC -> OCUUP : <<E2>> Subscribe
|||
  End
|||
  rnote over SMO
 Create all PNF Inventory placeholders
  endrnote
  Loop foreach O-DU in O-CU-CP.DUs
    SMO -> SMO: Inventory.Add(\n\tPNF,\n\tO-DU,\n\tO-DU.ID\n)
    Loop foreach O-RU in O-DU.RUs
      SMO -> SMO: Inventory.Add(\n\tPNF,\n\tO-RU,\n\tO-RU.ID\n)
    end
```

```
  end
end
|||
== O-RAN Service Resource PNF Deploy ==
group PNF Registration and Configuration
  Tech -> ODU ** : Poweron
  rnote over ODU
   controller address as
   per O-RAN O1 Spec
  endrnote
  ODU -> Collector : Register O-DU (ID)
  Collector -> SMO: Notify PNF Online
  SMO -> SMO: DU_Cfg = Generate (\n\t Near-RT RIC_Cfg,\n\tO-CU-CP_Cfg,\n\tO-CU-UP)
  SMO -> ODU: Configure (O-DU_Cfg)
  rnote over SMO,ODU
   Near-RT RIC cannot subscribe to O-DU msgs until O-DU exists
  endrnote
  SMO -> NearRTRIC: Configure xAPPs for O-DU
  Alt Near-RT RIC needs to subscribe to O-DU
    NearRTRIC -> ODU : <<E2>> Subscribe
|||
  End
  Tech -> ORU ** : Poweron
  alt Hierarchical (O-DU) management O-RU
|||
    ORU -> ODU: Register
    rnote left ORU
      controller address as per WG4.MP.0-v01.00
      additional actions for hybrid case not shown
    endrnote
    ODU -> Collector: Config Change Notification: O-RU Online (O-RU.ID)
    Collector -> SMO : Notify PNF Online
    SMO -> ODU: O-DU.Configure O-RU (RU.ID, SMO_RUConfig)
    ODU -> ODU: O-RUConfig = Merge(\n\t O-DU.Config,\n\tSMO_O-RUConfig)
    ODU -> ORU: RI.Configure\n(O-RUConfig)
|||
  Else Flat (SMO) management O-RU
    ORU -> Collector: Register O-RU (RU.ID)
     rnote left ORU
     controller address as per O-RAN O1 Spec
     endrnote
    Collector -> SMO : Notify PNF Online
    SMO -> SMO: O-RU_Config = Build (\n\tRU[id].Cfg,\n\tO-DU Cfg)
    SMO -> ORU: Configure (O-RU_Config)
|||
  End
|||
end
|||
@enduml
```

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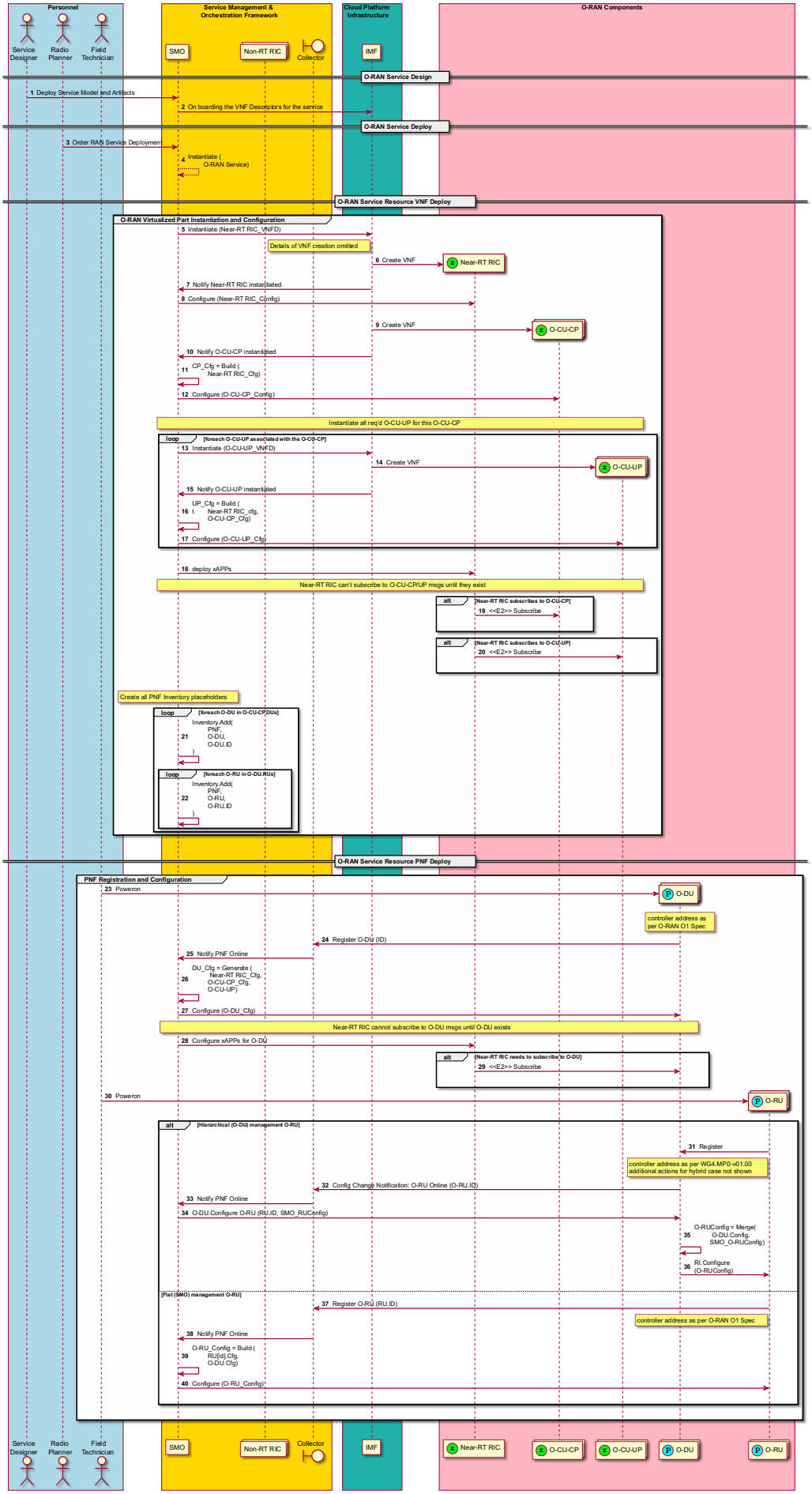


**Figure 2-1: O-RAN Service Provisioning**

# Chapter 3. OAM Architecture

## 3.1 Architectural Principles

The following section provides architecture principals guiding the support of OAM in the O-RAN architecture. Common OAM functions should be supported through a common set of OAM interface protocols across the different components of the O-RAN architecture

Management Services should, to the degree possible, align with existing standards specifications:

- 3GPP 5G Specifications for management interfaces
- ETSI NFV Specifications for life cycle management
- O-RAN WG4.MP.0-v01.00 (Future enhancements to align to 3GPP can be considered.)

O-RAN OAM specifications should refer to the 3GPP and ETSI specs and not replicate them here. O-RAN OAM specifications must identify needed extensions to support O-RAN and exceptions which cannot be supported. It is the goal of O-RAN to drive any needed extensions into standards to maintain alignment between O-RAN and existing standards.

## 3.2 Architecture Requirements

Defines the Architecture requirements applicable to the O-RAN reference architecture. Architecture requirements are derived from Use Cases to be supported and define the functional needs the architecture aims to satisfy.

The initial set of requirements in this document are derived from the O-RAN Service Provisioning Use Case. More requirements may be added in future versions of the OAM Architecture.

### 3.2.1 Functional Requirements

| REQ | Description | Note |
|---|---|---|
| [REQ-M&O-FUN1] | O-RAN OAM Architecture must support the interaction between the Service Management and Orchestration Framework and the Infrastructure Management Framework through O1* interface to perform virtualized resource orchestration. | Use Case |
| [REQ-M&O-FUN2] | O-RAN OAM Architecture must support the capability for the Service Management and Orchestration Framework to consume the provisioning management service exposed by each O-RAN managed element, whether implemented as PNF or VNF, through the O1 interface. | O-RAN-WG1.OAM Interface Specification [7] |
| [REQ-M&O-FUN3] | O-RAN OAM Architecture must support creation, modification and termination of VNFs in an O-RAN network by the Service Management and Orchestration Framework | Use Case |
| [REQ-M&O-FUN4] | O-RAN OAM Architecture must support registration and inventory of newly activated VNFs and PNFs by the Service Management and Orchestration Framework | Use Case |
| [REQ-M&O-FUN5] | O-RAN OAM Architecture must support collection of status change and other indications from VNFs and PNFs by the Service Management and Orchestration Framework | Use Case |
| [REQ-M&O-FUN6] | O-RAN OAM Architecture must support configuration of VNFs and PNFs by the Service Management and Orchestration Framework, including, for | Use Case |

| | | |
|---|---|---|
| | example, addressing information needed to allow them to connect to each other | |
| [REQ-M&O-FUN7] | O-RAN OAM Architecture must support management of PM jobs, PM data collection/storage/query/statistical reports from O-RAN Components | Use Case to be added |
| [REQ-M&O-FUN8] | O-RAN OAM Architecture must support operation logging and operation authority of Managed Elements | Use Case to be added |
| [REQ-M&O-FUN9] | O-RAN OAM Architecture must support management of Managed Functions contained within a Managed Element | ETSI 3GPP TS 28.622 |
| [REQ-M&O-FUN10] | O-RAN OAM Architecture must support hierarchical and hybrid management of O-RAN O-DU and O-RU components as defined in O-RAN-WG4.MP.0-v01.00 | Use Case & O-RAN MP Spec [6] |
| [REQ-M&O-FUN11] | O-RAN OAM Architecture and interfaces must support network slicing, where an instance of O-RAN managed function may be associated with one or more slices. | Use Case to be added |
| [REQ-M&O-FUN12] | O-RAN OAM Architecture must support O1 interface for all Managed Elements (with the exception of the RU) even if the Managed Element is deployed behind a NAT | O-RAN-WG1.OAM Interface Specification [7] |

### 3.2.2 Non-Functional Requirements

| | | |
|---|---|---|
