O-RAN系统架构及模块接口介绍

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什么是O-RAN

这里的O，是open，开放的意思。O-RAN就是开放无线接入网。

开放的含义：

- 接入网的非实时性应用软件与专用硬件分离，如网管，CU，脱离专用硬件，在通用的X86的Linux服务器上运行。
- 接入网的实时性要求高的软件与硬件依然强绑定，如DU或AAU，但需要提供可定制化的配置接口，便于第三方软件或设备可以配置专用软硬件设备的功能。
- 让更多的第三方软件和硬件厂家参与进来，大家遵循统一的接口标准，让无线接入网中的不同软件实体，能够实现互联互通，打破单一设备厂家的垄断。

ORAN是在5G 3GPP已有的各个网元接口协议基础之上进行了扩展，以支持新的开放性的要求，ORAN协议包括两部分：

（1）4G/5G的3GPP协议；

（2）ORAN为 开放性和自能性目标新增加的协议和规范。

ORAN开放的动机

动机之一：ORAN首先由中国移动等运营商提出来的，最初是想通过把RAN系统中非实时的应用软件从专用硬件上剥离开来，降低整个RAN系统设备一次性投入的成本。

动机之二：通过非实时软件的“云化”, 降低整个RAN系统的运营成本。

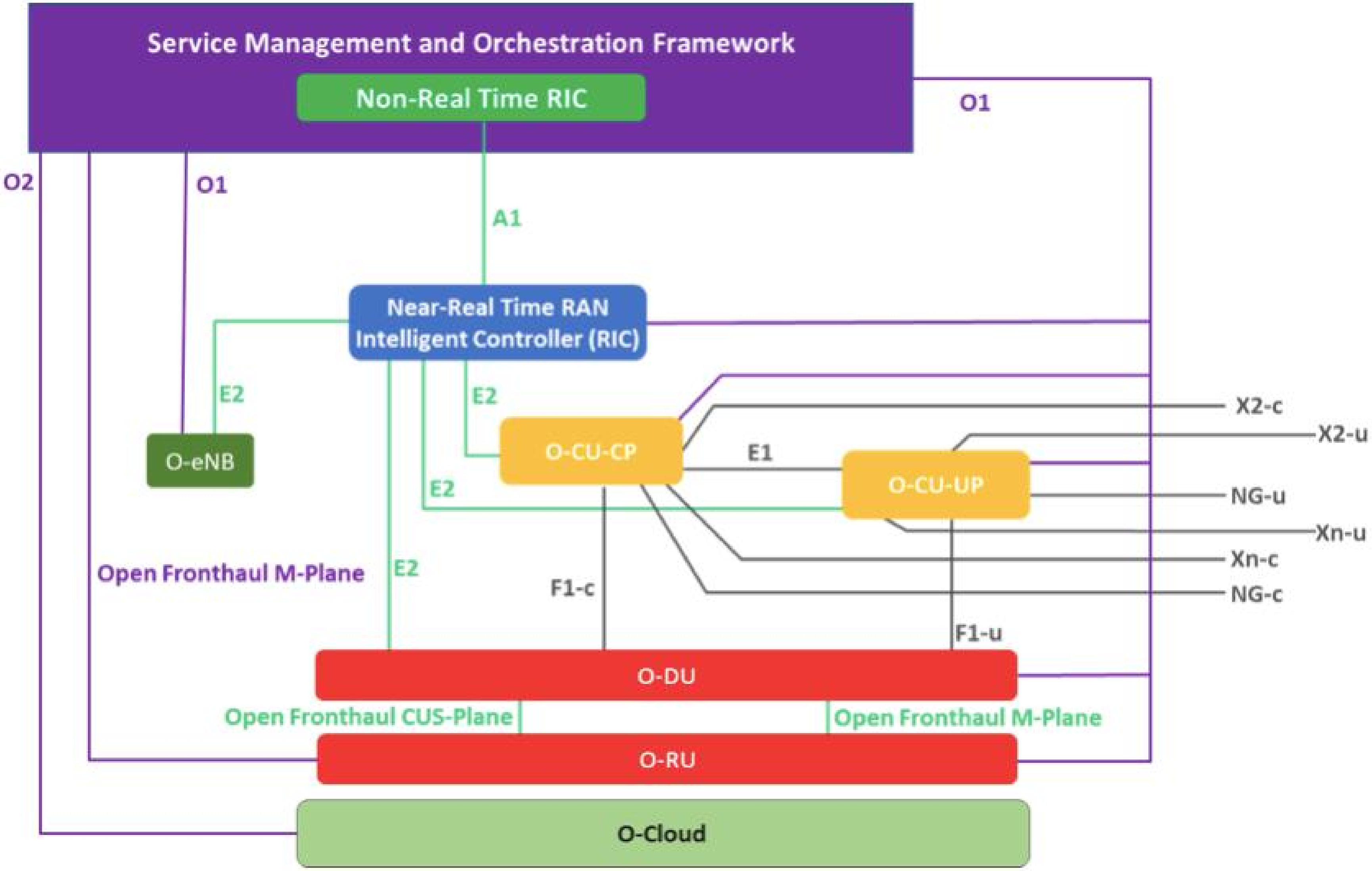
动机之三：通过实现RAN系统中各个网元的网络功能虚拟化NFV，非常方便的重构已有的网络部署。

动机之四：应用软件与专用设备分离、剥离后，运营商可以引入更多的第三方软硬件的开发商，打破设备商的垄断。

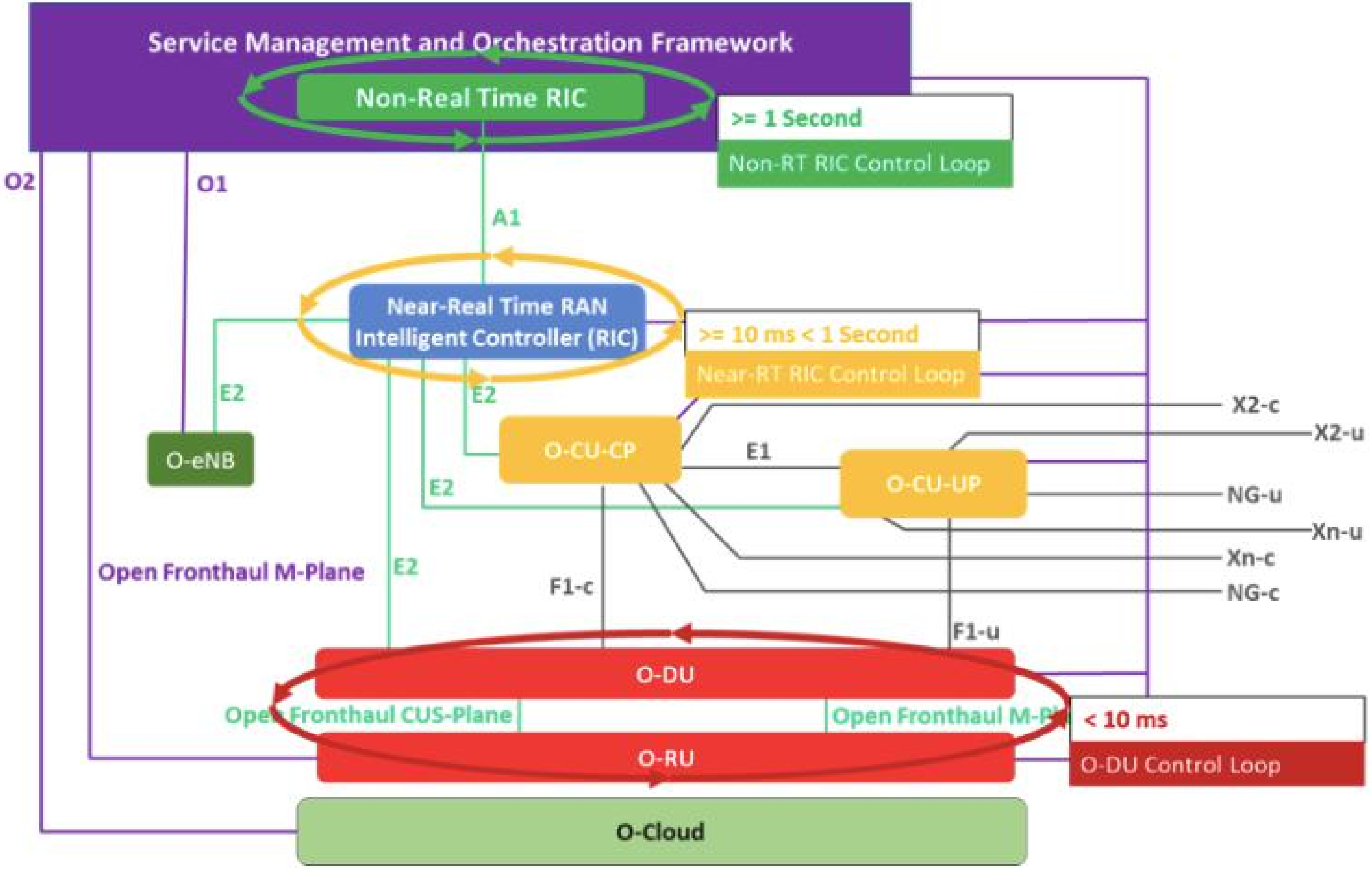
ORAN协议概述

- 引领行业走向开放、可互操作的接口、RAN虚拟化、大数据和支持人工智能。
- 最大限度地使用通用的、现成的硬件和软件平台，最大限度地减少专有硬件。
- 指定开放的API和接口，推动标准化组织酌情采纳它们，并在适当的地方探索开源。

O-RAN Logical Architecture



O-RAN Control Loops



Service Management and Orchestration (SMO)

The SMO is a consolidation of a wide variety of management services and provides many network management like functionalities. The key capabilities of the SMO that provide RAN support in O-RAN are:

- FCAPS interface to O-RAN Network Functions(O1)---OAM
- Non-RT RIC for RAN optimization(A1)
- O-Cloud Management, Orchestration and Workflow Management(O2)

