O-RAN.WG3.TS.UCR-R004-v07.00

Technical Specification

O-RAN Work Group 3 (Near-Real-time RAN Intelligent Controller)

Use Cases and Requirements

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Contents

Foreword

This Technical Specification (TS) has been produced by WG3 of the O-RAN Alliance.

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where:

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Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the O-RAN Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in O-RAN deliverables except when used in direct citation.

Introduction

This document provides O-RAN WG3 Near-RT RIC Use Cases and Requirements, including E2 interface.

1 Scope

The present document specifies the initial use cases that have been approved within O-RAN WG3. The purpose of the use cases is to help identify requirements for O-RAN defined interfaces and functions, specifically Near-RT RIC functions and E2 interface, eventually leading to formal drafting of interface specifications. For each use case, the document describes the motivation, resources, steps involved, and data requirements. Finally, the requirements clause details the functional and non-functional requirements derived from these use cases.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non- specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, O-RAN cannot guarantee their long-term validity.

The following referenced documents are necessary for the application of the present document.

[1] 3GPP TS 22.261: “Service Requirements for the 5G System”, Release 16, October 2020

[2] 3GPP TS 23.203: “Policy and Control Control Architecture”, Release 16, December 2019

[3] 3GPP TS 23.501: “System Architecture for the 5G System (5GS)”, Release 16, September 2020

[4] 3GPP TS 28.530: “3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Management and orchestration; Concepts, use cases and requirements”, Release 16, December 2020

[5] 3GPP TS 28.541: “Management and orchestration; 5G Network Resource Model (NRM); Stage 2 and stage 3”, Release 16, November 2020

[6] 3GPP TS 28.552: “Technical Specification Group Services and System Aspects; Management and orchestration; 5G performance measurements”, Release 16, September 2020

[7] 3GPP TS 32.425: “Telecommunication management; Performance Management (PM); Performance measurements Evolved Universal Terrestrial Radio Access Network (E-UTRAN), Release 16, January 2020

[8] 3GPP TS 36.300: “Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2”, Release 16, October 2020

[9] 3GPP TS 36.314: “Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 – Measurements”, Release 16, July 2020

[10] 3GPP TS 36.321: “Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification”, Release 16, October 2020

[11] 3GPP TS 36.331: “Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification”, Release 16, October 2020

[12] 3GPP TS 36.423: “Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)”, Release 16, October 2020

[13] 3GPP TS 37.340: “NR; Multi-connectivity; Overall description; Stage-2”, Release 16, October 2020

[14] 3GPP TS 38.300: “NR and NG-RAN Overall Description”, Release 16, October 2020

[15] 3GPP TS 38.214: “NR; Physical Layer Procedures for Data”, Release 16, October 2020

[16] 3GPP TS 38.314: “NR; Layer 2 measurements”, Release 16, October 2020

[17] 3GPP TS 38.321: “NR; Medium Access Control (MAC) protocol specification”, Release 16, October 2020

[18] 3GPP TS 38.331: “NR; Radio Resource Control (RRC); Protocol specification”, Release 16, October 2020

[19] 3GPP TS 38.423: “NG-RAN; Xn Application Protocol (XnAP)”, Release 16, October 2020

[20] 3GPP TS 38.463: “NG-RAN; E1 Application Protocol (E1AP)”, Release 16, October 2020

[21] 3GPP TS 38.473: “NG-RAN; F1 Application Protocol (F1AP)”, Release 16, October 2020

[22] GSMA: “Generic Network Slice Template Version 4.0”, November 2020

[23] O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00: “O-RAN Working Group 1, Use Cases Detailed Specification v8.0”

[24] O-RAN.WG2.A1AP: “O-RAN Working Group 2, O-RAN A1 interface: Application Protocol”

[25] O-RAN.WG3.E2SM-v02.00: “O-RAN Working Group 3, Near-Real-time RAN Intelligent Controller, E2 Service Model (E2SM)”

[26] 3GPP TS 38.133: "NR; Requirements for support of radio resource management", Release 16, April 2022

[27] 3GPP TS 38.215: “NR; Physical layer measurements”, Release 16, April 2022

[28] O-RAN.WG2.UCR: "O-RAN Working Group 2, Non-RT RIC & A1 Interface: Use Cases and Requirements"

[29] O-RAN.WG2.AIML: “O-RAN Working Group 2, AI/ML workflow description and requirements”

[30] O-RAN.WG1.O-RAN-Architecture-Description-v06.00: “O-RAN Architecture Description”

[31] 3GPP TS 23.501: “System architecture for the 5G System (5GS); Stage 2”, Release 17, March 2021

[32] ORAN-WG1.Use Cases Detailed Specification R003 v11.00: “O-RAN Work Group 1 (Use Cases and Overall Architecture), Use Cases Detailed Specification”

[33] 3GPP TS 28.310: "Management and orchestration; Energy efficiency of 5G", Release 18, March 2023

[34] O-RAN.WG4.CUS.0-R003-v13: “O-RAN Working Group 4, Control, User and Synchronization Plane Specification”

[35] O-RAN.WG4.MP.0-R003-v13: “O-RAN Working Group 4, Management Plane Specification”

[36] O-RAN WG3 E2SM-KPM: “O-RAN Work Group 3, Near-Real-time RAN Intelligent Controller, E2 Service Model (E2SM), KPM”

[37] O-RAN WG3 E2SM-RC: “O-RAN Work Group 3 (WG-3), Near-Real-time RAN Intelligent Controller, E2 Service Model (E2SM), RAN Control”

[38] O-RAN.WG4.CUS.0-R003-v14: “O-RAN Working Group 4, Control, User and Synchronization Plane Specification”

[39] O-RAN.WG4.MP.0-R003-v14: “O-RAN Working Group 4, Management Plane Specification”