| [REQ-M&O-NFUN1] | O-RAN OAM Architecture must support the introduction of new and more cost-effective technologies into the RAN through open, standard interfaces | O-RAN white paper [5] |
| [REQ-M&O-NFUN2] | O-RAN OAM Architecture must support virtualization of RAN components, allowing operators use of common, off-the-shelf hardware implementations | O-RAN white paper [5] |
| [REQ-M&O-NFUN3] | O-RAN OAM Architecture must support use of Analytics and Artificial Intelligence/Machine Learning to improve network efficiency and performance and reduce operations costs | O-RAN white paper [5] |

### 3.2.3 Security Requirements

| | | |
|---|---|---|
| [REQ-M&O-NFUN4] | O-RAN OAM Architecture must support security of interactions between the components of an O-RAN network | See note |

Note: more detailed requirements for security will be addressed in future versions of the OAM Architecture.

## 3.3 Reference Architecture

The reference architecture defines a set of basic architectural building blocks – management services, managed functions and managed elements – for the O-RAN management domain.

## 3.3.1 Architectural Building Blocks

### 3.3.1.1 Management Services

Management Services offer capabilities to manage and orchestrate managed elements. Managed elements expose their management services to managers. Managers consume the management services.

Examples of Management Services supported by O-RAN include:

- Provisioning
- Fault Supervision
- Performance Assurance
- Trace Management
- File Management
- Software Management
- Communication Surveillance
- Startup and Registration of a Physical Network Function (PNF)
- Instantiation and Termination of a Virtualized Network Function (VNF)
- Scaling Management Services for VNF

'The definition of supported management services and their APIs will be covered in the OAM O1 Interface specification [7].

### 3.3.1.2 Managed Elements

The definition of a Managed Element (ME) is given in 3GPP TS 28.622 [3] section 4.3.3. The ME supports communication over management interface(s) to the manager for purposes of control and monitoring.

Examples of O-RAN Managed Elements include:

- O-RAN Managed Functions deployed individually as MEs (e.g., Near-RT RIC ME, CU-CP ME, CU-UP ME, O-DU ME, O-RU ME).
- Central Unit (CU) composed of CU-CP and CU-UP
- ME composed of Near-RT RIC, CU-CP, CU-UP, DU and RU

A variety of deployment examples and their OAM interfaces are given in a later section. Choice of deployment options will be based on operator requirements.

### 3.3.1.3 Managed Functions

The definition of a Managed Function (MF) is given in 3GPP TS 28.622 [3] section 4.3.4. An MF instance is managed using the management interface(s) exposed by its containing ME instance.

O-RAN managed functions include:

- Near-Real-Time Radio Intelligent Controller (Near-RT RIC)
- O-RAN Central Unit – Control Plane (O-CU-CP)
- O-RAN Central Unit – User Plane (O-CU-UP)
- O-RAN Distributed Unit (O-DU)

- O-RAN Radio Unit (O-RU)

#### 3.3.1.4 Service Management and Orchestration Framework

Service Management and Orchestration Framework is responsible for the management and orchestration of the managed elements under its span of control. The framework can for example be a third-party Network Management System (NMS) or orchestration platform.

Service Management and Orchestration Framework must provide an integration fabric and data services for the managed functions. The integration fabric enables interoperation and communication between managed functions within the O-RAN domain. Data services provide efficient data collection, storage and movement capabilities for the managed functions. In order to implement multiple OAM architecture options together with RAN service modeling, the modeling of different OAM deployment options and OAM services (integration fabric etc.) must be supported by SMO

#### 3.3.1.5 Non-Real Time Radio Intelligent Controller

The non-RT RIC is a part of the Service Management & Orchestration Framework and communicates to the near-RT RIC using the A1 interface. [5]

Non-RT control functionality (> 1s) and near-Real Time (near-RT) control functions (< 1s) are decoupled in the RIC. Non-RT functions include service and policy management, RAN analytics and model-training for some of the near-RT RIC functionality, and non-RT RIC optimization.

#### 3.3.1.6 Control Loop Support

O-RAN defines 3 control loops with different latency bands [5]. It is not expected that these loops are hierarchical but instead run in parallel. This does not mean that an ME with an inner loop will not generate its own event as result of an inner loop failure, but it will not simply propagate the lower level event received by the inner loop. The three loops are roughly defined as:

- Loop 1: In the DU for per TTI/msec resource scheduling (<10 millisecond)
- Loop 2: In the Near-RT RIC and CU for resource optimization (10 milliseconds to 1 second)
- Loop 3: In the Service Management and Orchestration Framework for ML Training, Trending, Orchestration (> 1 second)

## 3.3.2 Basic OAM Architecture

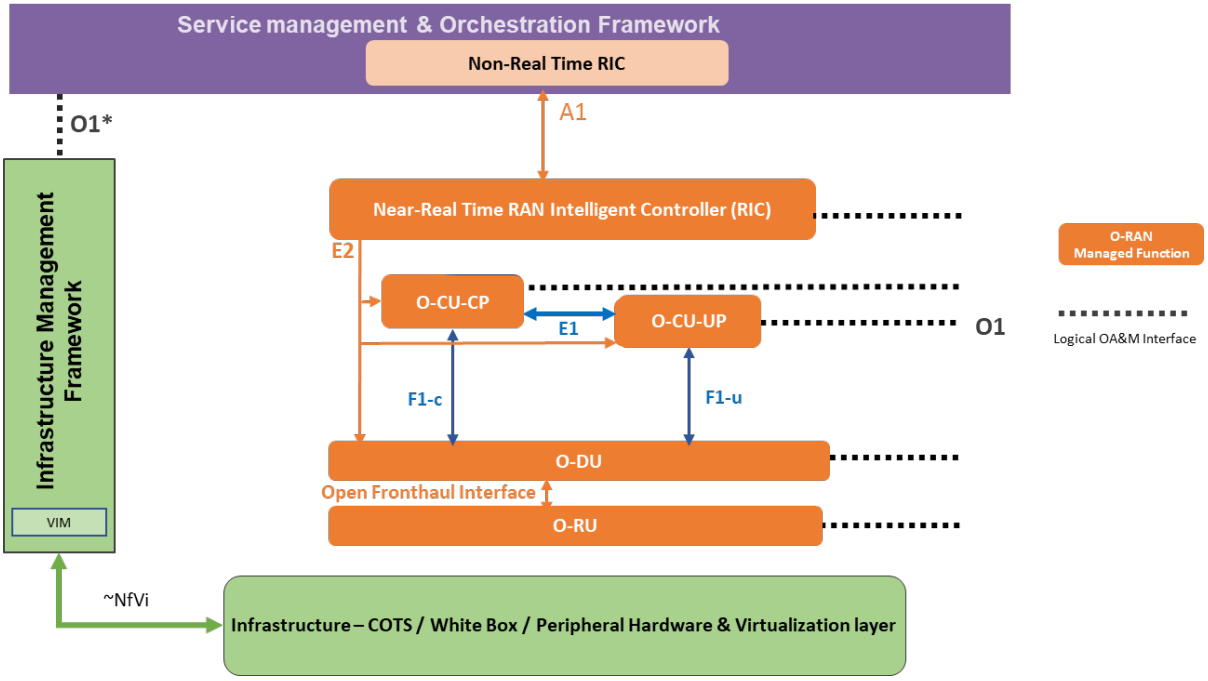



**Figure 3-1 O-RAN OAM Logical Architecture**

Figure 3-1 shows the overall O-RAN OAM Logical Architecture. In the original figure, the interface between the Manager and the O-RAN components for control purposes was identified as A1. The O-RAN OAM Architecture adds another interface for OAM functions, labeled O1 (OAM). O1 is the interface between the O-RAN Managed Element and the management entity. Note: the figure uses 5G terminology, however the same principles will apply for LTE/4G. Mapping to LTE/4G may be added in future. Also, the O1* interface for management of the Infrastructure Management Framework may have requirements that differ from the other O1 interfaces and requires further study. The green boxes together comprise the Cloud Platform Infrastructure shown in Figure 2-1.