FCAPS: Fault, Configuration, Accounting, Performance, Security

RIC: RAN Intelligent Controller

FCAPS to O-RAN Network Functions

- Performance Management (PM)   ---- performance and measurement data report
- Configuration Management (CM)
- Fault Management (FM) ---- alarm
- File Management ---- file transfer
- Communications Surveillance (Heartbeat) --- survive
- Trace   ---- trace data(cell,call,ue etc.) report
- Physical Network Function (PNF) Discovery   --- startup and registration
- PNF Software Manage   ---- software update

O-Cloud Management

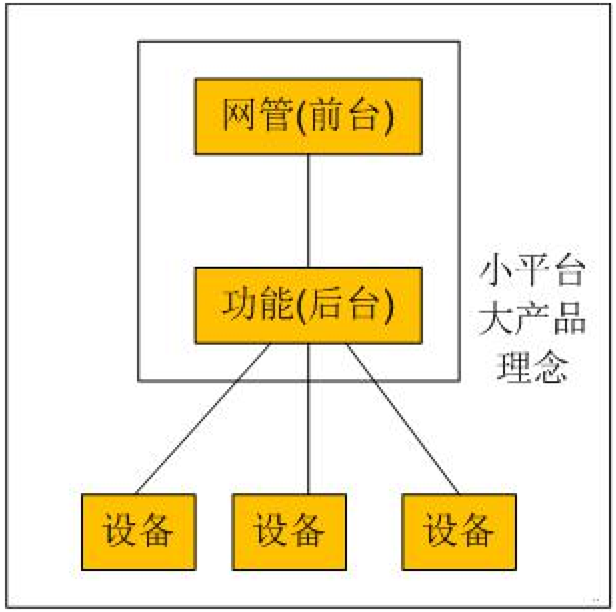
- Discovery and administration of O-Cloud Resources
- Scale-In, Scale-Out for O-Cloud
- FCAPS (PM, CM, FM, Communication Surveillance) of O-Cloud
- Software Management of Cloud Platform
- Create, Delete Deployments and Associated Allocated O-Cloud Resources

SMO与现有网管系统的区别

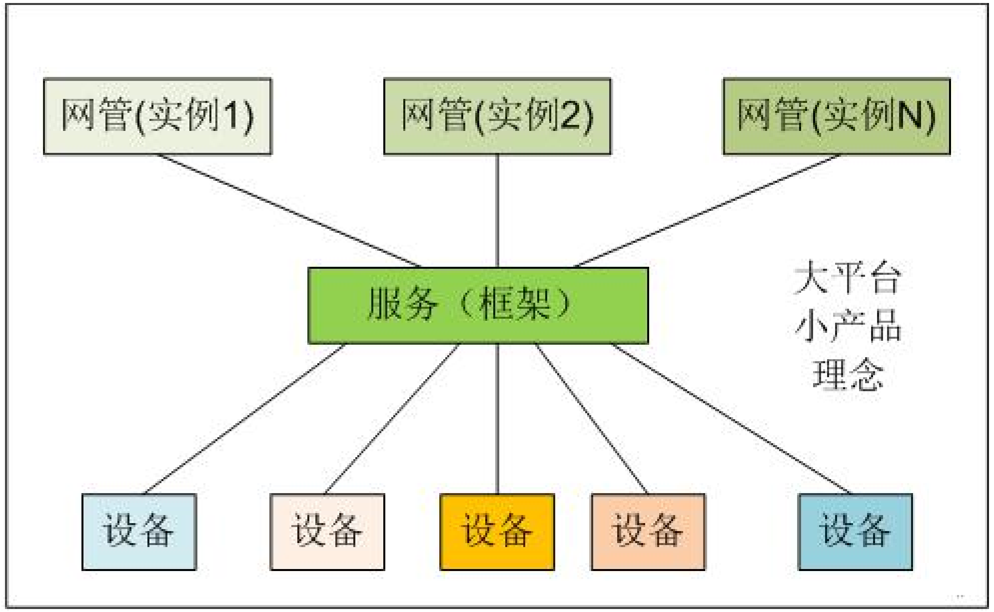
服务化：SMO提供的是对设备运营管理的各种服务，而不是综合化后的实际网管。实际的、具体的、网络运营管理功能，由下图中的网管实例1,2,N来实施的。

开放化：SMO服务框架是一个开放的运营管理平台，可以集成符合O-RAN规范的任何厂家的5G产品，可以应用符合O-RAN规范的任何厂家的5G网络运营管理软件。为5G进入定制化、垂直的工业领域提供了技术保障。

智能化：利用人工智能、虚拟化、云计算、大数据分析、边缘计算等技术，实现对网络设备和网络功能的快速重构、智能运营与管理。



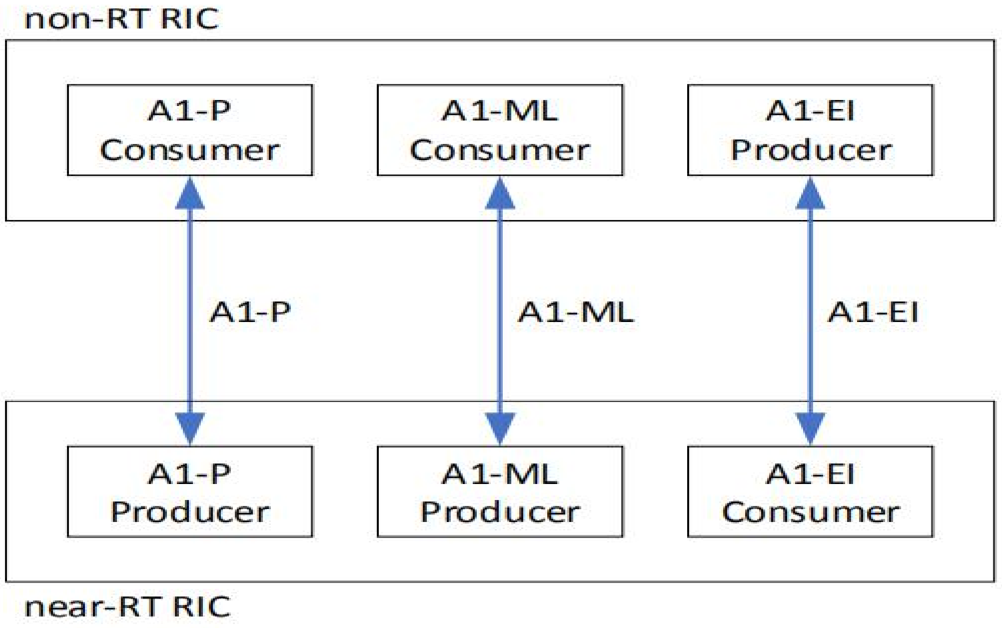
传统的单一厂家的专有网管



基于服务的、开放的网管框架

Non-RT RIC

The primary goal of Non-RT RIC is to support intelligent RAN optimization by providing policy-based guidance, ML （machine learning） model management and enrichment information to the near-RT RIC function.



Near-RT RIC

The Near-RT RIC hosts one or more xApps that use E2 interface to collect near real-time information and provide value added services. The Near-RT RIC control over the E2 nodes is steered via the policies and the enrichment data provided via A1 from the Non-RT RIC.

O-Cloud

O-Cloud是一个云计算平台，底层是由满足O-RAN要求的物理基础设施节点（如通用的计算机或专用硬件平台）和云平台软件、O-RAN相关的管理和编排功能三部分组成。

O-RAN一个重要的目标，就是尽可能的把现有RAN的功能从专有的硬件和专有的嵌入式操作系统平台上剥离，迁移到通用的硬件、通用操作系统、通用的云平台上，并尝试开放软件接口，甚至软件开源。

01接口

Requirements

Transport Layer Security (TLS)

Management Service providers and consumers that use TLS SHALL support TLS v1.2 or higher.

HyperText Transfer Protocol (HTTP)

Management Service providers and consumers that use HTTP SHALL support HTTP v1.1 or higher.

Network Configuration Protocol

NETCONF协议提供一套管理网络设备的机制，用户可以使用这套机制增加、修改、删除网络设备的配置，获取网络设备的配置和状态信息。

通过NETCONF协议，网络设备可以提供一组完备规范的API(Application Programming Interface)；应用程序可以直接使用这些API，向网络设备下发和获取配置。

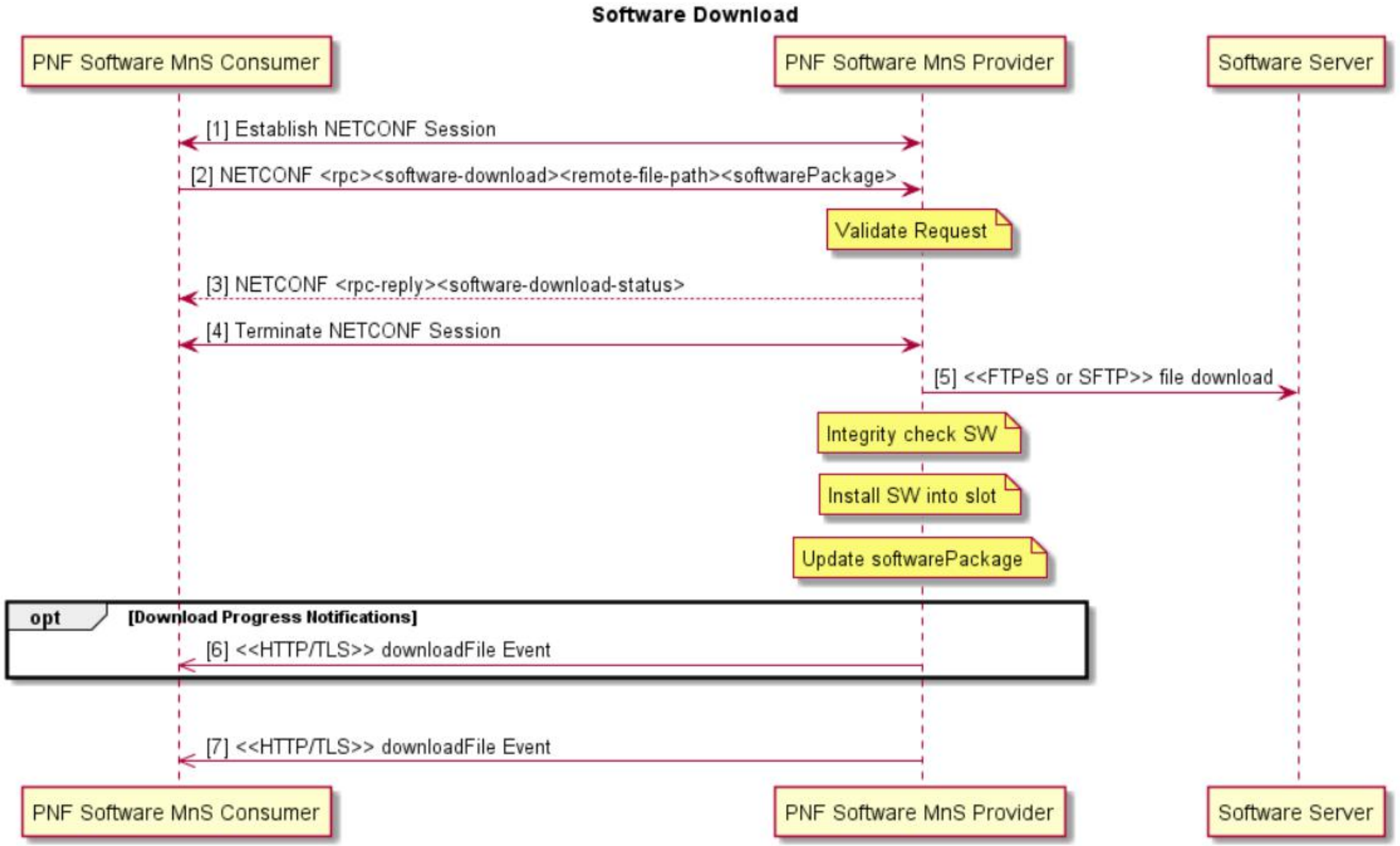
- get
- get-config
- edit-config
- lock
- unlock
- close-session
- kill-session