[40] 3GPP TS 38.323: “NR; Packet Data Convergence Protocol (PDCP) specification”, Release 17.5, July 2023

[41] 3GPP TS 25.321: “Universal Mobile Telecommunications System (UMTS); Medium Access Control (MAC) protocol specification”, Release 17, May 2022

[42] O-RAN.WG3.E2SM-RC-R003-v05.00: “O-RAN Work Group 3 (WG-3), Near-Real-time RAN Intelligent Controller, E2 Service Model (E2SM), RAN Control”

[43] 3GPP TS 38.212: “5G: NR; Multiplexing and channel coding”, Release 16.8.0, January 2022

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non- specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, O-RAN cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

[i.1] 3GPP TR 21.905: “Vocabulary for 3GPP Specifications” [i.2] O-RAN.WG1.mMIMO-Use-Cases-TR-v01.00: "O-RAN Working Group 1, Massive MIMO Use Cases Technical Report"

[i.3] 3GPP TR 23.700-40: "Study on enhancement of network slicing; Phase 2", March 2021

[i.4] ORAN-WG1.Use Cases Energy Saving Technical Report R003 v02.00: "O-RAN Work Group 1 (Use Cases and Overall Architecture), Network Energy Saving Use Cases Technical Report"

[i.5] 3GPP TR 28.813: "Study on new aspects of Energy Efficiency (EE) for 5G", Release 17, December 2021

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms and definitions [given in 3GPP TR 21.905 [i.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 [i.1].

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.

A1-policy based traffic steering process mode: An operational mode in which the Near-RT RIC is configured through A1 policy to use traffic steering actions to ensure a more specific notion of network performance (for example, applying to smaller groups of E2 nodes and UEs in the RAN) than that which it ensures in the background traffic steering.

Background traffic steering processing mode: An operational mode in which the Near-RT RIC is configured through O1 to use traffic steering actions to ensure a general background network performance which applies broadly across E2 nodes and UEs in the RAN.

Baseline RAN behavior: The default RAN behavior as configured at the E2 nodes by SMO.

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

E2 node: A logical node terminating E2 interface. In the present document, 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.

Intents: A declarative policy to steer or guide the behavior of RAN functions, allowing the RAN function to calculate the optimal result to achieve stated objective.

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.

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 (e.g., UE basis, cell basis) data collection and actions over E2 interface.

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-eNB (O-RAN eNB): An eNB or ng-eNB that supports E2 interface.

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 orchestration & management entities (orchestration/NMS) and O-RAN managed elements, for operation and management, by which FCAPS management, software management, file management and other similar functions can be achieved.

RAN UE group: Aggregations of UEs whose grouping is set in the E2 nodes through E2 procedures also based on the scope of A1 policies. These groups can then be the target of E2 CONTROL or POLICY messages.

Traffic steering action: The use of a mechanism to alter RAN behavior. Such actions include E2 procedures such as CONTROL and POLICY.

Traffic steering inner loop: The part of the traffic steering processing, triggered by the arrival of periodic TS related KPM (Key Performance Measurement) from E2 node, which includes UE grouping, setting additional data collection from the RAN, as well as selection and execution of one or more optimization actions to enforce traffic steering policies.

Traffic steering outer loop: The part of the traffic steering processing, triggered by the Near-RT RIC setting up or updating traffic steering aware resource optimization procedure based on information from A1 policy setup or update, A1 Enrichment Information (EI) and/or outcome of Near-RT RIC evaluation, which includes the initial configuration (preconditions) and injection of related A1 policies, triggering conditions for TS changes.

Traffic steering processing mode: An operational mode in which either the RAN or the Near-RT RIC is configured to ensure a particular network performance. This performance includes such aspects as cell load and throughput, and it can apply differently to different E2 nodes and UEs. Throughout this process, traffic steering actions are used to fulfill the requirements of this configuration.

Traffic steering target: The intended performance result that is desired from the network, which is configured to Near-RT RIC over O1.

3.2 Symbols

Void

3.3 Abbreviations

For the purposes of the present document, the abbreviations [given in 3GPP TR 21.905 [i.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 [i.1].

KPI	Key Performance Indicator
KQI	Key Quality Indicator
MBB	Mobile BroadBand
SMG	Spatial Multiplexing Group
SMO	Service Management and Orchestration

4 Use cases

4.1 Use case 1: Traffic steering

This use case provides the motivation, description, and requirements for Near-RT RIC and E2 interface to support traffic steering, whose end-to-end requirements are specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23].

4.1.1 Background and goal of the use case

The rapid traffic growth and multiple frequency bands utilized in a commercial network make it challenging to steer the traffic in a balanced distribution. Typical controls are limited to adjusting the cell reselection and handover parameters; and modifying load calculations and cell priorities.

The goal of Near-RT RIC traffic steering is to interpret the policies received over A1 and to determine the optimum changes it can make towards achieving those goals. It may also leverage the A1 enrichment information. Traffic steering may reuse mechanisms provided by other use cases to effect the changes necessary to achieve its goals.

More specifically, Near-RT RIC triggers E2 procedure and related control/policies so as to obtain network performance that would fulfill the criteria identified in the A1 policies.

4.1.2 Entities/resources involved in the use case

1) OAM functions in SMO domain:
    - Collect necessary measurement metrics from network level measurement report and enrichment data (can acquire data from application) for constructing/training relevant AI/ML models.
    - Deploy or update, configure the relevant TS optimization AI/ML models to Near-RT RIC via O1.

2) Non-RT RIC in SMO domain:
    - Send A1 policies and receive policy feedback to/from Near-RT RIC to drive resource optimization at RAN level.
    - E.g., TS targets as specified in O-RAN.WG2.A1AP [24].