The O1 OAM Interface includes implementation of Fault, Configuration, Accounting, Performance, Security (FCAPS) functions, File management and software management functions to ME (s) virtualized and physical alike. In the case of virtualized Network Elements (NEs), the interface describes standardized interfaces for orchestration and monitoring of the infrastructure resource used to deploy the software as a separate entity. In the case of pure monolithic architectures with fully integrated hardware and software, the hardware is reported with the software. For details of the management services supported by O1, see [7].

As shown in the figure, there is a logical OAM interface to individual O-RAN Managed Functions, however in practice the grouping of Managed Functions into Managed Elements will determine where actual O1 interfaces are terminated. More detail is explained in subsequent sections. The O1 interface could be the terminated directly on the Service Management & Orchestration Framework or in a hierarchical model could be terminated on a Managed Element which manages other O-RAN Managed Functions.

The sections below identify possible management topologies, for example, the basic “flat” model of OAM relationships as well as the hierarchical model of O-DU to O-RU relationship and the hybrid model of O-DU to O-RU relationship defined in the O-RAN Front Haul M-Plane specification, as well as example deployment options.

## 3.3.3 OAM Models and Deployment Options

This section provides examples of possible models and deployments of Managed Functions into Managed Elements. Adoption of a single model is not required in the O-RAN OAM Architecture, rather multiple model deployments may be supported in a network.

### 3.3.3.1 Flat Management Architecture Model

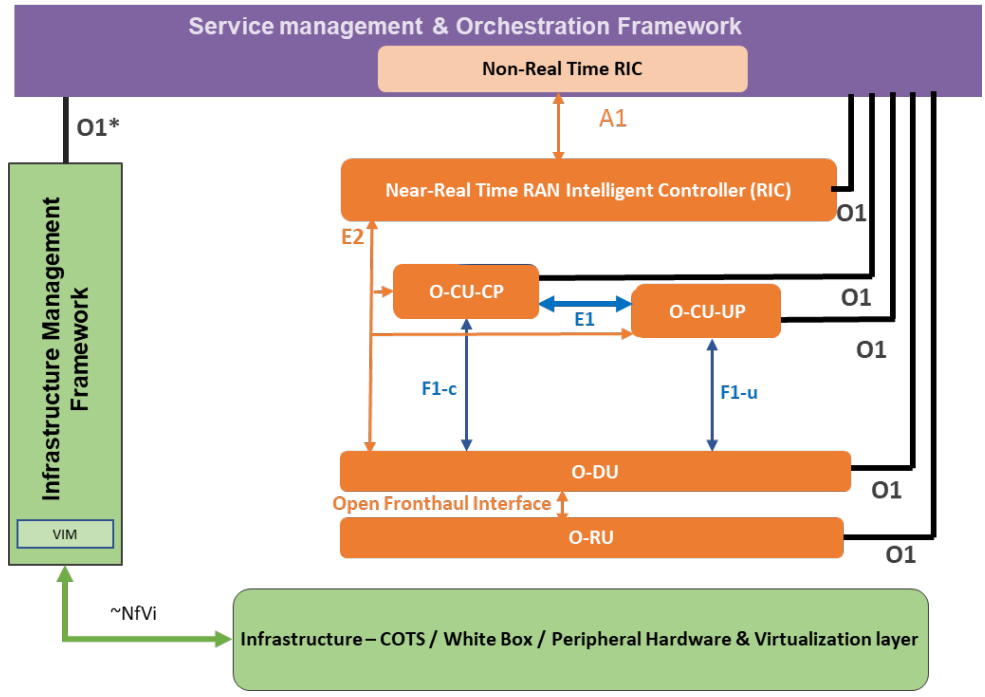



**Figure 3-2: Flat Model**

In the Flat management model, all the MFs comprising the O-RAN architecture are also MEs and expose an O1 interface to the SMO. Note: The Open Front Haul M-Plane specification is not currently optimized to support flat management of the O-RU and this is for further study.

NM/orchestration platforms provide a distributed deployment model of NM functions which allows for greater scaling and lower latency functions that traditional centralized monolithic NM implementations. In this specification, no specific platform is required, however the NM is assumed to have orchestration capabilities. Therefore, deployment of collectors, analytics, configuration and control functions can be potentially collocated with some of the NEs. This allows for localized processing and localized scaling to handle the expected large number of NEs to be managed. The NM functions can be distributed across the network edge and therefore handle a logically flat architecture. Additionally, the NM architectures supports low latency measurement collection, processing, and delivery to the RIC as a form of policy guidance or data update.

### 3.3.3.2 Hierarchical Management Architecture Model

Where the distributed NM architecture is not available it may be desirable to deploy a hierarchical management architecture where a higher level ME is used to manage a subnetwork of MEs as shown in Figure 3.3, where the O-DU manages the O-RU using the Open Front Haul M-Plane interface.

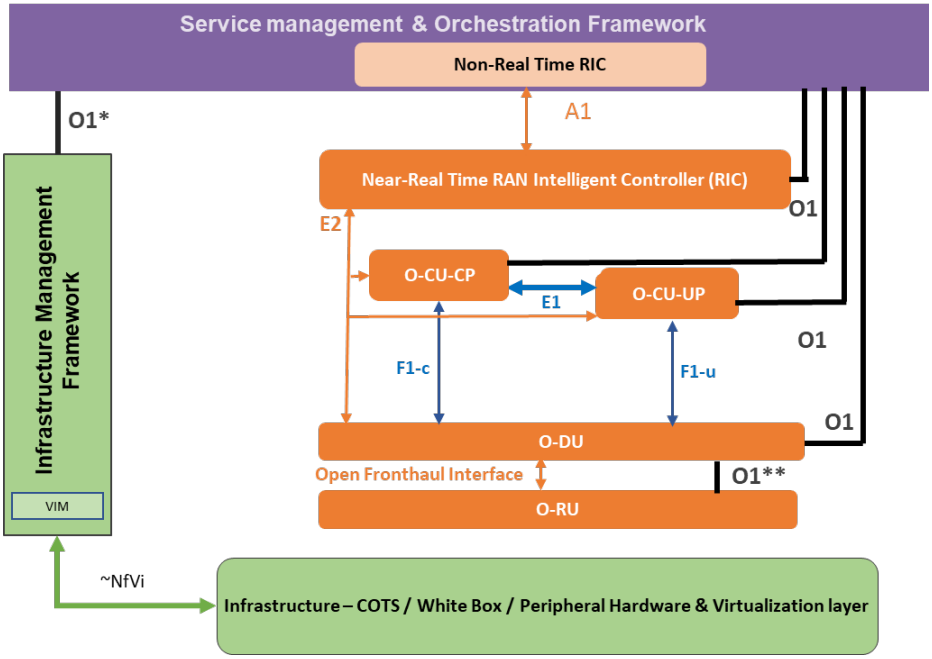



**Figure 3-3: Hierarchical Model Example**

In the example of the figure 3-3, the O-RU is managed by an O1** interface to the O-DU rather than the Service Management & Orchestration Framework, so there is a hierarchical relationship between Service Management & Orchestration and the O-DU. The O-DU must provide a consistent and standardized view of the subtending O-RUs as specified above.

### 3.3.3.3 Hybrid Management Architecture Model

In the Hybrid management architecture, the O-RU is managed partially by the O-DU and partially by the SMO.

The management by O-DU is via the M-Plane (O1**), and the M&O manages the O-RU through the O1 interface.

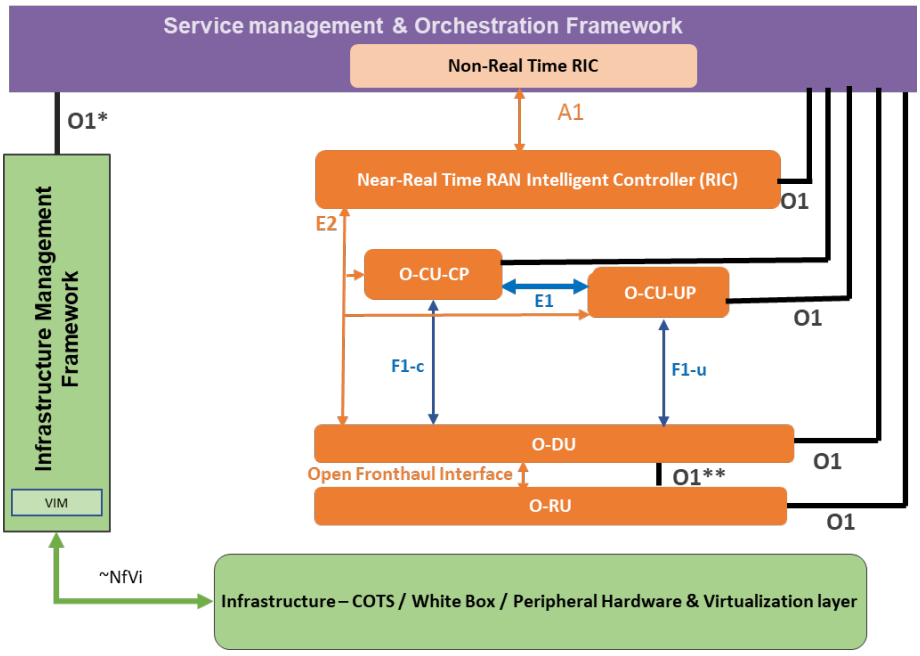



**Figure 4-4: Hybrid Model**

Management responsibility is divided in this case between the O-DU and the Service Management & Orchestration Framework. O1** in the figure is the Open Front Haul M-Plane [6] interface. The O-RU supports connection to

multiple clients as well as access control that can be used to control the privileges available to a particular client in M-Plane [6].

### 3.3.3.4 Example Managed Deployment Options

In aggregated equipment, the Managed Element contains multiple internal Managed Functions. This section provides a number of examples showing how the OAM architecture is applied to different groupings of Managed Functions into Managed Elements. Use cases associated with different deployment options are defined in [8].

Figure 3-5 shows a single Managed Element that contains CU-CP, CU-UP, O-DU and O-RU Managed Functions.

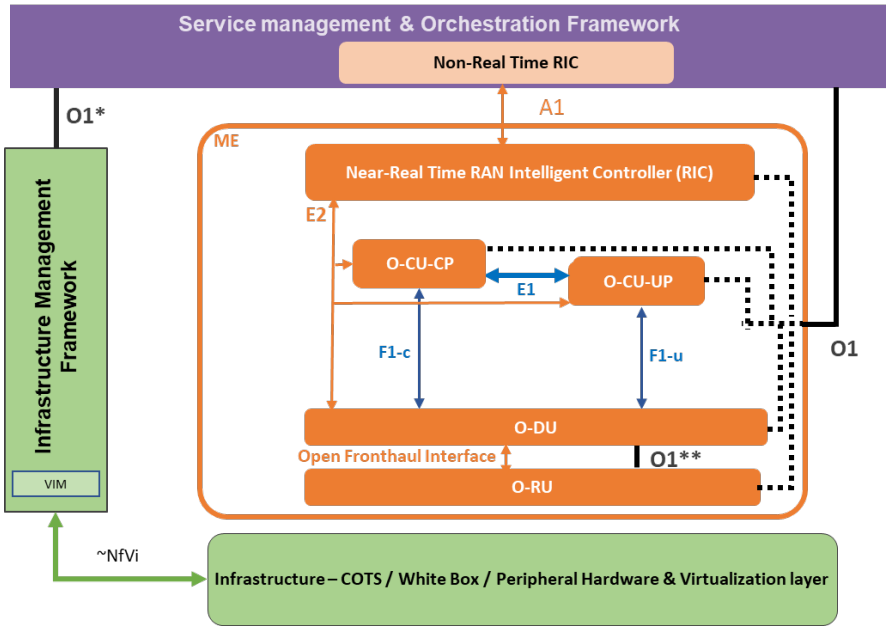



**Figure 3-5: Example with Single Integrated ME**

As shown in the figure 3-4, there is a single O1 interface to the Managed Element. However, the O1 interface still provides a consistent and standardized view of the Managed Functions that are contained within the Managed Element.

Figure 3-5 shows another example where the Near-RT RIC has been split off as a standalone ME.

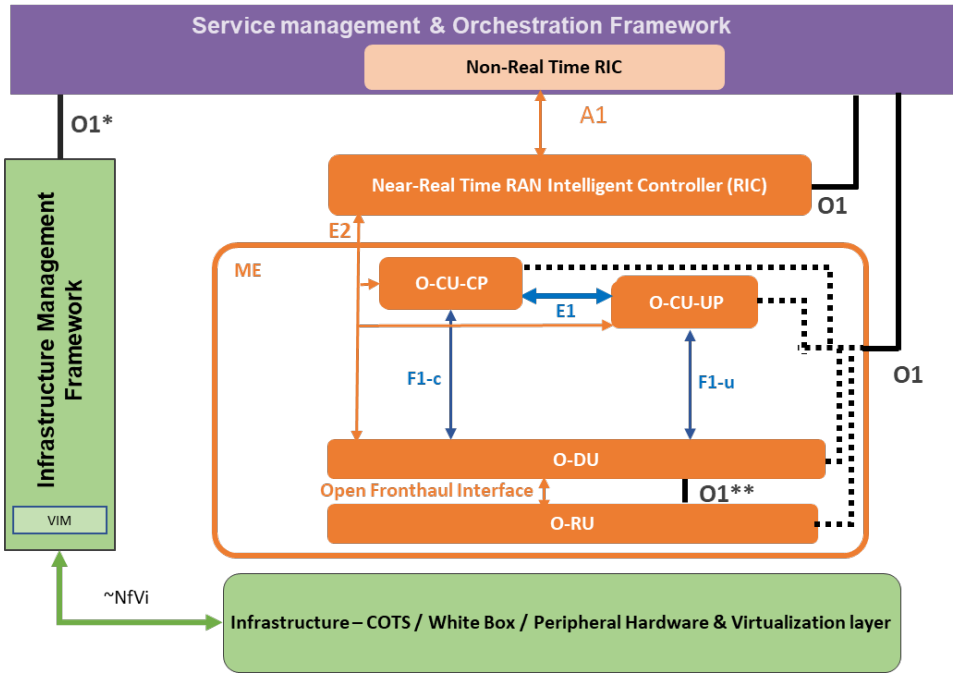


**Figure 3-6: Example with Single Integrated ME + Standalone Near-RT RIC**

In the example of Figure 3-5, there are separate O1 interfaces supported by each ME. The ME containing the Near-RT RIC Managed Function supports management of only this function through its O1 interface, while the ME containing the other Managed Functions provides a view of all contained functions.

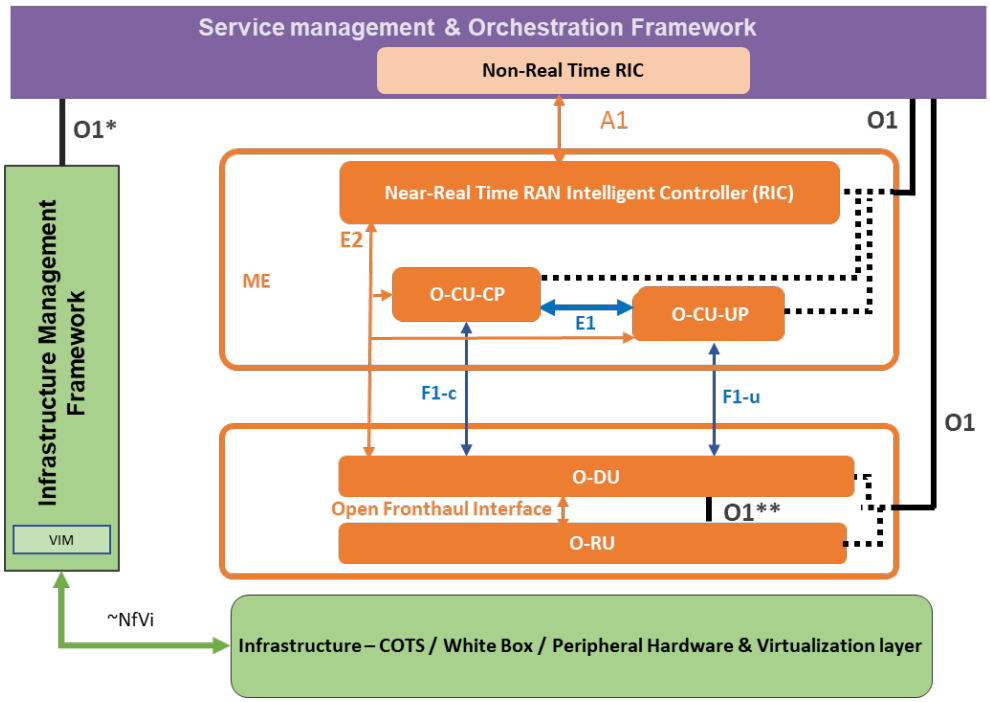



**Figure 3-7: Example ME aggregating Near-RT RIC, O-CU-CP and O-CU-UP**

Figure 3-7 shows an alternative example with two Managed Elements containing the Near-RT RIC/O-CU-CP/O-CU-UP, and the O-DU and O-RU Managed Functions, respectively. Again, the O1 interfaces from the MEs provide a consistent and standardized view of the contained Managed Functions.

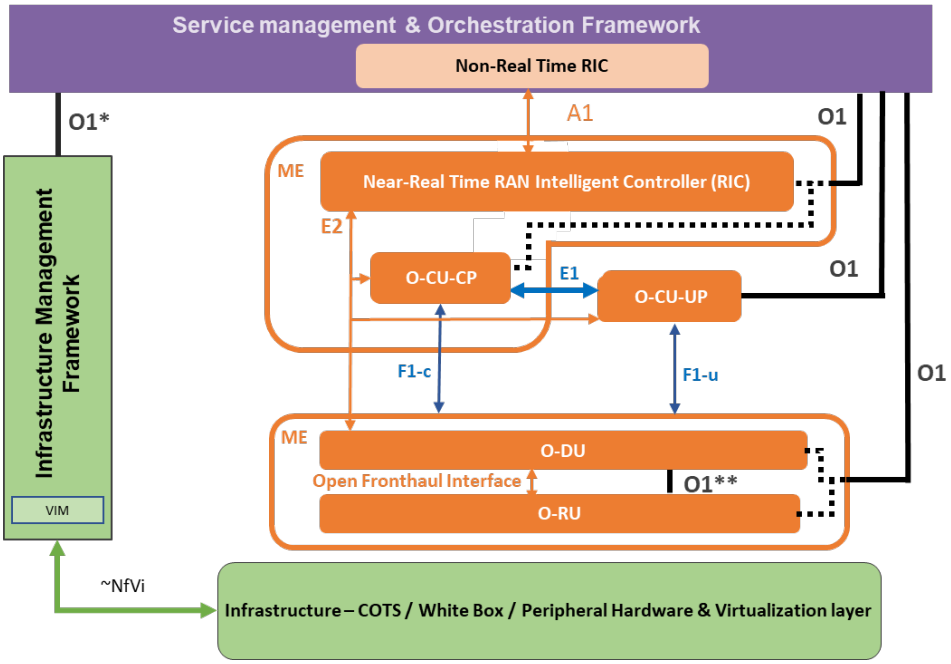