- writable-running
- rollback-on-error
- validate
- xpath

3GPP Event

3GPP IS Notification	TS 28.532 section Reference
notifyNewAlarm	3GPP TS 28.532, Section 12.2.2.2.2
notifyNewSecurityAlarm	3GPP TS 28.532, Section 12.2.2.2.3
notifyAckStateChanged	3GPP TS 28.532, Section 12.2.2.2.4
notifyClearedAlarm	3GPP TS 28.532, Section 12.2.2.2.5
notifyAlarmListRebuilt	3GPP TS 28.532, Section 12.2.2.2.6
notifyChangedAlarm	3GPP TS 28.532, Section 12.2.2.2.7
notifyComments	3GPP TS 28.532, Section 12.2.2.2.8
notifyPotentialFaultyAlarmList	3GPP TS 28.532, Section 12.2.2.2.9
notifyCorrelatedNotificationChanged	3GPP TS 28.532, Section 12.2.2.2.10
notifyChangedAlarmGeneral	3GPP TS 28.532, Section 12.2.2.2.11

A example


Software Download
PNF Software MnS Consumer
PNF Software MnS Provider
Software Server
[1] Establish NETCONF Session
[2] NETCONF <rpc><software-download><remote-file-path><softwarePackage>
Validate Request
[3] NETCONF <rpc-reply><software-download-status>
[4] Terminate NETCONF Session
[5] <<FTPeS or SFTP>> file download
Integrity check SW
Install SW into slot
Update softwarePackage
opt
[Download Progress Notifications]
[6] <<HTTP/TLS>> downloadFile Event
[7] <<HTTP/TLS>> downloadFile Event
PNF Software MnS Consumer
PNF Software MnS Provider
Software Server

A1接口

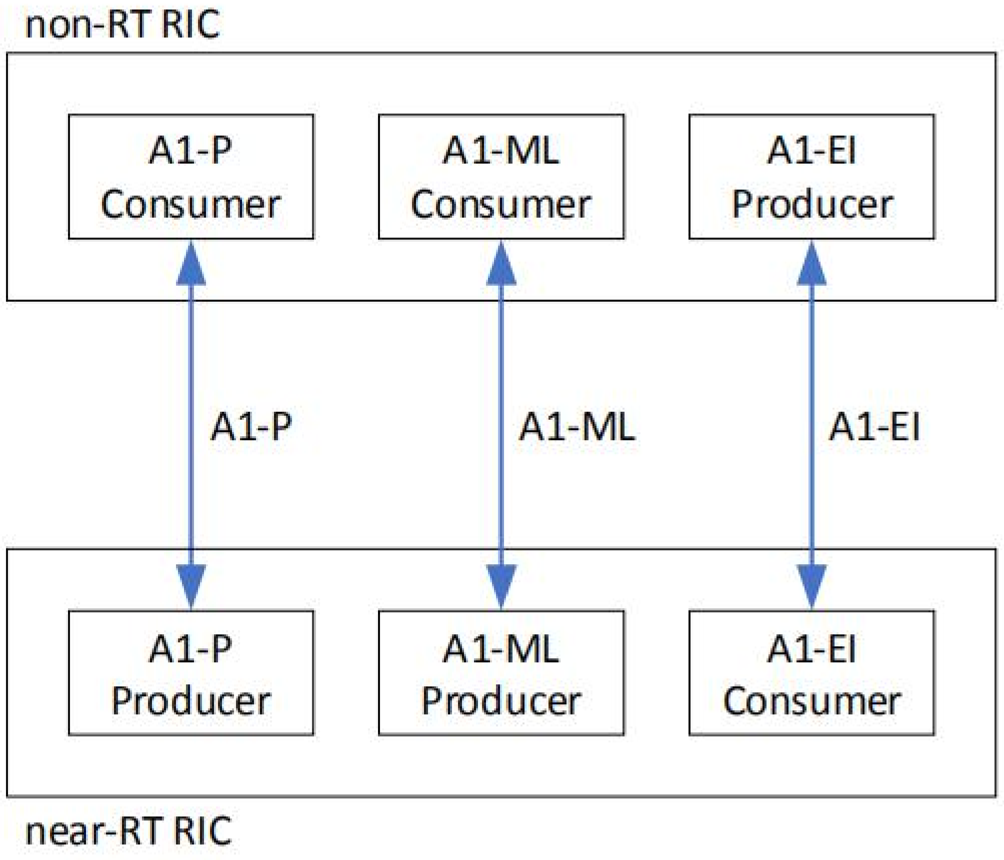
Introduction

The A1AP contains APIs for the services defined in :

A1-P – Policy Management Service

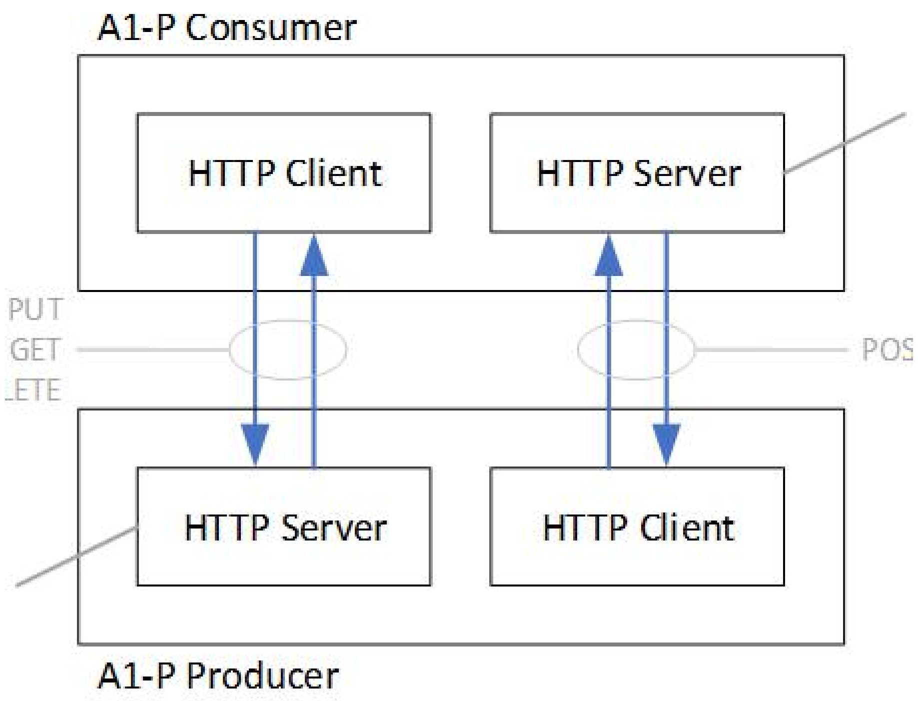
A1-ML – ML Model Management Service

A1-EI – Enrichment Information Service



Policy Management Service

The A1AP is based on signaling between the A1-P Consumer residing in the non-RT RIC and the A1-P Producer residing in the near-RT RIC. Both the A1-P Consumer and the A1-P Producer contains a HTTP Client and a HTTP Server.