3) Near-RT RIC:
    - Supports update of AI/ML models from SMO.
    - Supports inference, such as traffic prediction, using AI/ML models from Non-RT RIC based on network data, e.g., measurement reports from E2 node.
    - Supports interpretation and execution of A1 policies from Non-RT RIC.
    - Sends TS resource optimization related policies and commands to E2 node to influence RRM behavior.
    - Sends the relevant A1 policy feedback to Non-RT RIC for potential policy update.
    - Sends the relevant O1 performance data to OAM functions; these can be used by Non-RT RIC for potential policy update.

4) E2 node:
    - Supports reporting of UE context, network measurements, and UE measurements to Near-RT RIC over E2 interface.
    - Executes policies and commands received from Near-RT RIC over E2 interface.
    - Supports network and UE performance report to OAM functions in SMO domain over O1 interface.

4.1.3 Solutions

In this clause the possible processing modes of traffic steering are described. Three general traffic steering processing modes and the transitions between them are shown in figure 4.1.3-1.

These modes represent the way the Near-RT RIC (or RAN) operates on a given group of UEs, and not the operation of any component as a whole. As such, the Near-RT RIC, could be operating in both modes 1 and 2 concurrently for different sets of UEs. For example, the transition from mode 0 or 1 to 2 occurs only for a group of UE defined by the A1 policy scope. At the same time, other UE groups may still be handled in mode 0 and/or 1.

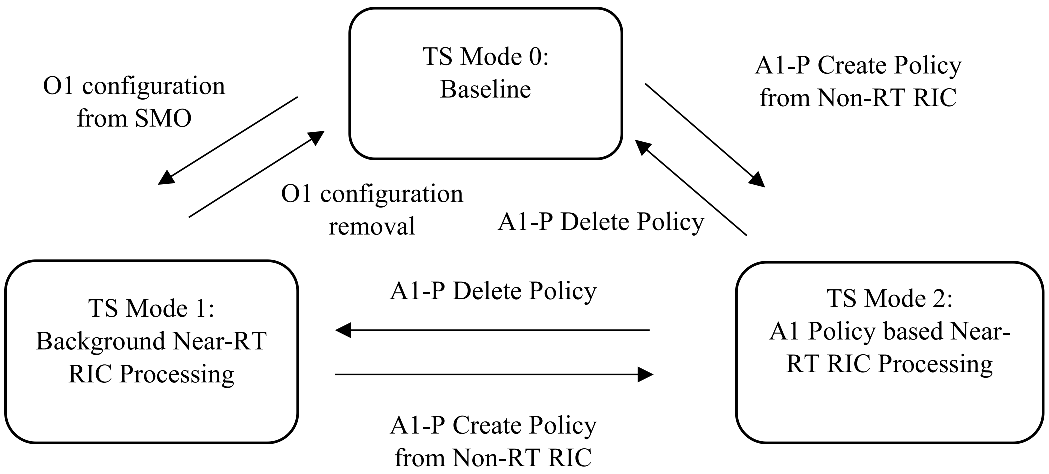

Figure 4.1.3-1: Traffic steering processing modes

The three processing modes are described in more detail below:

0. "Baseline" traffic steering behavior: OAM functions in SMO domain uses O1 configuration on one or more E2 node to set up a desired baseline behavior. This also sets up baseline performance monitoring of E2 node by the SMO. In this mode, Near-RT RIC is not involved.

1. "Background" Near-RT RIC processing: OAM functions in SMO domain uses O1 configuration of Near-RT RIC to set up a desired "background Near-RT RIC behavior". In this mode the Near-RT RIC sets up E2 mechanisms to monitor E2 node and uses traffic steering related E2 mechanisms to achieve the desired background behavior of the set of E2 nodes connected to the Near-RT RIC.

2. "A1-policy based" Near-RT RIC processing: This mode can be entered from either mode 0 or mode 1. Non-RT RIC in SMO domain uses A1-P to specify an A1 guided behavior for a targeted subset of E2 nodes or UEs. If entering this from mode 1, this will have the effect of modifying the existing Near-RT RIC "background" behavior to include a more specific A1 guided behavior. In this mode, the Near-RT RIC can either set up or modify E2 mechanisms used to monitor E2 nodes and will use traffic steering related E2 mechanisms to obtain the desired behavior of some targeted sub-set of E2 nodes or UEs. This mode terminates when the corresponding A1-P policy delete message is received from Non-RT RIC in SMO domain and the system returns to either mode 0 or mode 1, depending on whether or not OAM functions in SMO domain had previously configured the optional Near-RT RIC "background" role (mode 1).

NOTE: Processing mode 0 is strictly not in scope for WG3. It is described here for completeness and to clearly state what is the starting point prior to the WG2 and WG3 defined mechanisms.

Processing mode 2 contain an 'outer loop' and an 'inner loop'. In the inner loop, a number of different "E2 mechanism" can be used (policy, report/control or insert/control) towards a number of different target RAN functions in order to either exercise existing RAN mechanisms or modifying their ongoing behavior. The appropriate mechanism and target RAN function would depend upon the RAN function capabilities to support a given E2 mechanism, the A1-P scope and policy, the O1 configuration of the RIC and the performance observed through E2 monitoring.

4.1.3.1 Near-RT RIC A1-policy based traffic steering

The context of Near-RT RIC A1-policy based traffic steering is captured in table 4.1.3.1-1.