**Figure 3-8: Example with Three MEs**

Figure 3-8 shows an alternative example with three Managed Elements containing the Near-RT RIC/CU-CP, the CU-UP, and the O-DU and O-RU Managed Functions, respectively. Again, the O1 interfaces from the MEs provide a consistent and standardized view of the contained Managed Functions.

Finally, Figure 3-9 shows a similar grouping of Managed Functions, but with the Near-RT RIC separated as its own Managed Element. The same architectural concepts apply.

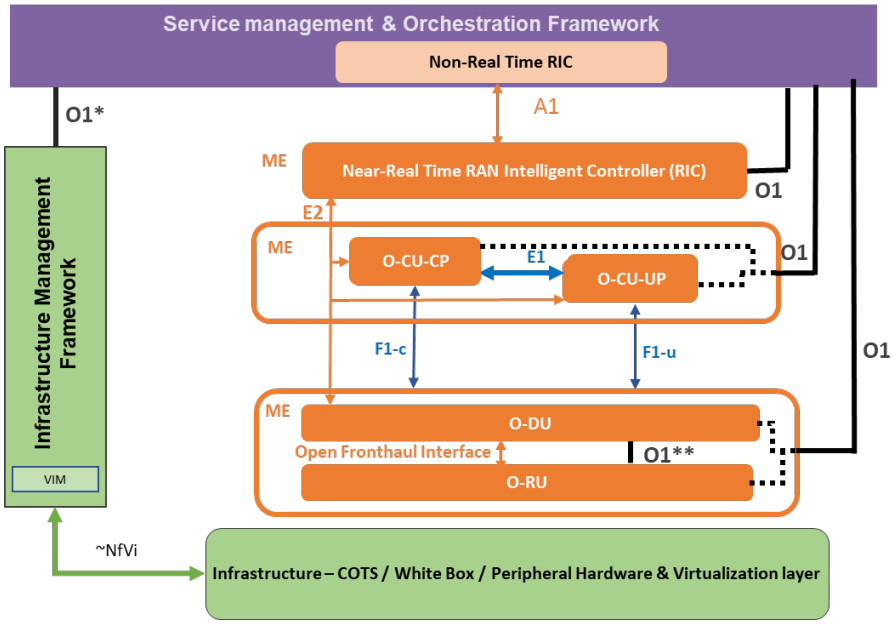



**Figure 3-9: Example with Three MEs including Standalone Near-RT RIC**

## 3.3.4 Managed Elements Deployed behind a NAT

Service Providers prefer to not deploy Managed Elements (ME) behind a NAT, but there are cases where this cannot be avoided, for example:

- exhaustion of public IPv4 addresses
- managed elements deployed in large complexes not owned by the Service Provider (Apartments, Sports Venues etc.)
- managed elements connected via third-party networks using a NAT

When a Service Provider deploys managed elements behind a NAT it is critical that they are able to retain full management control of these elements.

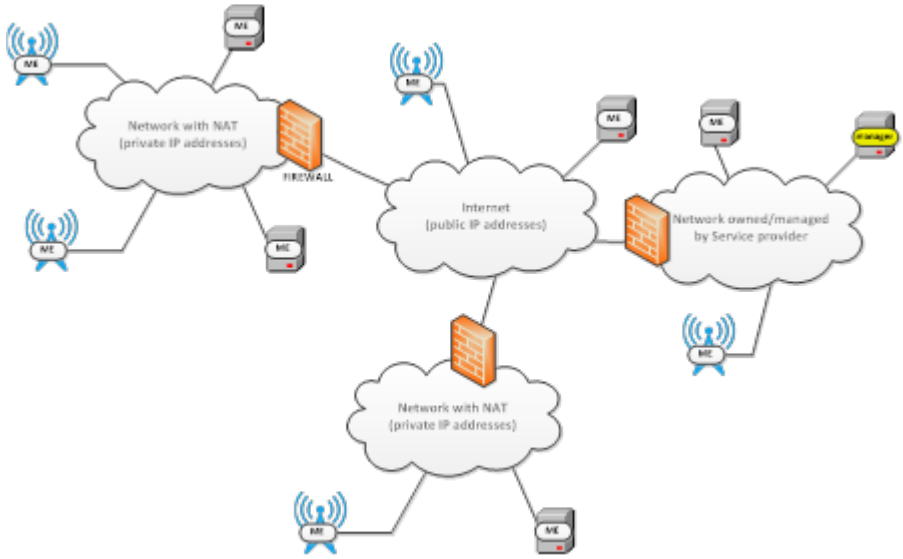



**Figure 3.3.4.1 O-RAN MEs behind a NAT**

Four methods of providing the O-RAN Manager with the ability to address a ME behind a NAT and identify data received from a ME behind a NAT are recommended in priority order:

1. ME uses IPv6 as Backhaul transport where possible eliminating the need for a NAT - exhaustion of public IPv4 addresses
2. ME establishes persistent VPN tunnel (e.g. IPSec) toward a VPN concentrator (gateway) located outside of network with the NAT. The ME is then accessible through the established tunnel.
3. ME uses a standard protocol (UPNP or PCP) to establish a port-forwarding rule at the firewall and automatically assign itself a port.
4. Service Provider manually configures the firewall to assign a port to each ME that resides within the protected network.

# Appendix A: Cardinality

This informative Appendix provides background information regarding the cardinality of different O-RAN architecture elements. It is not intended as a requirement on cardinality.

The RAN network has an expected hierarchical fan out. Therefore, the O-RAN sizing would be:

- Non-RT RIC (1..j)
- Near-RT RIC (1..k)
- CU-CP (1..m)
- CU-UP (1..n)
- O-DU (1..p)
- O-RU (1..q)

Where: 1<=j; j<=k; k<=m; m<=n; m<=p; p<=q

Due to resiliency and scaling aspects of cloud implementations an O-DU will logically be connected to one CU-CP. The CU-CP may in fact be a pool of CU-CP instances to handle loads.

CU-UP MEs will be pooled and aligned with the services they are configured to serve. The CU-CP will assign the CU-UP that an O-DU needs to connect to for a given UE session.

An O-DU may serve many O-RU MEs depending on its designed capacity to manage the loop 1 processing.

One Near-RT RIC will be connected to multiple CU-CP, CU-UP, and O-DU MEs. For resiliency the MEs may be connected to more than one Near-RT RIC, however, it shall not require duplication of data to be sent to each RIC instance.

A Near-RT RIC will be connected to one non-RT RIC.

# Appendix B: Sequence Diagram Template

This section provides a common template for the description of end-to-end use cases.

## B.1 Installing the PlantUML plugin for windows

Follow the installation instructions found at: https://github.com/plantuml/word-template

The plantuml.jar file can be downloaded from: http://sourceforge.net/projects/plantuml/files/plantuml.jar/download

The word "*.dotm" file to use would be in the "Template_Word_16" (https://github.com/plantuml/word-template/tree/master/Template_Word_2016) link.

Once you have the plugin installed you can select "Show PlantUML" which will unhide the text used to generate the diagrams.

## B.2 Plant UML Colors

The following Palette are the named colors recognized by PlantUML. Colors can also be defined by RGB Hexcode (RRGGBB).

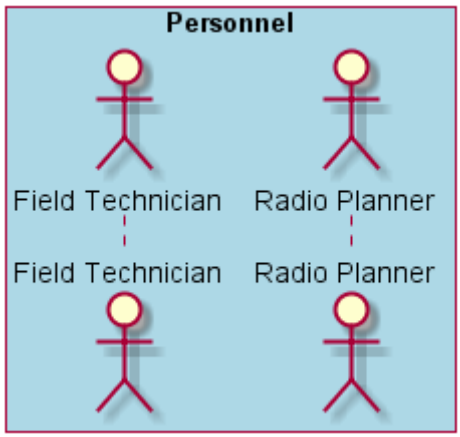
```
@startuml
colors
@enduml
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| APPLICATION | Crimson | DeepPink | Indigo | LightYellow | Navy | RoyalBlue | Turquoise |
| AliceBlue | Cyan | DeepSkyBlue | Ivory | Lime | OldLace | STRATEGY | Violet |
| AntiqueWhite | DarkBlue | DimGray | Khaki | LimeGreen | Olive | SaddleBrown | Wheat |
| Aqua | DarkCyan | DimGrey | Lavender | Linen | OliveDrab | Salmon | White |
| Aquamarine | DarkGoldenRod | DodgerBlue | LavenderBlush | MOTIVATION | Orange | SandyBrown | WhiteSmoke |
| Azure | DarkGray | FireBrick | LawnGreen | Magenta | OrangeRed | SeaGreen | Yellow |
| BUSINESS | DarkGreen | FloralWhite | LemonChiffon | Maroon | Orchid | SeaShell | YellowGreen |
| Beige | DarkGrey | ForestGreen | LightBlue | MediumAquaMarine | PHYSICAL | Sienna | |
| Bisque | DarkKhaki | Fuchsia | LightCoral | MediumBlue | PaleGoldenRod | Silver | |
| Black | DarkMagenta | Gainsboro | LightCyan | MediumOrchid | PaleGreen | SkyBlue | |
| BlanchedAlmond | DarkOliveGreen | GhostWhite | LightGoldenRodYellow | MediumPurple | PaleTurquoise | SlateBlue | |
| Blue | DarkOrchid | Gold | LightGray | MediumSeaGreen | PaleVioletRed | SlateGray | |
| BlueViolet | DarkRed | GoldenRod | LightGreen | MediumSlateBlue | PapayaWhip | SlateGrey | |
| Brown | DarkSalmon | Gray | LightGrey | MediumSpringGreen | PeachPuff | Snow | |
| BurlyWood | DarkSeaGreen | Green | LightPink | MediumTurquoise | Peru | SpringGreen | |
| CadetBlue | DarkSlateBlue | GreenYellow | LightSalmon | MediumVioletRed | Pink | SteelBlue | |
| Chartreuse | DarkSlateGray | Grey | LightSeaGreen | MidnightBlue | Plum | TECHNOLOGY | |
| Chocolate | DarkSlateGrey | HoneyDew | LightSkyBlue | MintCream | PowderBlue | Tan | |
| Coral | DarkTurquoise | HotPink | LightSlateGray | MistyRose | Purple | Teal | |
| CornflowerBlue | DarkViolet | IMPLEMENTATION | LightSlateGrey | Moccasin | Red | Thistle | |
| Cornsilk | Darkorange | IndianRed | LightSteelBlue | NavajoWhite | RosyBrown | Tomato | |