Service Operations

The main URI for A1 policies is:

…/policies

A single policy can be operated upon by adding the value of the policy identifier to the URI:

…/policies/{policyId}

The main URI for status of a single policy is:

…/policies/{policyId}/status

A1 policy procedure	HTTP method
Create policy	PUT
Query policy	GET
Update policy	PUT
Delete policy	DELETE
Notify policy	POST

procedure

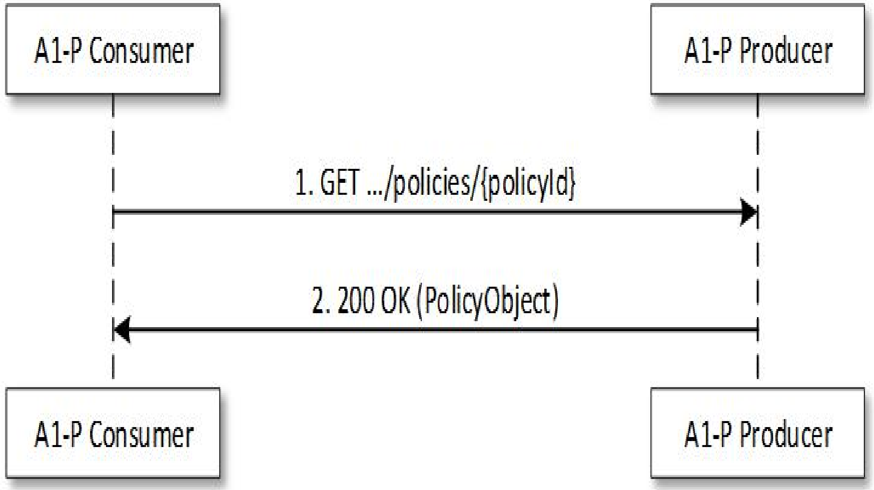
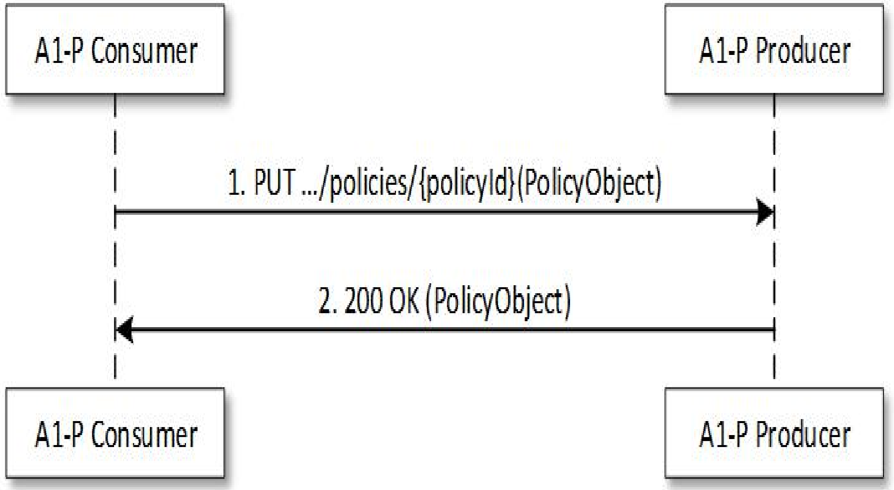
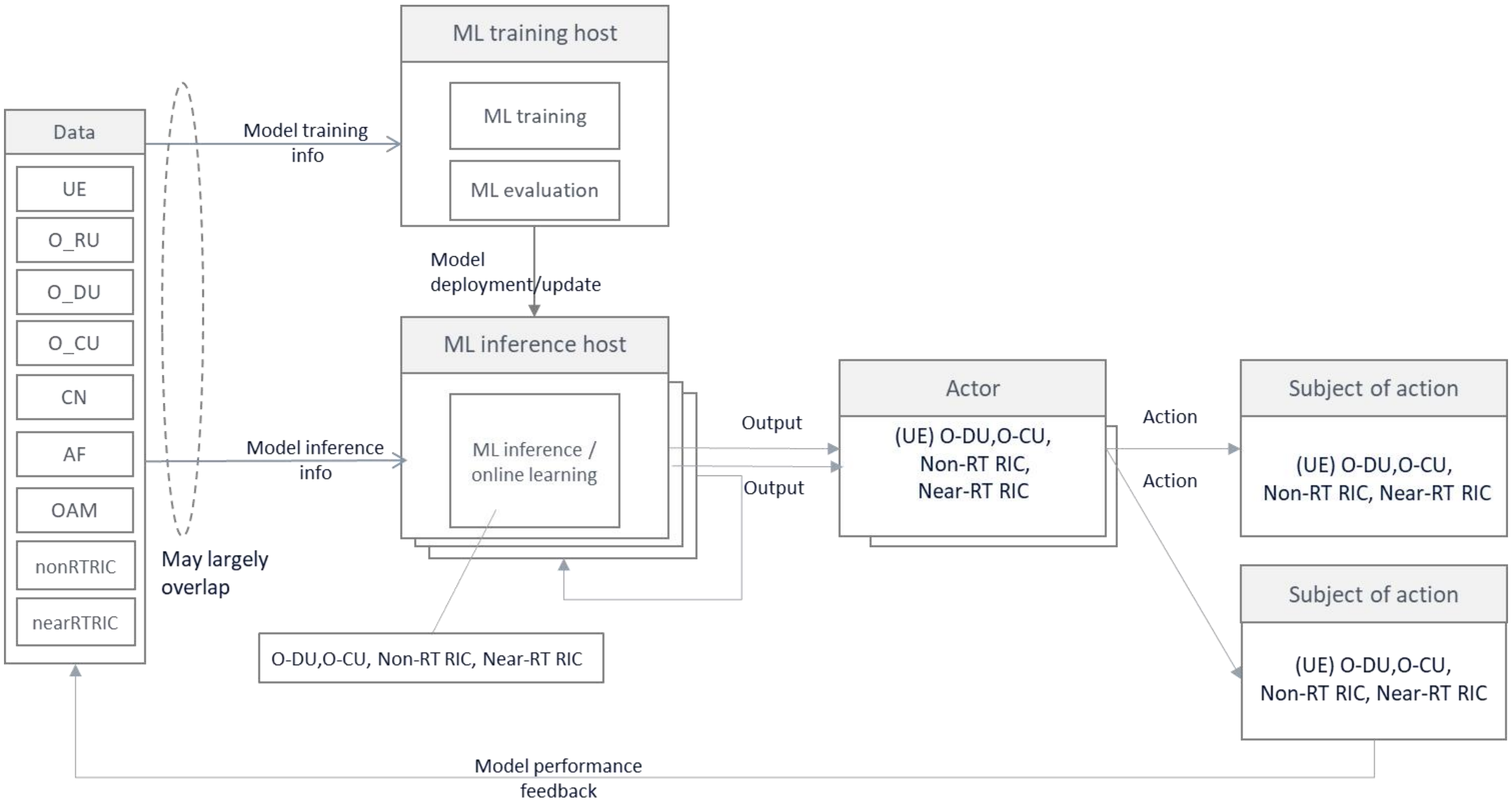


Figure 3.2.2.3-1 Query single policy procedure.