Table 4.1.3.1-1: Near-RT RIC A1-policy based traffic steering

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Drive traffic management in RAN in accordance with defined intents, policies, and enrichment information from the Non-RT RIC using A1 interface.	
Actors and Roles	- OAM functions in SMO domain: Performance data and training data collection, AI model management. - Non-RT RIC in SMO domain: Creates and updates A1 policies, AI model training targeting to TS optimization. - Near-RT RIC: Enforces A1 policies and generates RIC CONTROL and/or POLICY. - E2 node: RIC CONTROL and POLICY execution and RIC REPORT creation. Refer to 4.1.2 for more details.	
Assumptions	- All relevant functions and components are instantiated. - A1, O1 and E2 interface connectivity is established. - A1 policy scope defined.	
Pre-conditions	- Network is operational with default configuration. - OAM functions have configured a baseline measurement configuration and the Non-RT RIC has access to this data. - (optional) OAM functions have configured traffic steering targets in Near-RT RIC through O1 interface. - OAM functions have configured baseline traffic steering parameters in E2 node(s) through O1 interface. - (optional) Near-RT RIC has access to the necessary data related to traffic steering from the E2 node by means of a RIC report procedure. - Non-RT RIC analyzes the historical data from RAN for training the relevant AI/ML models to be deployed or updated in the Near-RT RIC, as well as AI/ML models required for non-real-time optimization of configuration and policies.	
Begins when	Non-RT RIC and/or Near-RT RIC perform data evaluation, determine that TS-aware optimization is required to be initiated or updated and establishes target(s).	
Step 1 (O)	(Start of outer loop control) Non-RT RIC evaluates the collected data and A1 policy feedback, if required, and generates or updates the appropriate TS-aware resource optimization policy, such as TS targets, and sends it to Near-RT RIC via A1 interface.	
Step 2 (O)	Non-RT RIC sends optional traffic steering related A1 enrichment information.	
Step 3 (M)	Based on received A1 policy and/or A1-EI from Non-RT RIC or internal trigger and/or internal evaluation and trigger, Near-RT RIC sets up or updates the TS-aware resource optimization procedure.	
Step 4 (M)	Near-RT RIC subscribes to a UE context information and measurement metrics via E2 interface.	
Step 5 (M)	(Start of inner loop control) E2 nodes report the UE context information and E2 measurements via RIC REPORT periodically or event-triggered.	
Step 6 (M)	Near-RT RIC evaluates the performance data from E2 nodes (including	

Use Case Stage	Evolution / Specification	<<Uses>> Related use
	performance data from different E2 nodes for the same UE) and finds the performance is out of TS targets which are indicated in the A1 policy and/or internal Near-RT RIC TS targets.	
Step 7 (M)	Based on the UE context information, E2 measurement metrics (RIC REPORT), and A1 policy, Near-RT RIC may generate new or modify the existing E2 policies and sends them to E2 nodes. Near-RT RIC may also generate control command(s) and send them to E2 node(s) to trigger re-allocation of radio resources so that TS indicators can move back to the limits outlined in the A1 policies. E2 node functions target of E2 policy and control commands may be: - E-UTRAN-NR dual connectivity - Carrier aggregation - Connected mode mobility - Idle mode mobility Step 4 to Step 7 may repeat. (End of inner loop control)	
Step 8 (O)	If required, Near-RT RIC sends information to the SMO domain using A1 policy feedback and/or O1-PM. The Non-RT RIC may use this information and information collected from E2 nodes using O1-PM as policy feedback to assess the performance of TS optimization function in Near-RT RIC, or to assess the outcome of the applied A1 policies. Subsequently, an A1 policy can be updated. In parallel, the Near-RT RIC may use available information to assess the performance of TS optimization function in Near-RT RIC, and/or to assess the outcome of the applied A1 policies. Subsequently, Near-RT RIC TS optimization targets can be updated Step 1 to Step 8 may repeat (End of outer loop control)	
Ends when	Non-RT RIC decides to delete TS-aware resource optimization policy and sends the related message or following internal trigger, the Near-RT RIC terminates the TS-aware resource optimization procedure.	
Exceptions	None.	
Post Conditions	Non-RT RIC continues to collect and monitor TS related measurement data from E2 node. Near-RT RIC continues to collect and monitor TS related measurement data from E2 node.	
Traceability	REQ-Near-RT-RIC-TS-FUN1, REQ-Near-RT-RIC-TS-FUN2, REQ-E2-TS-FUN1, REQ-E2-TS-FUN2, REQ-E2-TS-FUN3, REQ-E2-TS-FUN4, REQ-E2-TS-FUN5, REQ-E2-TS-FUN6, REQ-E2-TS-FUN7, REQ-E2-TS-FUN8, REQ-E2-TS-FUN9, REQ-E2-TS-FUN10	


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    Participant non as “Non-RT RIC”
End box

Box “O-RAN” #lightpink
   Participant near as “Near-RT RIC”
   Participant ran as “E2 Node”
End box

OAM <-> ran : <<O1>> RAN Data & Configuration collection
near <-> ran : <<E2>> RAN Data & Configuration collection
OAM -> non: TS Performance information
non-->non: (Mode 2) Collected Data Evaluation TS target generation
near-->near: (Mode 1) Collected Data Evaluation TS target generation

group OUTER LOOP CONTROL
   non --> near : 1:(opt.) <<A1>> A1 policy setup or update
   non --> near: 2: (opt.) <<A1-EI>> Traffic steering related A1 Enrichment Information
   near -> near : 3: TS optimization set-up or update
   near -> ran : 4: <<E2>> RIC SUBSCRIPTION REQUEST(UE context & Measurement Metrics)