## B.3 Depicting human actors as participants

The participant type Actor should be used. For Clarity these should be the first group and therefore always on the left side of the diagram. The color "#lightblue" has been identified as the background for this group of use case participants.

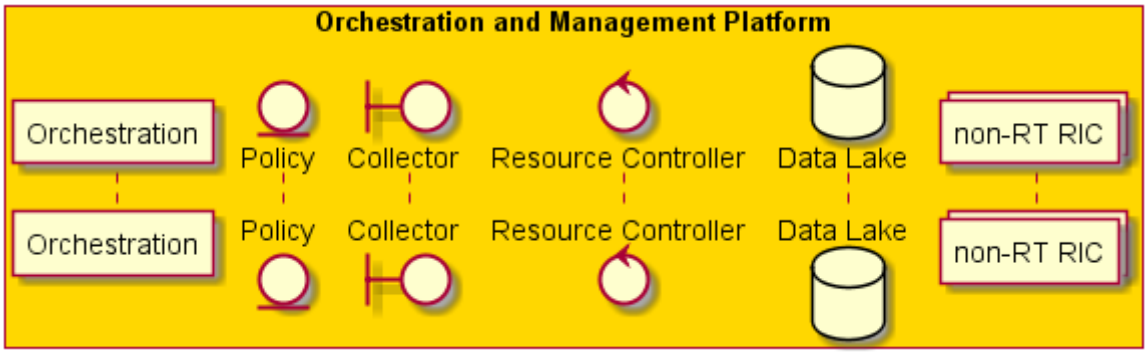
```
@startuml
Box "Personnel" #lightblue
   Actor FT as "Field Technician"
   Actor RP as "Radio Planner"
End box
@enduml
```




## B.4 Depicting Service Management and Orchestration Participants

Service Management and Orchestration participants can vary by type. The following UML shows the standard types for defined participants. Where needed additional participants can be added. For consistency these should be the second group unless the personnel group is not required which would make this the first group. The color "#gold" has been identified as the background for this group of use case participants.