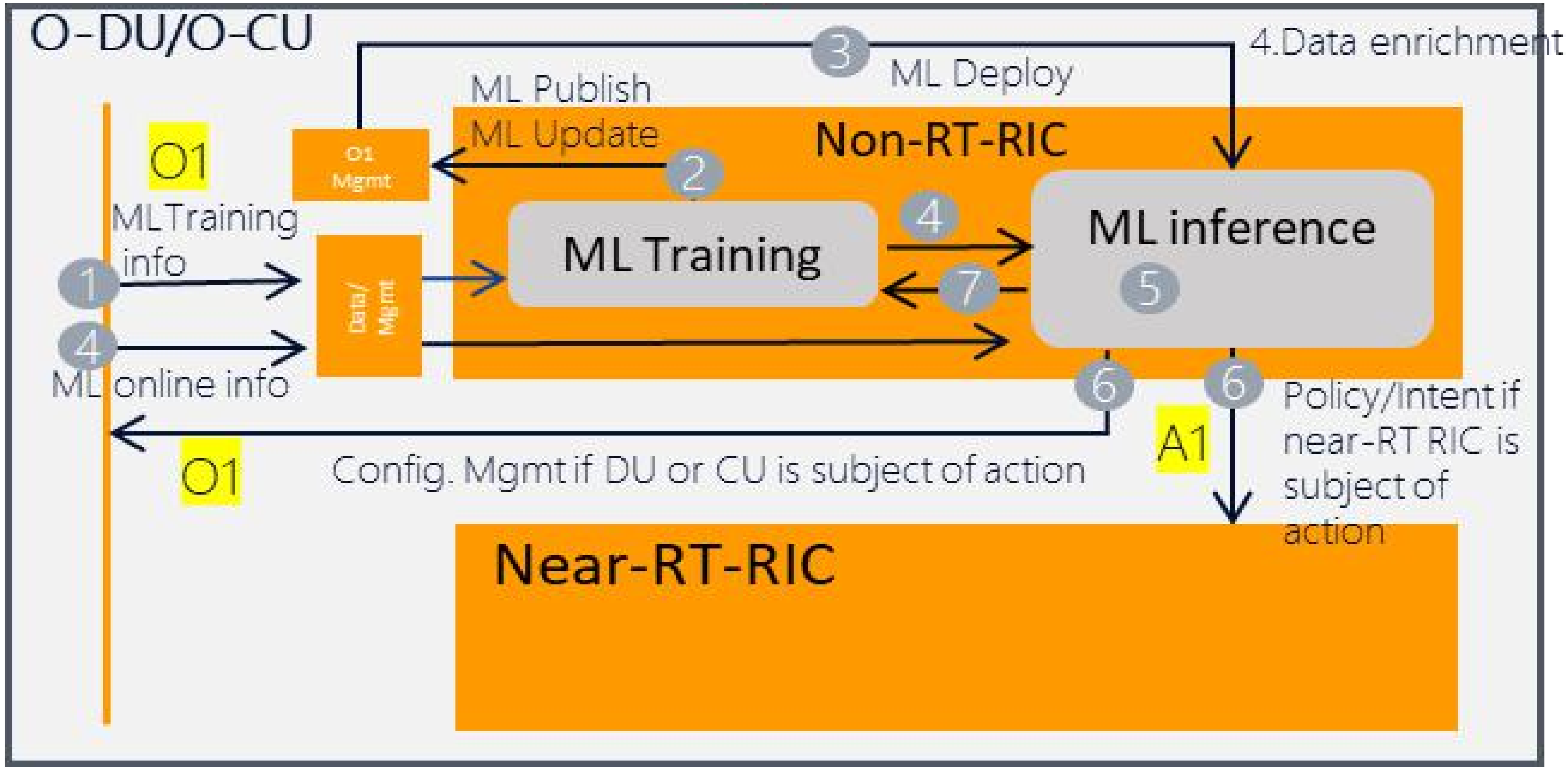


A1-ML modeling terminology



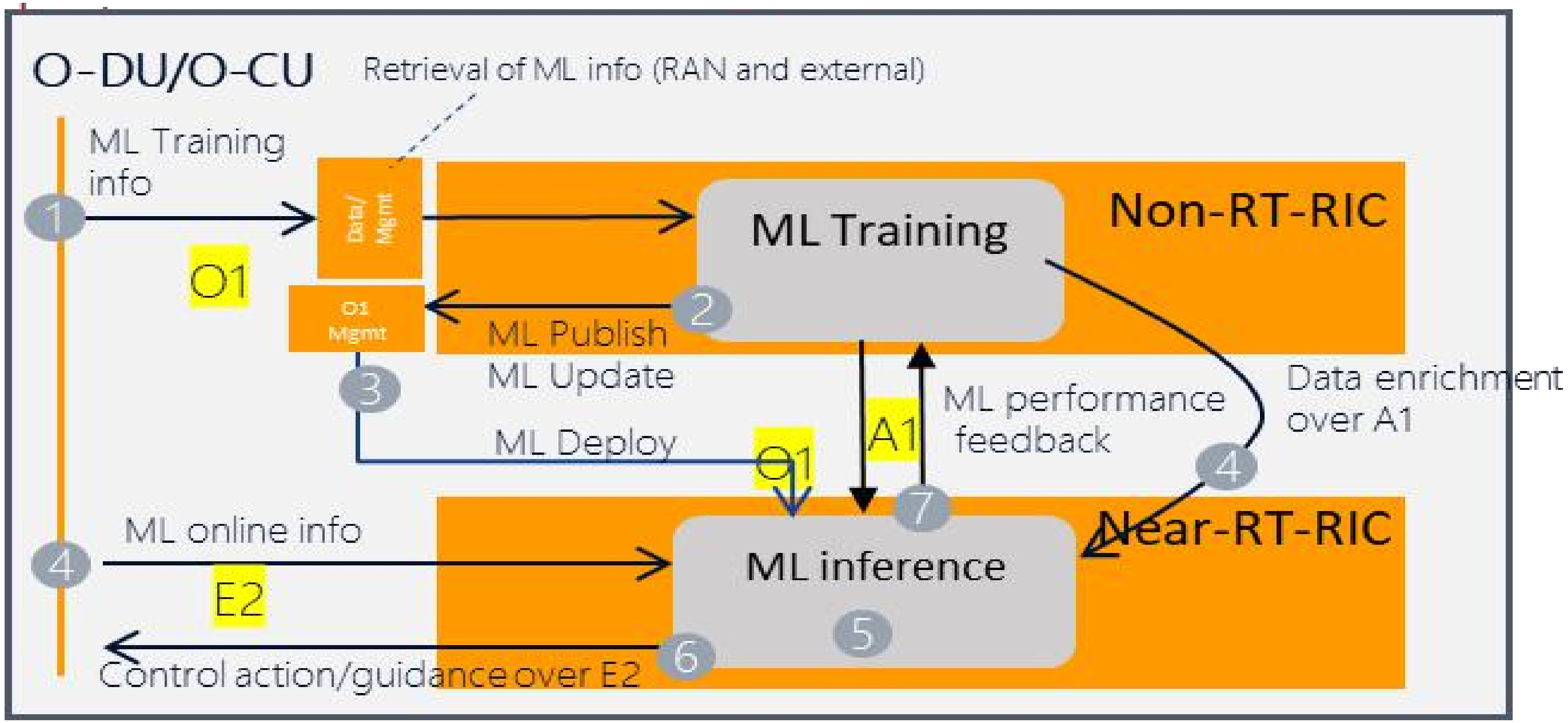
Deployment scenario 1.1 - ML training and inference host locations

Case 1.1: non-RT RIC as ML training host and ML inference host



Deployment scenario 1.2 - ML training and inference host locations

Case 1.2: non-RT RIC as ML training host, near-RT RIC as ML inference



Near-RT RIC

Near-RT RIC Internal Architecture

A1 termination, which terminates the A1 interface from the non-RT RIC

E2 termination, which terminates the E2 interface from an E2 Node

O1 termination, which terminates the O1 interface from SMO

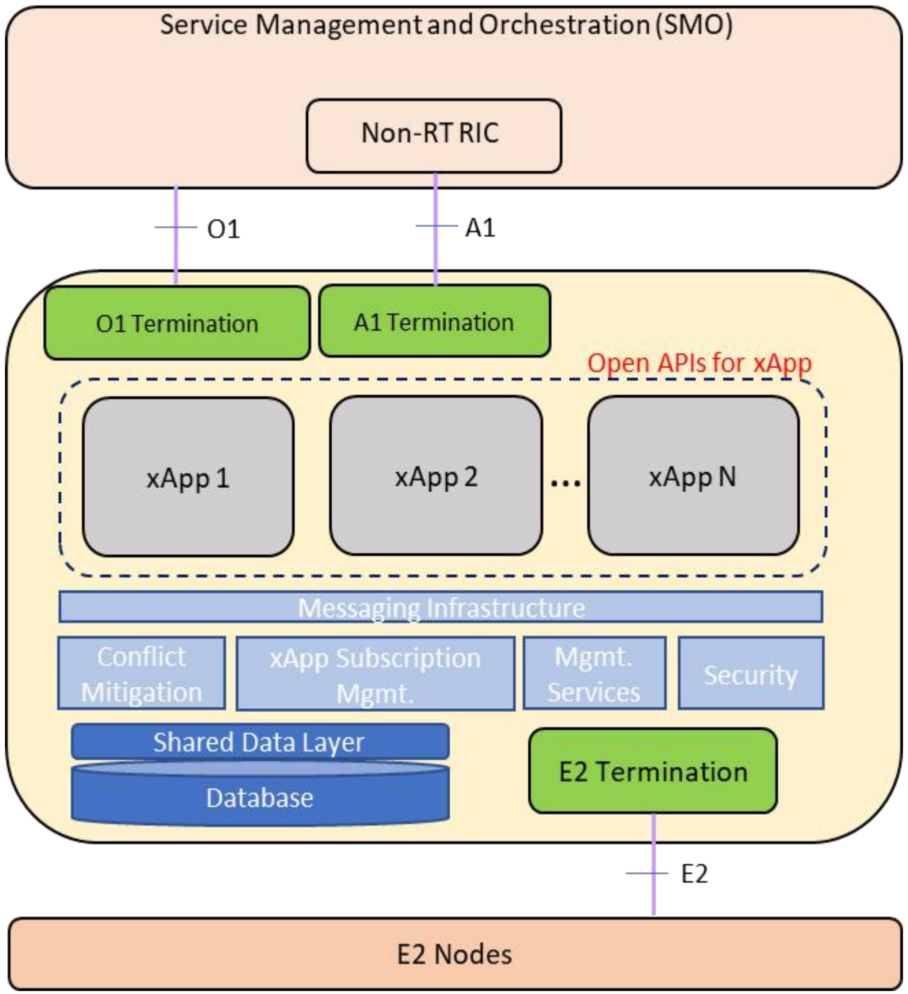
Messaging infrastructure, which enables message interaction amongst Near-RT RIC internal functions

Conflict mitigation, which resolves potentially overlapping or conflicting requests from multiple xApps

Management services

- Fault management, configuration management, and performance management
- Life-cycle management of xApps;

Database, which allows reading and writing of RAN/UE information



xApps

xApps consist of xApp descriptor and xApp image. xApp descriptor describes the packaging format of xApp image. xApp image is the software package.

The definition of xApp descriptor includes:

-The basic information of xApp, including name, version, provider, URL of xApp image, virtual resource requirements (e.g. CPU), etc. This information is used to support LCM of xApps.

-The FCAPS management specifications that specify the options of configuration, performance metrics collection, etc. for the xApp.

-The control specifications that specify the data types consumed and provided by the xApp for control capabilities (e.g. PM data that the xApp subscribes, the message type of control messages).

Open APIs for xApp

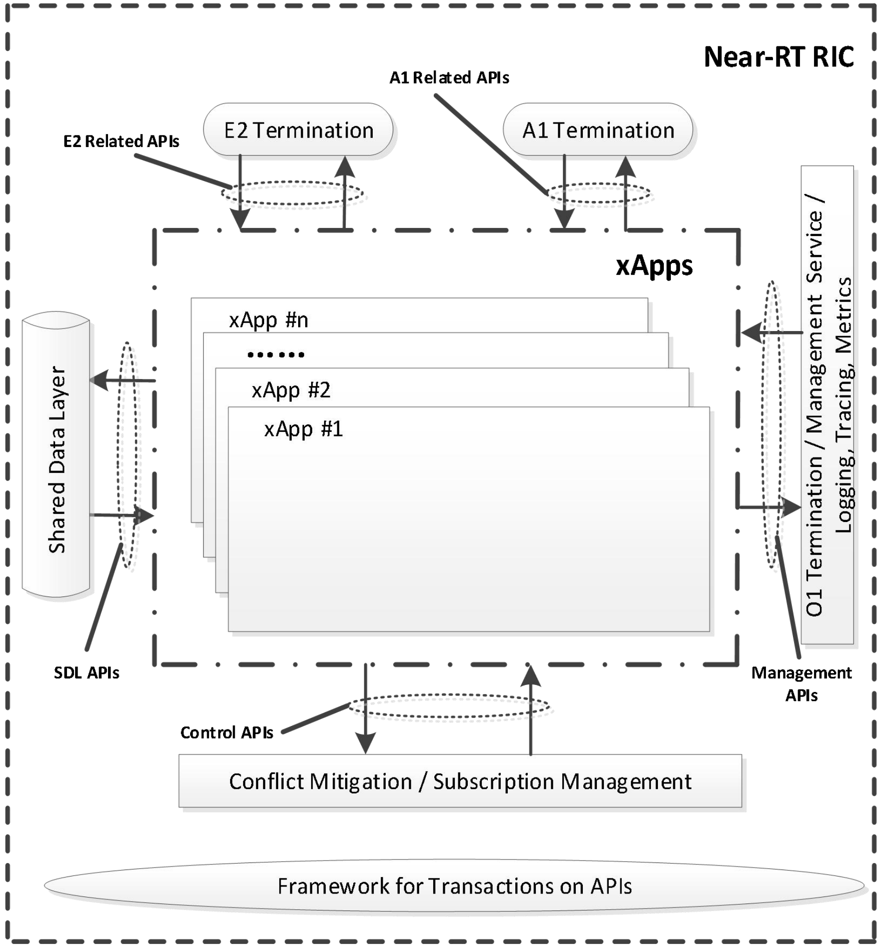
-A1 related APIs: the APIs between xApps and A1 Termination.