   group INNER LOOP CONTROL
      ran -> near: 5: <<E2>> RIC INDICATION (UE context & E2 measurement metrics)
      near -> near: 6: TS performance does not fulfill A1 policy requirements
      near --> ran : 7: (opt.) <<E2>> RIC SUBSCRIPTION REQUEST(REPORT or INSERT [UE
measurements & E2-node state])
      near <-- ran : (opt.) <<E2>> RIC INDICATION
      near --> ran : (opt.) <<E2>> RIC CONTROL REQUEST(TS optimization control parameters)
      near --> ran : (opt.) <<E2>> (opt.) RIC SUBSCRIPTION REQUEST(TS optimization POLICY)
   end
   OAM <-- near: (opt.) <<O1>> TS Performance information
   OAM -> non: TS Performance information
   non <-- near: (opt.) <<A1>> TS Performance information
   non -> non: TS Optimization Performance Evaluation
   near -> near: TS Optimization Performance Evaluation
end
non --> near: (opt.) <<A1>> A1 policy delete
near -> near: TS optimization stopped
near-> ran: <<E2>> RIC SUBSCRIPTION DELETE
@enduml
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The overall procedure for Near-RT RIC A1-policy based traffic steering use case is given in figure 4.1.3.1-1.

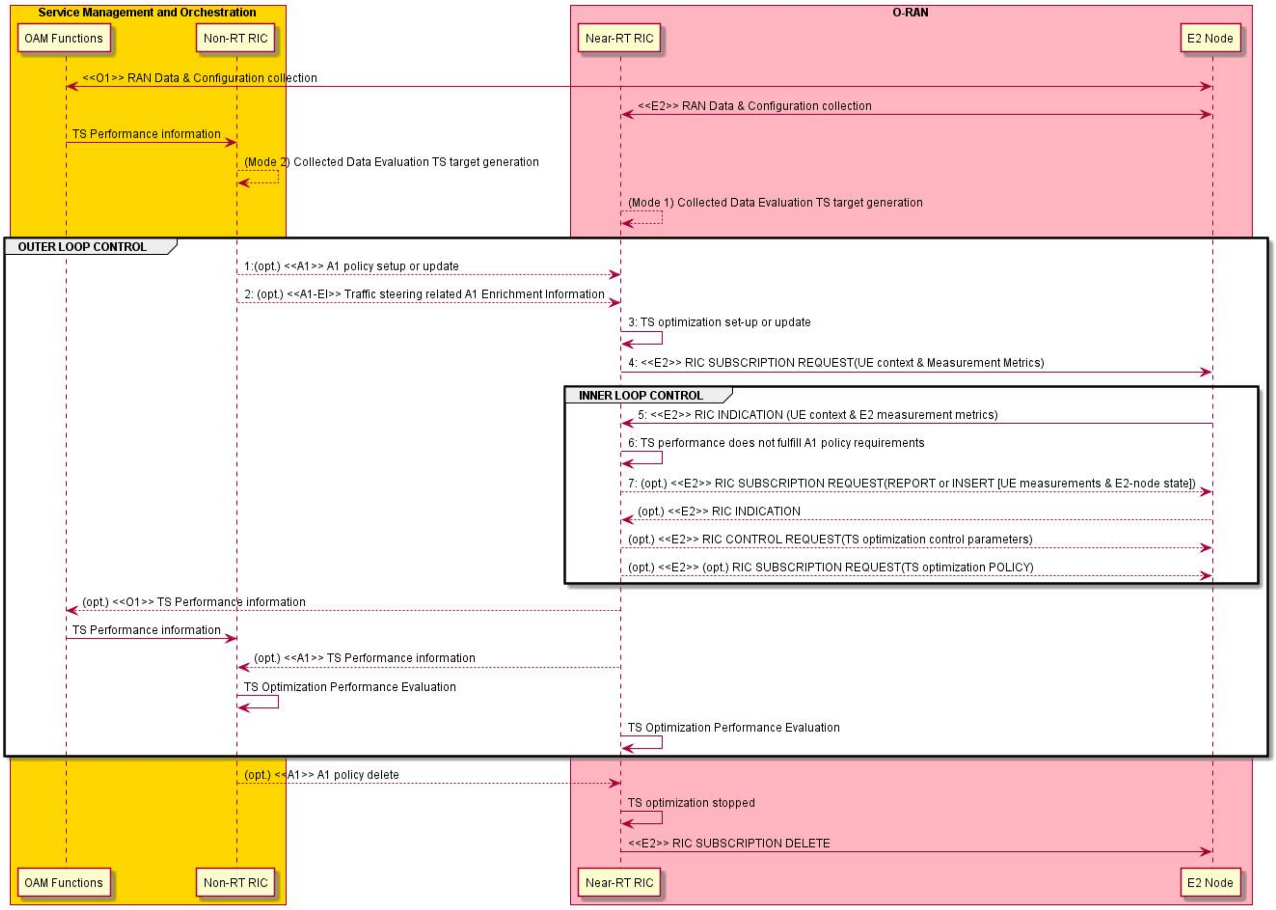

Figure 4.1.3.1-1: The overall procedure for Near-RT RIC A1-policy based traffic steering use case

4.1.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the traffic steering use case. The requirements are specified in clause 5.

4.1.4.1 Control over E2

Mobility control: Serving cell can be chosen based on the resource status and QoS of the UE(s) targeted by an A1 traffic steering policy. Moreover, load balancing can be achieved to improve the overall network performance. The following procedures can be used for traffic steering:

- Handover from the source cell to the target cell
- Configuration/reconfiguration of handover restriction list
- Configuration of idle mode mobility parameters
- Enable, disable, or modify CA (as specified in 3GPP TS 38.300 [14], 3GPP TS 36.300 [8], 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])
- Enable, disable, or modify dual connectivity (as specified in 3GPP TS 38.300 [14], 3GPP TS 36.300 [8], 3GPP TS 37.340 [13], 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])

Both RIC POLICY and RIC CONTROL can be used.