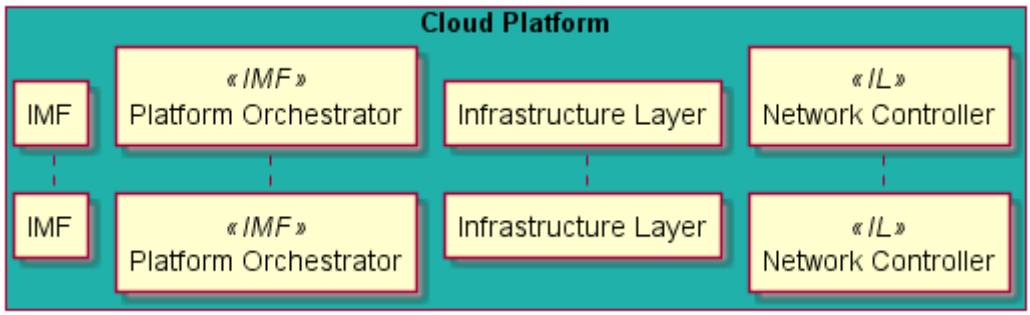
```
@startuml
Box "Orchestration and Management Platform" #gold
   participant SMO as "Orchestration"
   entity Policy
   boundary Collector
   control CTLR as "Resource Controller"
   Database "Data Lake"
   Collections RPGF as "non-RT RIC"
end box

@enduml
```




## B.5 Depicting Cloud Platform Participants

The Cloud platform has two basic components. The Infrastructure Management Function (IMF) and Infrastructure Layer. These components could be further broken down if needed for use case clarity in which case the stereotype of IMF or IL should be applied to the component. The color "#lightseagreen" has been identified as the background for this group of use case participants.

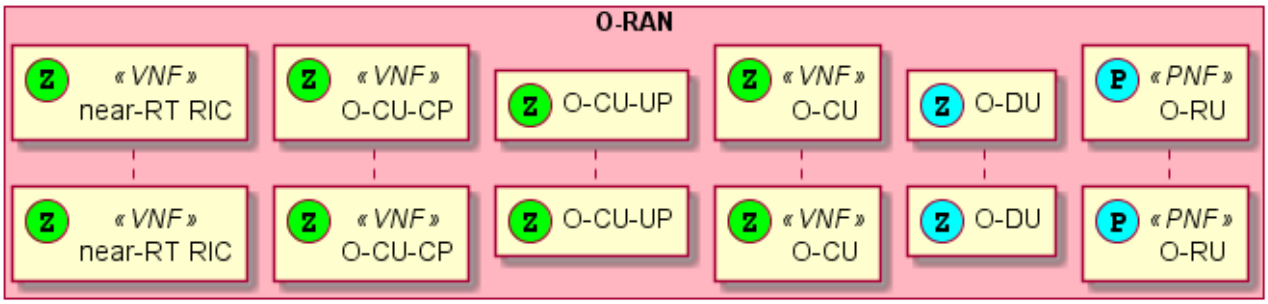
```
@startuml
Box "Cloud Platform" #lightseagreen
   participant IMF
   participant PO as "Platform Orchestrator" <<IMF>>
   Participant IL as "Infrastructure Layer"
   Participant NC as "Network Controller" <<IL>>
End box
@enduml
```




## B.6 O-RAN Managed Elements as participants

The O-RAN architecture defines 5 Managed Functions (MF) which can be deployed independently or aggregated in different ways into a Managed Element (ME). The O-CU is a predefined aggregation of the O-CU-CP and O-CU-UP. The use case is not limited to these but should be able to depict the managed functions embedded. Additionally, there are multiple deployment considerations regarding whether the ME is deployed on proprietary hardware or uses the "zbox" model. MEs on proprietary are likely always a Physical Network Function (PNF) whereas those on a "zbox" can be either a PNF or Virtual Network Function (VNF). he O- platform has two basic components. To depict the hardware model the circled "P" or "Z" should be used in the element stereotype. The color of circle should denote the deployment model of "PNF" or "VNF", which optionally can be included in the stereotype. VNFs use the color "#lime" while PNFs use the "#aqua". The color "#lightpink" has been identified as the background for this group of use case participants.

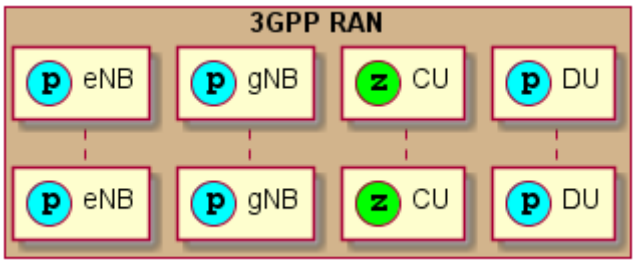
```
@startuml
Box "O-RAN" #lightpink
   Participant RIC as "near-RT RIC" <<(Z,lime) VNF>>
   Participant OCUCP as "O-CU-CP" <<(Z,lime) VNF>>
   Participant OCUUP as "O-CU-UP" <<(Z,lime)>>
   Participant OCU as "O-CU" <<(Z,lime) VNF>>
   Participant ODU as "O-DU" <<(Z,aqua)>>
   Participant ORU as "O-RU" <<(P, aqua) PNF>>
end box
@enduml
```




## B.7 3GPP RAN elements as participants

On occasion some use cases may need to show interaction between O-RAN and 3GPP elements. 3GPP defines both LTE and 5G elements. The gNodeB is also defined with a split defining the Centralized Unit (CU) and the Distributed Unit (DU). These participants are in the 3GPPP RAN box with a background of "#Tan". Like the O-RAN Physical, Virtual, Proprietary, and zBox are identified in the stereotype.

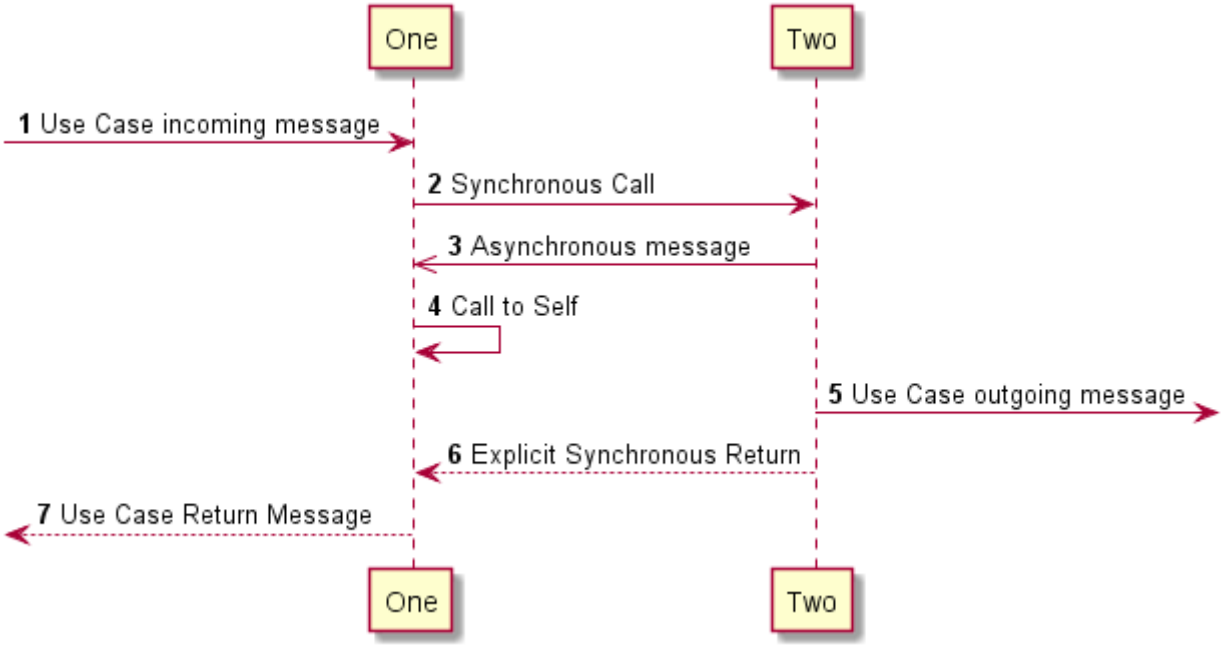
```
@startuml
Box "3GPP RAN" #Tan
   Participant eNB <<(p,aqua)>>
   Participant gNB <<(p,aqua)>>
   Participant CU <<(z,lime)>>
   Participant DU <<(p,aqua)>>
Endbox
@enduml
```




## B.8 Messaging

Autonumber should be used so that individual messages in a diagram can be easily referenced in conversation. Synchronous calls have an implicit return or the return can be implicitly depicted, often after a long block so as to provide clarity of where processing continues. Some use cases can be used with a start message and end with either a message or response. This is helpful when a common block can be used multiple times.

```
@startuml
Autonumber
Participant One
Participant Two
[-> One : Use Case incoming message
One -> Two: Synchronous Call
Two ->> One : Asynchronous message
One -> One : Call to Self
Two ->] : Use Case outgoing message
Two --> One : Explicit Synchronous Return
 [<-- One : Use Case Return Message
@enduml
```