-E2 related APIs: the APIs between xApps and E2 Termination.

-Management APIs: the APIs between xApps and management related functions, such as O1 termination, management services and logging, tracing, metrics collection.

-Control APIs: the APIs between xApps and the functions which are responsible for control, such as conflict mitigation, xApp subscription management, etc.

-SDL APIs: the APIs between xApps and Shared Data Layer.



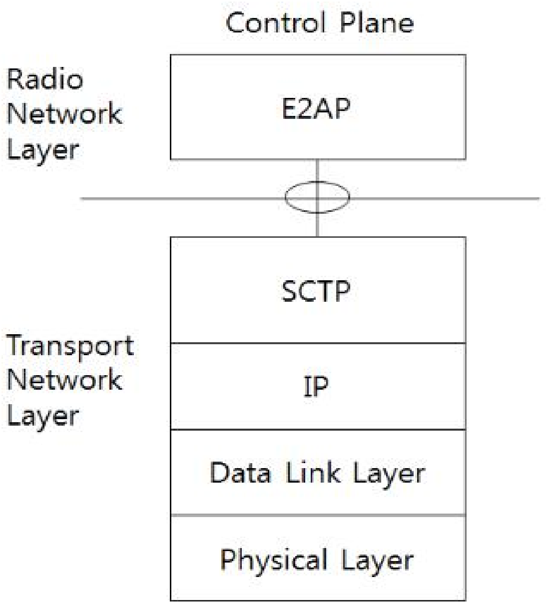
near-RT RIC小结

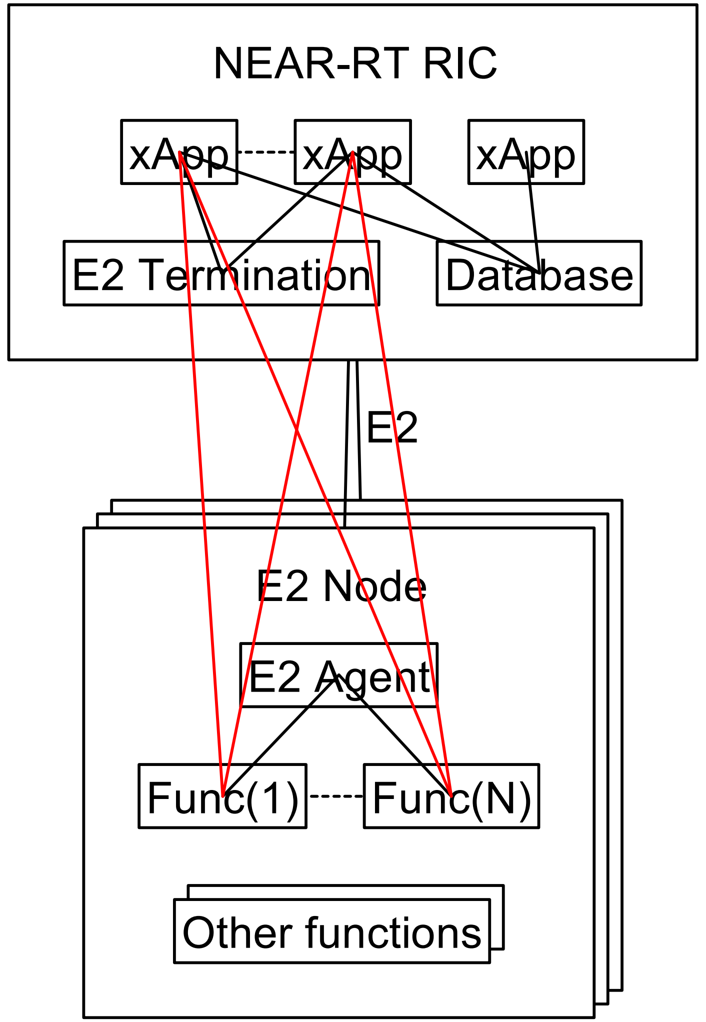
near RT RIC是O-RAN提出的一个新的逻辑网元，通常与CU一起部署在云端。是对传统的无线资源管理RRM的拆分与重写汇聚， 综合了无线资源管理RRM、切片管理、服务水平协议SLA与Qos、机器学习与预测、微服务架构、云部署、与移动边缘云计算MEC的协同等技术, 从而实现对5G无线接入网提供近实时的智能控制。

E2AP

Relationship between Near-RT RIC and E2 Node

One or more RAN functions that are controlled by the Near-RT RIC, i.e. supporting Near-RT RIC Services





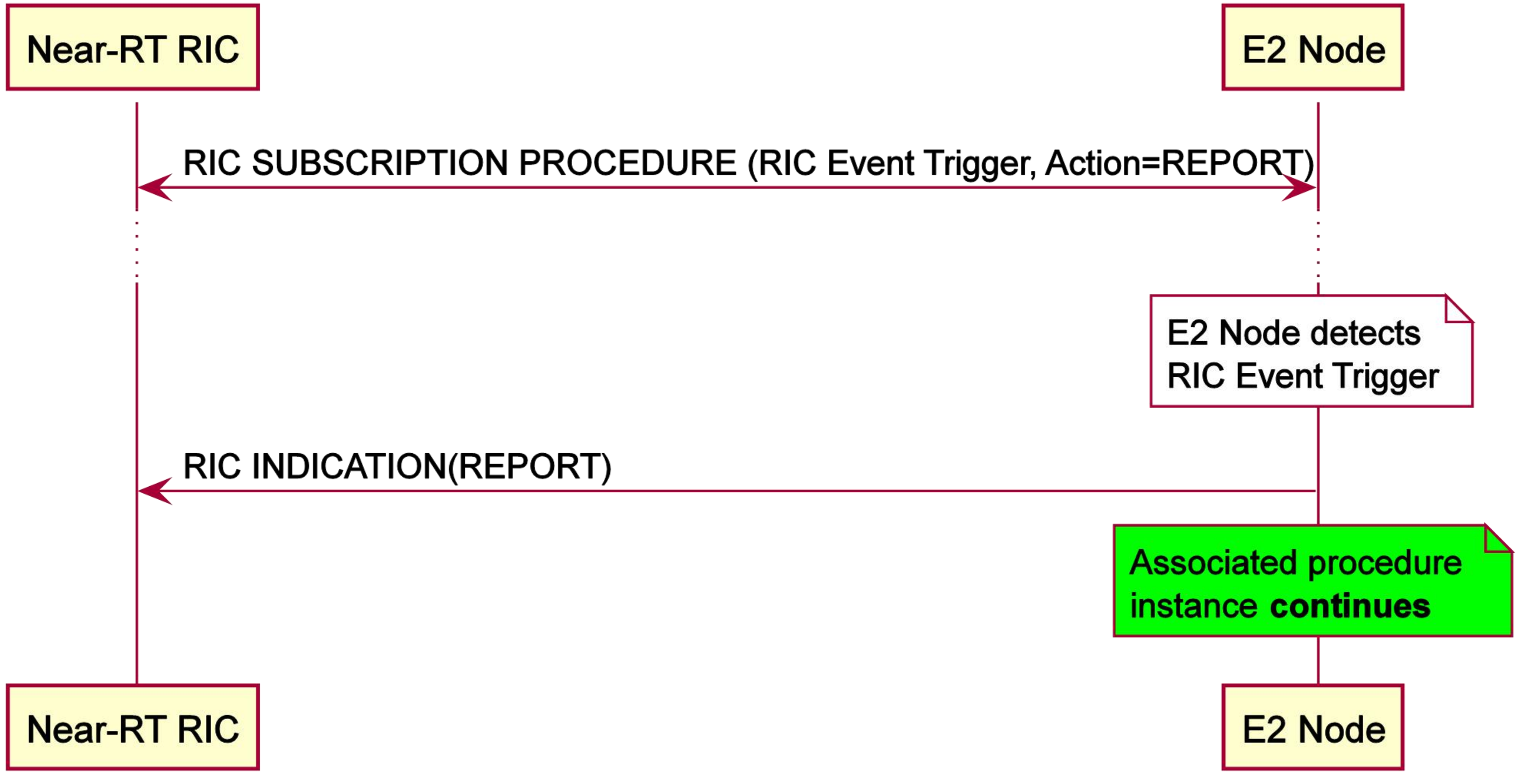
Elementary Procedures

Initiated by	Elementary Procedure	Initiating Message	Successful Outcome	Unsuccessful Outcome
			Response message	Response message
Near-RT RIC	RIC Subscription	RIC SUBSCRIPTION REQUEST	RIC SUBSCRIPTION RESPONSE	RIC SUBSCRIPTION FAILURE
Near-RT RIC	RIC Subscription Delete	RIC SUBSCRIPTION DELETE REQUEST	RIC SUBSCRIPTION DELETE RESPONSE	RIC SUBSCRIPTION DELETE FAILURE
E2 Node	RIC Service Update	RIC SERVICE UPDATE	RIC SERVICE UPDATE ACKNOWLEDGE	RIC SERVICE UPDATE FAILURE
Near-RT RIC	RIC Control	RIC CONTROL REQUEST	RIC CONTROL ACKNOWLEDGE	RIC CONTROL FAILURE
E2 Node	E2 Setup	E2 SETUP REQUEST	E2 SETUP RESPONSE	E2 SETUP FAILURE
Near-RT RIC or E2 Node	Reset	RESET REQUEST	RESET RESPONSE	