4.1.4.2 UE context information from E2 nodes

The followings are examples of UE context information identified as required:

- UE ID (as specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23])
- Slice level: S-NSSAI
- DRB level: e.g., established DRB ID, mapping with QoS flows, etc.
- QoS related: e.g., E-RAB level QoS parameters (4G, NSA) or QoS flow level QoS parameters (NG-RAN).
- UE capabilities: CA and DC capabilities

For example, UE ID, S-NSSAI, DRB ID, or QCI/5QI can be used to derive the QoS requirements and the resource occupation; the UE capabilities may be required to select the appropriate RRM action (e.g., CA/DC configuration).

4.1.4.3 Measurements from E2 nodes

The E2 measurements are necessary for inference and prediction in the Near-RT RIC as the driver for decisions in addition to KPMs. For the traffic steering use case, the Near-RT RIC can translate an A1 policy (relatively static targets) into a flexible selection of controls over E2 (e.g., handover control, DC, CA, idle mode mobility) by taking into account the RAN resource utilization, cell level and the UE level performance, the radio conditions, etc.

The examples of measurement information identified as required are listed in table 4.1.4.3-1 below.

Table 4.1.4.3-1: Measurements from E2 nodes

Measurement Type	Measurement Examples
Cell/SSB area related measurements	- DL/UL Total PRB Usage, Distribution of DL/UL Total PRB Usage, DL/UL GBR PRB Usage, DL/UL non-GBR PRB Usage, RRC Connection Number, Available RRC Connection Capacity Value, Mean and Maximum Number of Active UEs per DRB in the DL/UL, DL/UL Scheduling PDCCH CCE Usage, DL/UL Composite Available Capacity, DL/UL Cell PDCP SDU Data Volume (including secondary RAT usage for EN-DC/MR-DC), Handover success ratio - DL/UL SSB Area Total PRB Usage, DL/UL SSB Area GBR PRB Usage, DL/UL SSB Area non-GBR PRB Usage, SSB Area Capacity Value - DL/UL PRB usage per QCI, DL/UL PRB usage per 5QI, DL/UL PRB usage per slice, Slice Available Capacity Value *As specified in 3GPP TS 32.425 [7], 3GPP TS 28.552 [6], 3GPP TS 36.314 [9], 3GPP TS 38.314 [16], 3GPP TS 38.423 [19], 3GPP TS 38.463 [20] and 3GPP TS 38.473 [21]*
E2-node user plane measurements per-UE / UE group	- Average DL/UL throughput - DL/UL PRB usage - DL/UL Scheduled IP throughput - Buffer Status Information (e.g., UL BSR) *As specified in 3GPP TS 32.425 [7], 3GPP TS 28.552[6], 3GPP TS 36.314 [9], 3GPP TS 38.314 [16], 3GPP TS 38.423 [19], 3GPP TS 38.473 [21], 3GPP TS 38.463 [20], 3GPP TS 36.321 [10] and 3GPP TS 38.321 [17]*
UE L1/L2/L3 measurements	- RSRP and RSRQ measurements - SINR measurements - CQI/MCS measurements - Location and Velocity measurements *As specified in 3GPP TS 36.331 [11] and 3GPP TS 38.331 [18]*

4.1.4.4 E2 node configuration

Cell level configuration parameters, such as PCI, neighbor relations and related offsets etc. are needed at Near-RT RIC in order to e.g., configure UE measurements monitor cell level performance and manage mobility control (handover and cell reselection) according to the network topology and the related E2 parameters.

4.2 Use case 2: QoS based resource optimization

This use case provides the background and motivation for the O-RAN architecture to support near real-time QoS aware resource optimization.

Based on the end-to-end requirements for the QoS based resource optimization use case specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23], clause 3.8, some high-level functional descriptions and requirements over Near-RT RIC and E2 interface are introduced.

4.2.1 Background and goal of the use case

The network shall offer means to prioritize resources while preserving the required QoS properties, e.g., reliability, latency, bandwidth requirements, as specified in 3GPP TS 23.203 [2]. Current RAN network coverage and capacity depends on rigorous planning and configuration. However, due to varying nature of traffic demands and radio channels as well as multiple services to co-exist, it is hard to satisfy all QoS requirements simultaneously.

In summary, it is important for an E2 node to achieve QoS targets as smoothly as possible. The QoS aware resource optimization should provide a refined granularity of radio resource allocation based on varying radio conditions and traffics in order to meet the diverse requirements of reliability, latency, and bandwidth simultaneously. In addition, it should coordinate allocation of radio resources for co-existing multiple services, which may have different priorities, to achieve the optimal utilization of radio resources.

In case when the network performance data is observed outside the boundary of the defined QoS targets, the Near-RT RIC should be able to trigger re-allocation of radio resources so that the QoS indicators can move back within limits outlined in the A1 policies.

4.2.2 Entities/resources involved in the use case

1) OAM functions in SMO domain:

   - Collect necessary measurement metrics from network level measurement report and enrichment data (can acquire data from application) for constructing/training relevant AI/ML models.
   - Deploy or update, configure the relevant QoS optimization AI/ML models to Near-RT RIC via O1.

2) Non-RT RIC in SMO domain:

   - Send A1 policies to and receive policy feedback from Near-RT RIC to drive resource optimization at RAN level.
   - E.g., QoS targets as specified in 3GPP TS 23.203 [2], such as GFBR, MFBR, priority level, PDB.
   - See O-RAN.WG2.A1AP [24] for more information.

3) Near-RT RIC:

   - Support update of AI/ML models from SMO.
   - Support inference, such as QoS prediction, using AI/ML models from Non-RT RIC based on network data, e.g., measurement reports from E2 node.
   - Support interpretation and execution of A1 policies from Non-RT RIC.
   - Sending QoS resource optimization related policies and commands to E2 node to influence RRM behavior.
   - Sending the relevant A1 policy feedback to Non-RT RIC for potential policy update.
   - Sending the relevant O1 performance data to OAM functions, can be used by Non-RT RIC for potential policy update.