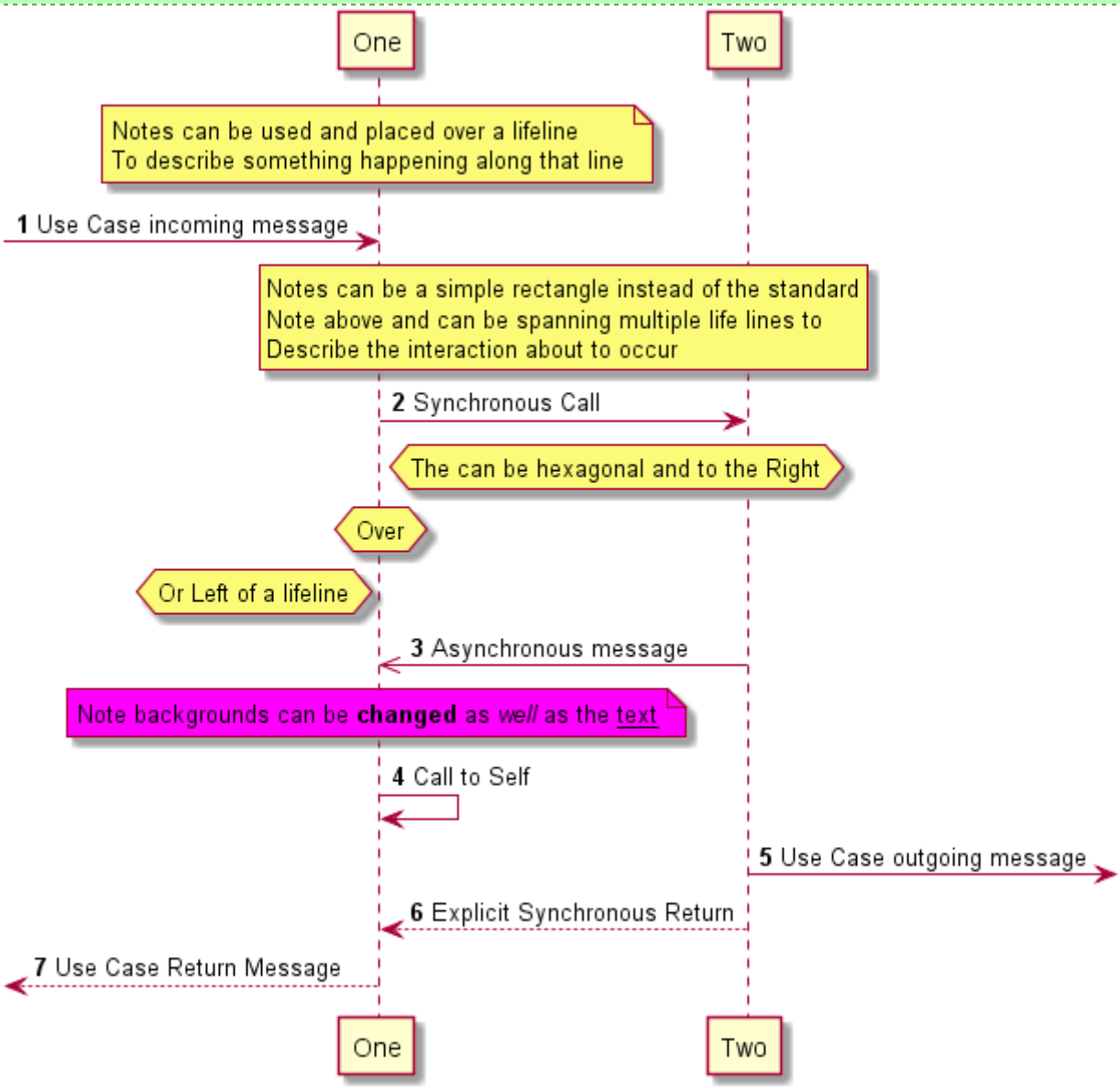



## B.9 Adding Comments

Comments can be added to the diagram. This is sometimes better than trying to describe the comment in text or for the picture to be able to standalone.

```
@startuml
Autonumber
Participant One
Participant Two
Note over One
Notes can be used and placed over a lifeline
To describe something happening along that line
End note
```

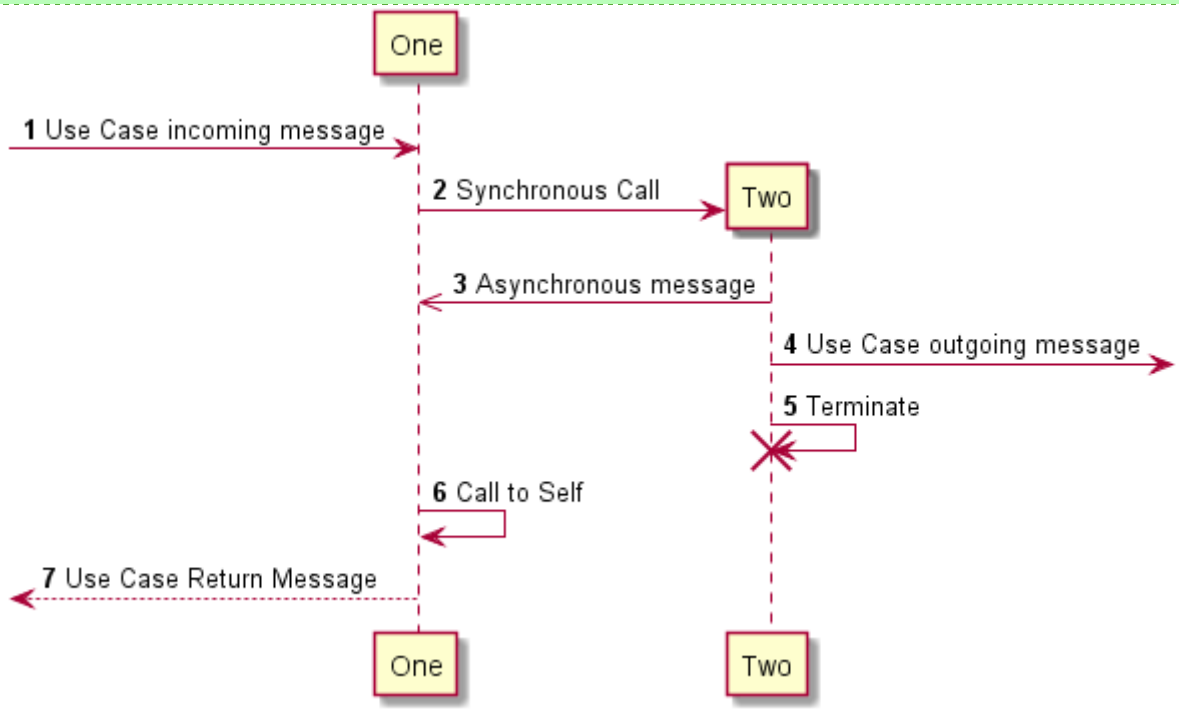
```
[-> One : Use Case incoming message
Rnote over One, Two
Notes can be a simple rectangle instead of the standard
Note above and can be spanning multiple life lines to
Describe the interaction about to occur
endrnote
One -> Two: Synchronous Call
Hnote right One
The can be hexagonal and to the Right
Endhnote
Hnote over One
Over
endhnote
Hnote left One
Or Left of a lifeline
endhnote
Two ->> One : Asynchronous message
Note over One #fuchsia
Note backgrounds can be **changed** as //well// as the __text__
End note
One -> One : Call to Self
Two ->] : Use Case outgoing message
Two --> One : Explicit Synchronous Return
 [<-- One : Use Case Return Message
@enduml
```



## B.10 Participant Creation/Deletion

Sometimes clarity is depicted by showing when a participant is created or first comes into being and likewise when it is destroyed. This is very helpful in understanding timing and existence of a participant. This happens with modifiers to the message.

```
@startuml
Autonumber
Participant One
Participant Two
[-> One : Use Case incoming message
One -> Two **: Synchronous Call
Two ->> One : Asynchronous message
Two ->] : Use Case outgoing message
Two -> Two !! : Terminate
One -> One : Call to Self
 [<-- One : Use Case Return Message
@enduml
```