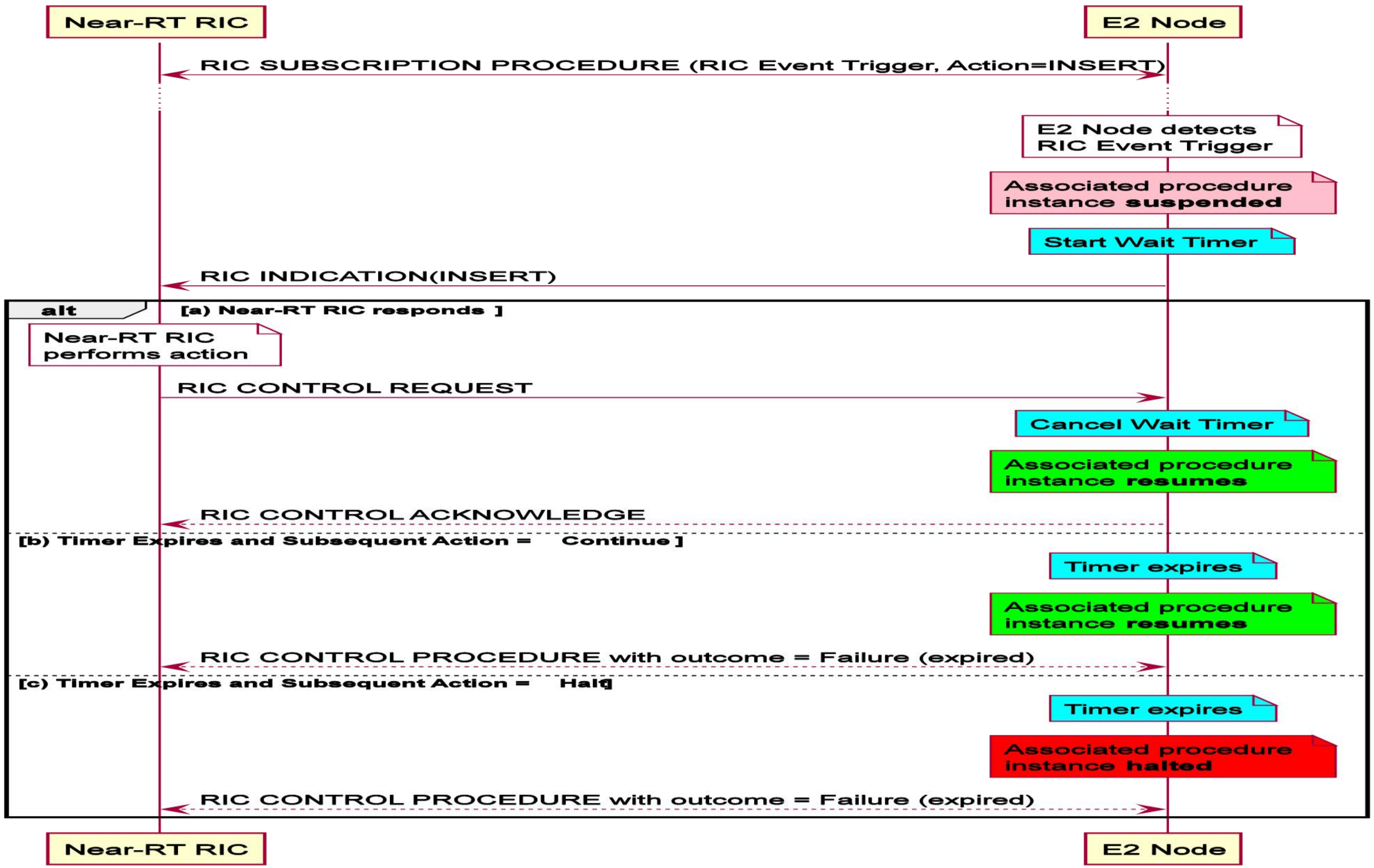
E2 Service Model (E2SM)

- REPORT
- INSERT
- CONTROL
- POLICY

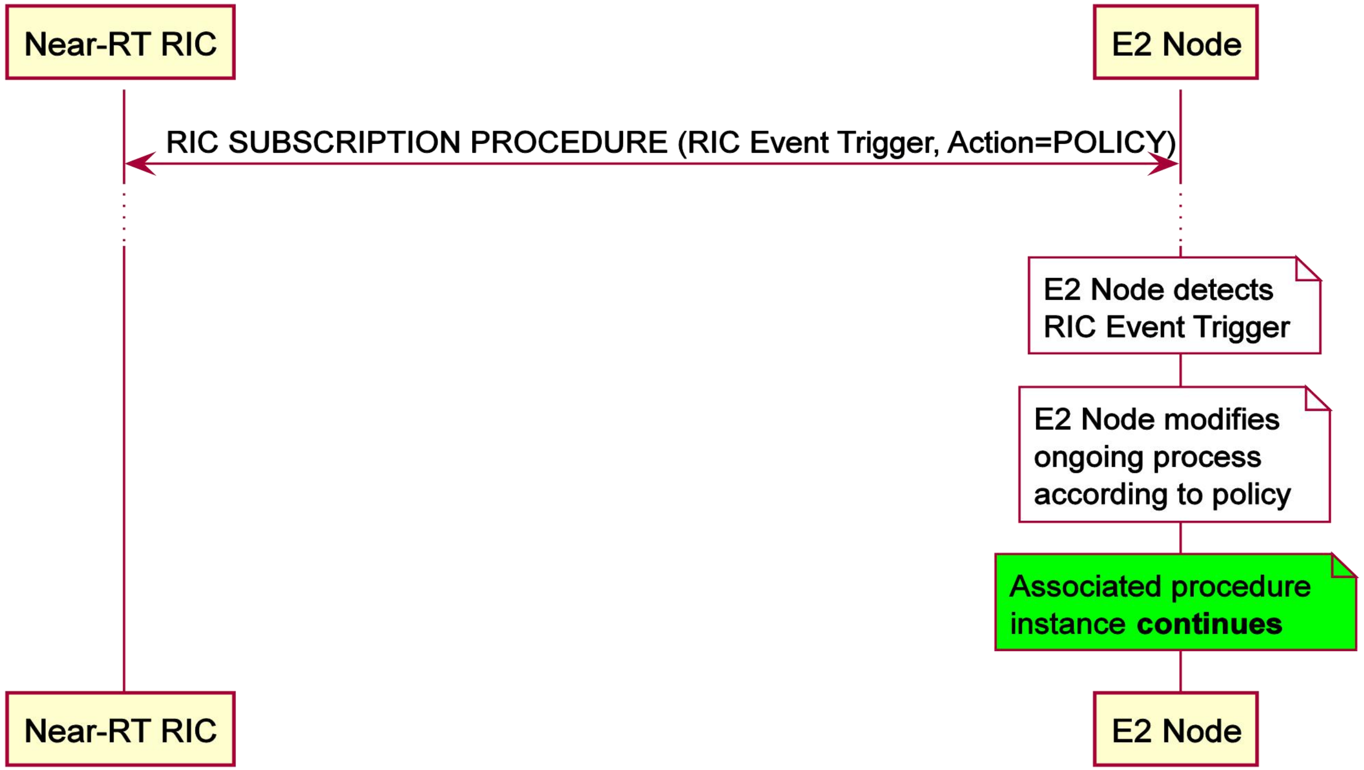
REPORT service procedure



INSERT service procedure

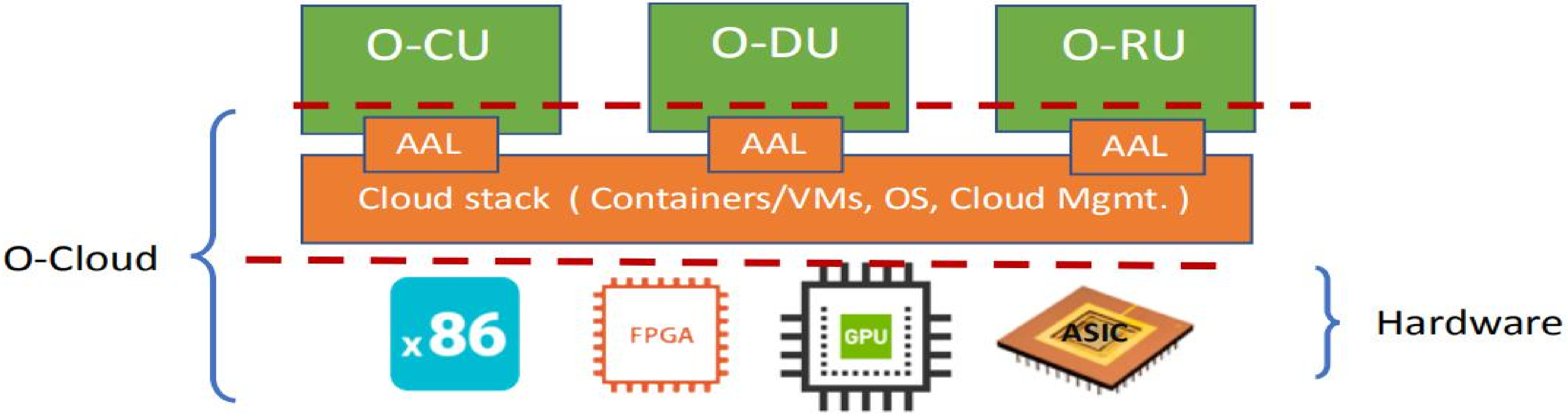


POLICY service procedure



O-CLOUD

Illustration of the O-Cloud Concept



There are three layers that we must consider when we discuss decoupling of hardware and software:

The hardware layer.

A middle layer that includes Cloud Stack functions as well as Acceleration Abstraction Layer functions.

A top layer that supports the virtual RAN functions.