4) E2 node:

   - Support reporting of UE context, network measurements, and UE measurements to Near-RT RIC over E2 interface.
   - Executes policies and commands received from Near-RT RIC over E2 interface.
   - Support network and UE performance report to OAM functions in SMO domain over O1 interface.

4.2.3 Solutions

The context of QoS based resource optimization use case is captured in table 4.2.3-1.

Table 4.2.3-1: QoS based resource optimization use case

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	QoS-aware resource optimization in E2 nodes in accordance with A1 policies and O1 configuration.	
Actors and Roles	- OAM functions in SMO domain: Performance data and training data collection, AI model training targeting to QoS optimization. - Non-RT RIC in SMO domain: Creates and updates A1 policies. - Near-RT RIC: Enforces A1 policies and generates RIC CONTROL and/or POLICY. - E2 node: RIC CONTROL and POLICY execution and RIC REPORT creation. Refer to 4.2.2 for more details.	
Assumptions	- All relevant functions and components are instantiated and configured. - A1, O1, E2 interface connectivity is established.	
Pre-conditions	Network is operational with default configuration. OAM functions have established RAN data collection, and Non-RT RIC has access to this data. Non-RT RIC analyzes the history data from RAN and triggers SMO to train the relevant AI/ML models which are deployed or updated in Near-RT RIC via O1 interface. Non-RT RIC and Near-RT RIC have exchanged capabilities for the support of QoS-aware resource optimization.	
Begins when	QoS-aware optimization policy is required to be initiated or updated.	
Step 1 (O)	**(Start of outer loop control)** Non-RT RIC evaluates the collected data and A1 policy feedback, if required, and generates or updates the appropriate QoS-aware resource optimization policy, such as QoS targets, and sends it to Near-RT RIC via A1 interface.	
Step 2 (M)	When Near-RT RIC receives an A1 policy from Non-RT RIC, Near-RT RIC initiates the corresponding optimization procedure.	
Step 3 (M)	**(Start of inner loop control)** Near-RT RIC subscribes to a UE context information and measurement metrics via E2 interface.	
Step 4 (M)	E2 nodes report the UE context information and E2 measurements via RIC REPORT periodically or event-triggered.	
Step 5 (M)	Near-RT RIC evaluates the performance data from E2 nodes (including performance data from different E2 nodes for the same UE) and finds the performance is out of QoS targets which are indicated in the A1 policy. If performance is within the targets, Near-RT RIC keeps monitoring.	
Step 6 (M)	Based on the UE context information, E2 measurement metrics (RIC REPORT), and A1 policy, Near-RT RIC may generate new or modify the existing E2 policies and sends them to E2 nodes. Near-RT RIC may also generate control command(s) and send them to E2 node(s) to trigger re-allocation of radio resources so that QoS indicators can move back to the limits outlined in the A1 policies. Step 3 to Step 6 may repeat. **(End of inner loop control)**	

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Step 7 (O)	If required, Near-RT RIC sends policy feedback to Non-RT RIC to assess the performance of QoS optimization function in Near-RT RIC, or to assess the outcome of the applied A1 policies. Subsequently, an A1 policy can be updated. Step 1 to Step 7 may repeat **(End of outer loop control)**	
Ends when	Non-RT RIC decides to delete QoS-aware resource optimization policy and sends the related message to Near-RT RIC.	
Exceptions	-	
Post Conditions	Non-RT RIC continues to collect and evaluate RAN data related to the QoS-aware optimization use case.	
Traceability	REQ-E2-QoS-FUN1, REQ-E2-QoS-FUN2, REQ-E2-QoS-FUN3, REQ-E2-QoS-FUN4, REQ-E2-QoS-FUN5, REQ-E2-QoS-FUN6	

```
@startuml
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skinparam BoxPadding 8
skinparam defaultFontSize 12

Box “Service Management and Orchestration” #gold
    Participant OF  as “OAM Functions”
    Participant non as “Non-RT RIC”
End box

Box “O-RAN” #lightpink
   Participant near as “Near-RT RIC”
   Participant ran  as “E2 Node”
End box

group OUTER LOOP CONTROL

ran <-> OF   : <<O1>> RAN data collection
OF   -> non  : Collected data
non  -> non  : Collected data evaluation & QoS target generation
non  -> near : <<A1-P>> A1 policy setup or update
near -> near : QoS optimization initiated

group INNER LOOP CONTROL
      near -> ran  : <<E2>> RIC SUBSCRIPTION REQUEST (UE context and/or Measurement metrics)
      ran  -> near : <<E2>> RIC INDICATION (UE context and/or Measurement metrics)
       non  -> near : (opt.) <<A1-EI>> QoS related A1 Enrichment Information
      near -> near : QoS performance monitoring
      near -> ran : (opt.) <<E2>> RIC SUBSCRIPTION REQUEST (QoS optimization RIC POLICY)
      near -> ran : (opt.) <<E2>> RIC CONTROL REQUEST (QoS optimization RIC CONTROL)
end

OF <- near : (opt.) <<O1>> QoS optimization related performance information
OF ->  non : (opt.) Performance information
non -> non : QoS optimization performance evaluation
end

non  -> near : <<A1-P>> A1 policy delete
near -> ran  : <<E2>> RIC SUBSCRIPTION DELETE

@enduml
```

The overall procedure for Qos based resource optimization use case is given in figure 4.2.3-1.