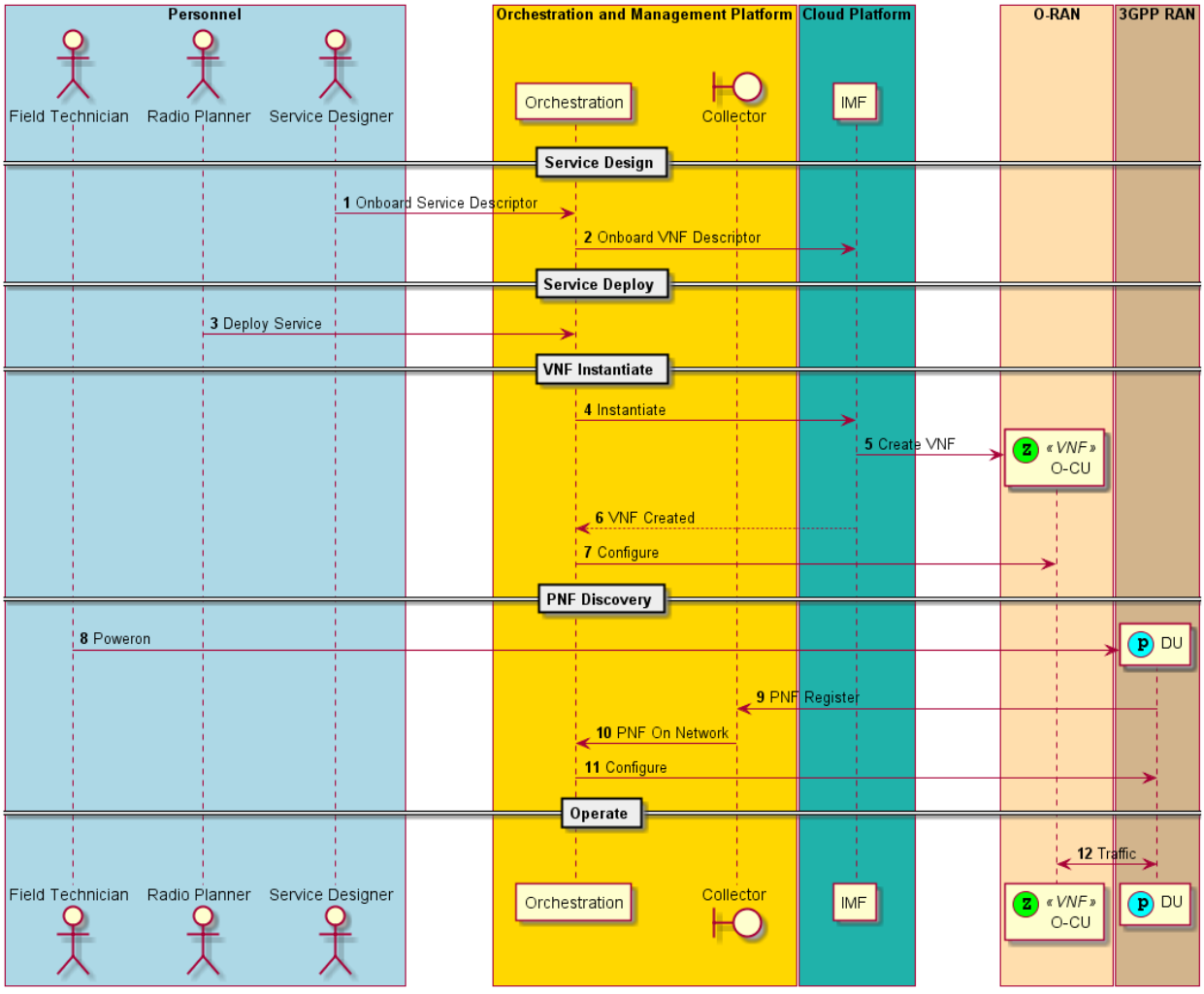



## B.11 Dividers

In some cases, it is helpful to provide divisions of separate activities of the use case. This can be to define pre-requisite activity such as configuration or subscriptions to an event. It can also be used to depict stages of a lifecycle.

```
@startuml
Autonumber
Box "Personnel" #lightblue
  Actor FT as "Field Technician"
  Actor RP as "Radio Planner"
  Actor SD as "Service Designer"
End box

Box "Orchestration and Management Platform" #gold
  participant SMO as "Orchestration"
  boundary Collector
end box

Box "Cloud Platform" #lightseagreen
   participant IMF
End box
```

```
Box "O-RAN" #NavajoWhite
   Participant OCU as "O-CU" <<(Z,lime) VNF>>
end box

Box "3GPP RAN" #Tan
   Participant DU <<(p,aqua)>>
Endbox

== Service Design ==
SD -> SMO : Onboard Service Descriptor
SMO -> IMF : Onboard VNF Descriptor
== Service Deploy ==
RP -> SMO : Deploy Service

== VNF Instantiate ==
SMO -> IMF : Instantiate
IMF -> OCU ** : Create VNF
IMF --> SMO : VNF Created
SMO -> OCU : Configure
== PNF Discovery ==
FT -> DU **: Poweron
DU -> Collector : PNF Register
Collector -> SMO : PNF On Network
SMO -> DU : Configure
== Operate ==
DU <-> OCU : Traffic
@enduml
```




## B.12 Grouping and References

Grouping can be used for many different aspects. In UML there are many types of groups. PlantUML support the basic three. Any of the group types can be nested. “Alt” for conditional processing which can show different path processing rather than just a sunny day scenario. It can also be used to show any logical, as the condition is stated in the swim lane, processing. Sometimes the message and the grouping boundary are close and need some separation. Use the “|||” to create that space.

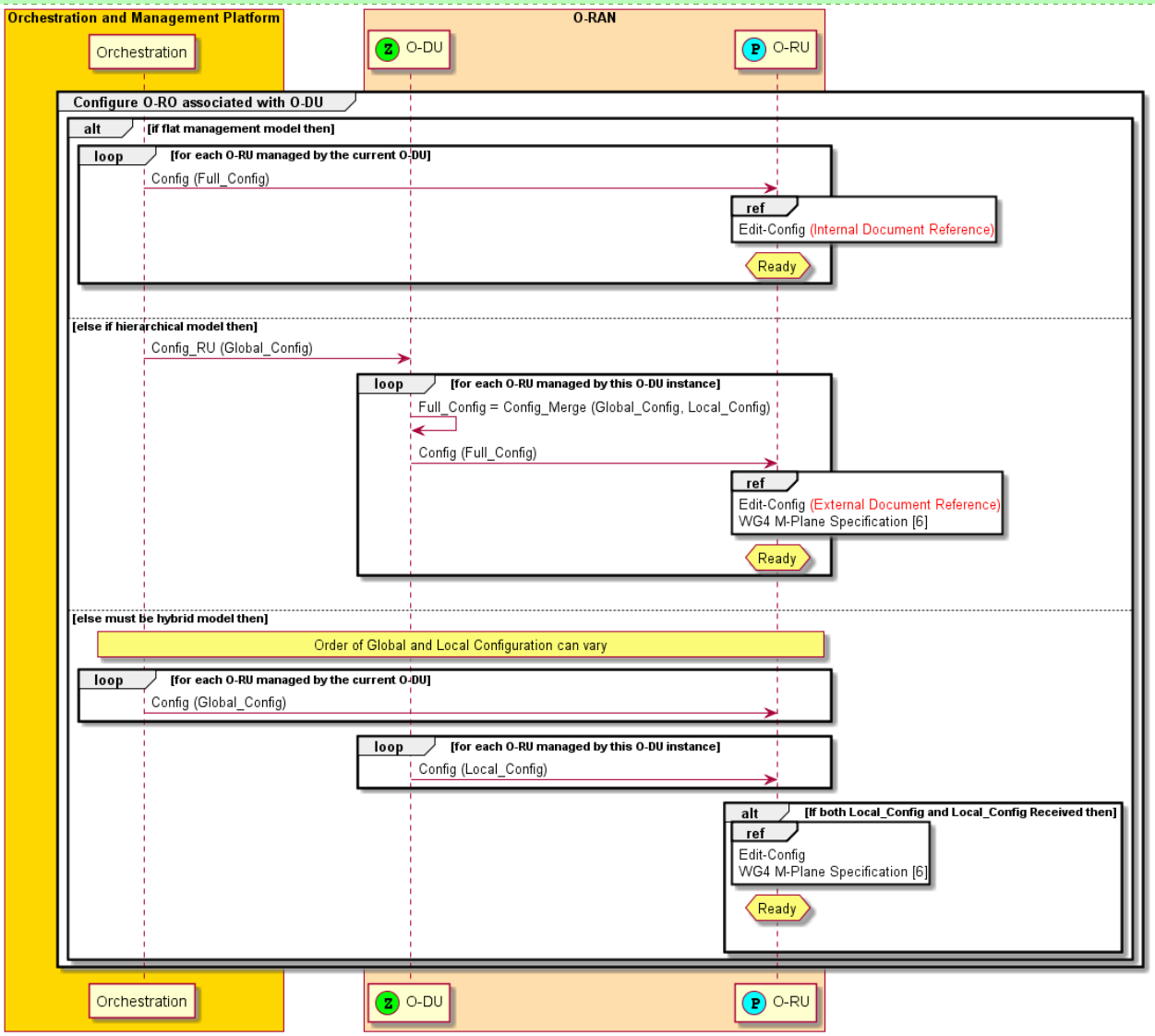
The “loop” group is used to show iterations or conditional loops. The loop condition is stated on the lines and contain the statements within the loop.

The last kind of group is the fragment. This is a logic group of a sequence of events that go together. The tag line at the top describes the group.

Although references look like groups they cannot be nested. Use the single line version for references to use cases in the current document. The Multi-Line version should be used for reference to use cases in an external document.

```
@startuml
Box “Orchestration and Management Platform” #gold
   participant SMO as “Orchestration”
end box

Box “O-RAN” #NavajoWhite
   Participant ODU as “O-DU” <<(Z,lime)>>
   Participant ORU as “O-RU” <<(P, aqua)>>
end box

Group Configure O-RU associated with O-DU
Alt if flat management model then
  Loop for each O-RU managed by the current O-DU
   SMO -> ORU : Config (Full_Config)
   ref over ORU : Edit-Config <color red>(Internal Document Reference)</color>
   Hnote over ORU
      Ready
   Endhnote
  End
|||
Else else if hierarchical model then
   SMO -> ODU : Config_RU (Global_Config)
  Loop for each O-RU managed by this O-DU instance
   ODU -> ODU : Full_Config = Config_Merge (Global_Config, Local_Config)
   ODU -> ORU : Config (Full_Config)
   ref over ORU
     Edit-Config <color red>(External Document Reference)</color>
     WG4 M-Plane Specification [6]
   End ref
   Hnote over ORU
      Ready
   endhnote
  end
|||
Else else must be hybrid model then
   Rnote over SMO, ORU
      Order of Global and Local Configuration can vary
   Endrnote
  Loop for each O-RU managed by the current O-DU
   SMO -> ORU : Config (Global_Config)
  end
  Loop for each O-RU managed by this O-DU instance
   ODU -> ORU : Config (Local_Config)
  end
   Alt If both Local_Config and Local_Config Received then
   ref over ORU
     Edit-Config
     WG4 M-Plane Specification [6]
   End ref
   Hnote over ORU
      Ready
   endhnote
|||
```

```
    End
End
end
@enduml
```



# Annex ZZZ : O-RAN Adopter License Agreement

BY DOWNLOADING, USING OR OTHERWISE ACCESSING ANY O-RAN SPECIFICATION, ADOPTER AGREES TO THE TERMS OF THIS AGREEMENT.

This O-RAN Adopter License Agreement (the "Agreement") is made by and between the O-RAN Alliance and the entity that downloads, uses or otherwise accesses any O-RAN Specification, including its Affiliates (the "Adopter").

This is a license agreement for entities who wish to adopt any O-RAN Specification.

## 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 Implementation" means any system, device, method or operation (whether implemented in hardware, software or combinations thereof) that fully conforms to a Final 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 a Compliant Implementation (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 a Compliant Implementation 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 patent license under their Necessary Claims to make, have made, use, import, offer to sell, lease, sell and otherwise distribute Compliant Implementations; provided, however, that such license shall not extend: (a) to any part or function of a product in which a Compliant Implementation is incorporated that is not itself part of the Compliant Implementation; 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 licensing commitment includes the distribution by the Adopter's distributors and the use by the Adopter's customers of such licensed Compliant Implementations.

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 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 patent license under their Necessary Claims to make, have made, use, import, offer to sell, lease, sell and otherwise distribute Compliant Implementations; provided, however, that such license will not extend: (a) to any part or function of a product in which a Compliant Implementation is incorporated that is not itself part of the Compliant Implementation; 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 licensing commitment 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 Implementations.

# 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.