Traffic steering USE CASE

背景原因

商业网络中业务量的快速增长和多个频段的使用，使得如何在一个均衡的分布中引导业务量变得非常困难。

典型的控制仅限于调整小区重选和切换参数；以及修改负荷计算和单元优先级。

此外，现有蜂窝网络中的RRM（无线资源管理）功能都是以小区为中心的。即使在一个小区内的不同区域，无线环境也会有变化，例如相邻小区的覆盖范围、信号强度，然而，基于传统控制策略的基站以类似的方式对待所有UE，并且通常关注于以小区为中心的平均性能，而不是以UE为中心。

目前此类解决方案存在以下局限性：

1） RRM控制很难适应多样化的场景和优化目标。

2） 流量控制/管理策略通常是被动的，很少利用预测网络和UE性能的能力。

3） 非最优流量管理，响应时间慢，这是由于各种因素造成的，例如无法选择一组正确的ue进行控制操作。这进一步导致非最优系统和UE性能，例如吞吐量降低和切换失败增加。

基于以上原因，此用例的主要目标是允许操作员灵活地配置所需的优化策略，利用正确的性能标准，并利用机器学习来实现智能和主动交通控制。

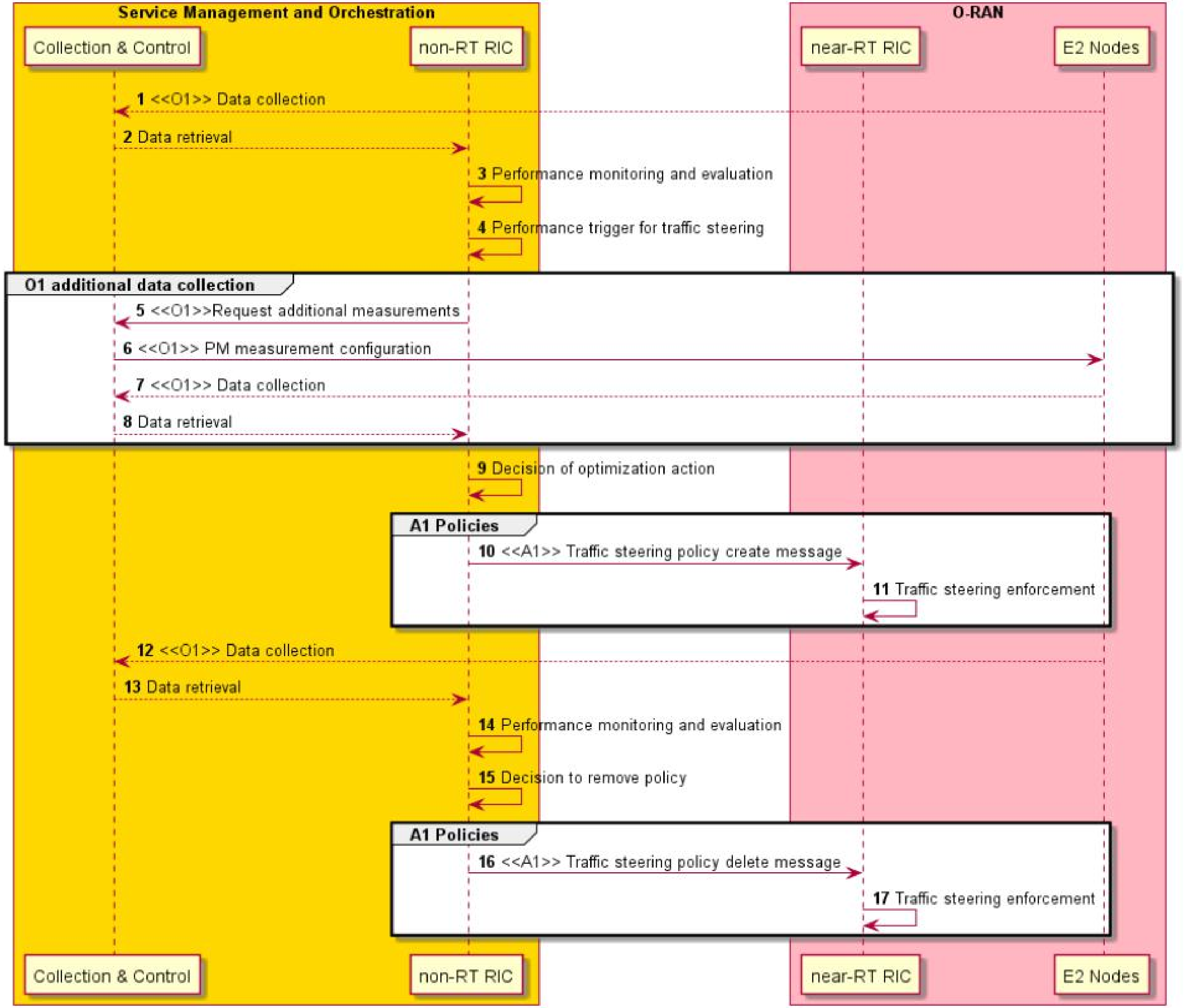
需要数据

1） 服务和相邻小区的RSRP/RSRQ/CQI信息的测量报告。

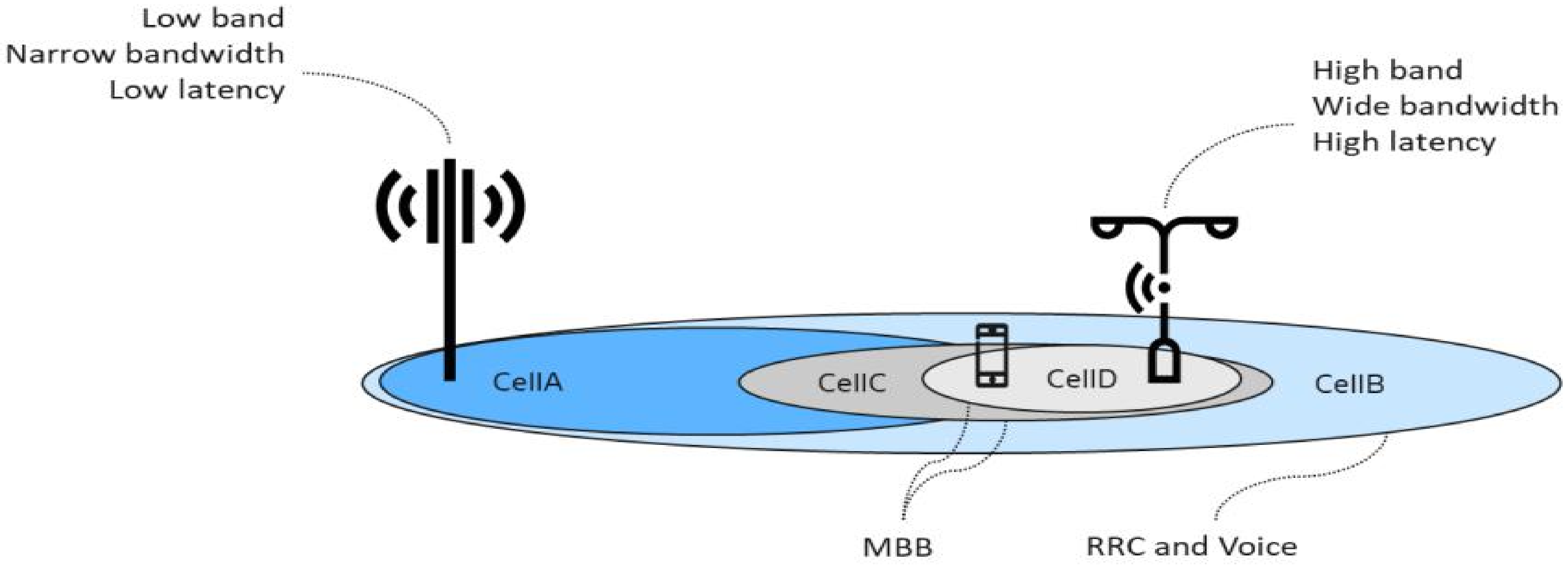
2） 移动/切换成功和切换指示失败等。

3） 小区负载统计信息，如活动用户或连接数、每个TTI的计划活动用户数、PRB利用率和CCE利用率等形式的信息。

4） 每用户性能统计信息，如PDCP吞吐量、RLC或MAC层延迟等。


Service Management and Orchestration
O-RAN
Collection & Control
non-RT RIC
near-RT RIC
E2 Nodes
1 <<O1>> Data collection
2 Data retrieval
3 Performance monitoring and evaluation
4 Performance trigger for traffic steering
O1 additional data collection
5 <<O1>>Request additional measurements
6 <<O1>> PM measurement configuration
7 <<O1>> Data collection
8 Data retrieval
9 Decision of optimization action
A1 Policies
10 <<A1>> Traffic steering policy create message
11 Traffic steering enforcement
12 <<O1>> Data collection
13 Data retrieval
14 Performance monitoring and evaluation
15 Decision to remove policy
A1 Policies
16 <<A1>> Traffic steering policy delete message
17 Traffic steering enforcement
Collection & Control
non-RT RIC
near-RT RIC
E2 Nodes

UE id=1的UE属于由S-NSSAI=1标识的子网片，具有语音（5QI=1）和建立的MBB（5QI=9）连接，进入由四个频带覆盖的区域。non-RT RIC明白业务的要求和特性，并决定让语音和RRC连接驻留在低频带上（这里由宏小区B覆盖成为PCell），而MBB连接最好使用更高的频带（这里由较小的小区C和D提供，成为SCells），并尽可能避免使用低频段。



策略1

```
{
    "policy_id": "1",
    "scope": {
    "ue_id": "1",
    "slice_id": "1",
    "qos_id": "1",
    “cell_id”: ”X” // Policy for Cell X, where X is one of A, B, C or D
    },

    "statement": {
    "cell_id_list": "B",
    "preference": "Shall",
    "primary": true // Control plane on Cell B (becoming PCell)
    },

    "statement": {
    "cell_id_list ": "B",
    "preference": "Shall",
    "primary": false // Voice on Cell B
    }
}
```

策略2

```
{
    "policy_id": "2",
    "scope": {
    "ue_id": "1",
    "slice_id": "1",
    "qos_id": "9",
    "cell_id": "X" // Policy for Cell X, where X is one of A, B, C or D
    },

    "statement": {
    "cell_id_list ": {"B", "A"},
    "preference": "Avoid",
    "primary": false // Avoid MBB on Cell A and Cell B
    },

    "statement": {
    "cell_id_list": {"C", "D"},
    "preference": "Prefer",
    "primary": false // Prefer MBB on Cell C and Cell D
    }
}
```

现状

设备供应商：

- 华为是最大的5G供应商，没有参与O-RAN联盟；
- 中兴直接象征性的摆个样子；
- 爱立信处于中立；
- 三星积很积极；
- Nokia很活跃。

新型的O-RAN供应商：

- 最重要的三个O-RAN新型供应商：Altiostar、Mavenir、Parallel Wireless全部来自美国。

传统的运营商：

- 中国移动率先支持vRAN和O-RAN的大型运营商之一，在目前的这种大环境下，中国移动还会积极推进吗？
- 美国的AT&T和西班牙电信对O-RAN最积极。

谢谢