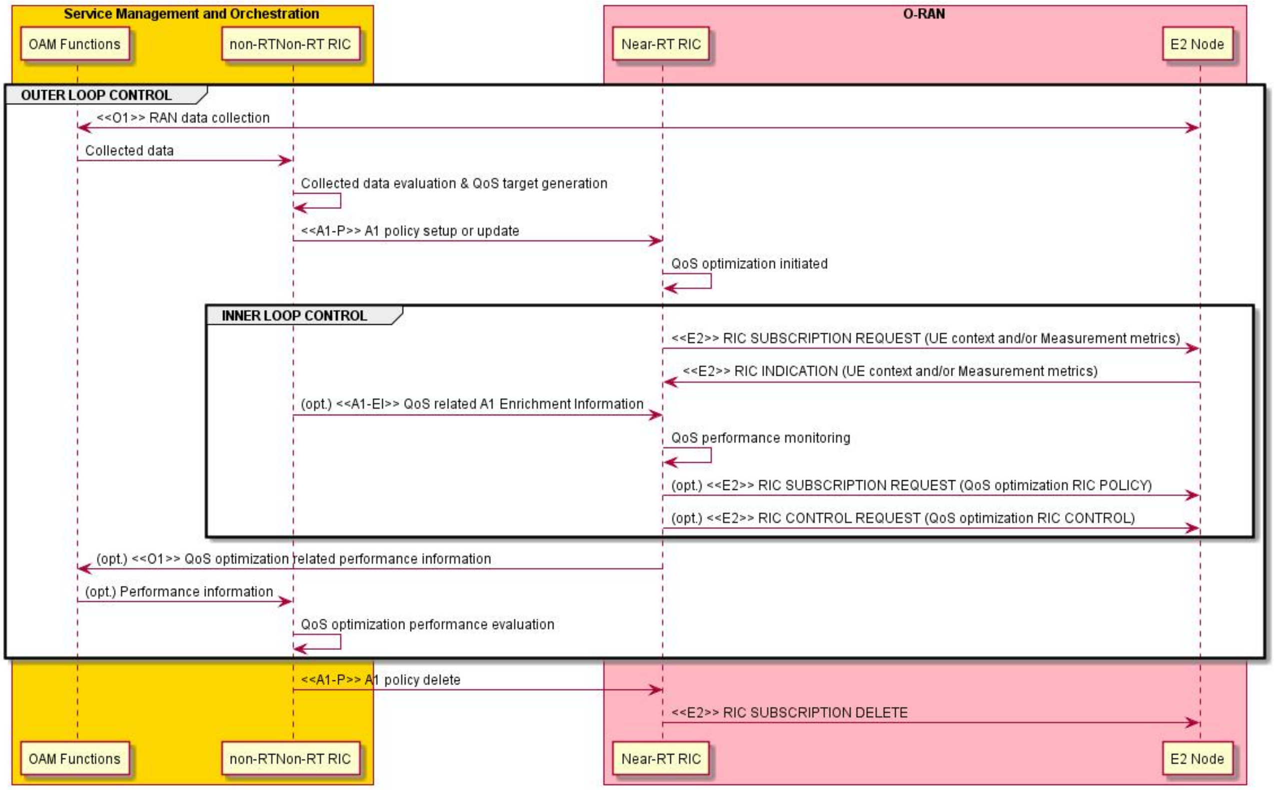

Figure 4.2.3-1: The overall procedure for Qos based resource optimization use case

4.2.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the QoS based resource optimization use case. The requirements are specified in clause 5.

4.2.4.1 Control over E2

1) **DRB control:** RB control can be applied for modification of the following QoS properties:

- DRB QoS modification (as specified in 3GPP TS 38.473 [21] and 3GPP TS 23.501 [3]): The DRB level QoS may be tuned to accommodate A1 policy requirement.
- QoS flow remapping (as specified in 3GPP TS 38.473 [21]): The mapping relationship between QoS flows and DRBs may be adjusted.
- Logical channel reconfiguration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): The relevant parameters can be considered, e.g., priority, prioritized bit rate, bucket size duration, etc.
- Radio admission control (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): DRB admission control such as reject, or release may be applied.
- Modification of dual-connectivity DRB (as specified in 3GPP TS 37.340 [13]): Change of bearer termination point (MN or SN) and/or bearer types (MCG/SCG/split), and control of split ratio for a split bearer.
- Activation and deactivation of packet duplication and configuration of the number of legs in DC, CA, or DC+CA scenarios (as specified in 3GPP TS 36.300 [8] and 3GPP TS 38.300 [14]).

RIC CONTROL (e.g., request for QoS flow remapping) or RIC POLICY (e.g., DRB admission policy) can be applicable.

2) **Radio resource allocation**, such as configuration of DRX, semi-persistent scheduling (SPS), or guidance for the scheduling and rate selection in MAC. For example, based on prediction, an E2 policy or control to reconfigure SPS configuration or *ConfiguredGrantConfig* for UL may be generated.

   - DRX reconfiguration (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Long DRX cycle length, short DRX cycle length as well as short DRX cycle timer can be considered.
   - SR periodicity reconfiguration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Both *sr-ProhibitTimer* and *sr-TransMax* can be treated.
   - SPS configuration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Both *SPS-Config* (DL) and *ConfiguredGrantConfig* (UL) can be treated.
   - Reconfiguration of slice level PRB quota (as specified in 3GPP TS 28.541 [4])
   - Configuration of CQI table with certain target block error rate (as specified in 3GPP TS 38.214 [15])

Both RIC POLICY and RIC CONTROL can be used. For example, SPS can be configured via RIC CONTROL; RIC POLICY can be used, e.g., to set the guidance for the scheduler.

3) **Radio access control:** Depending on operator's policies, deployment scenarios, subscriber profiles, and available services, different criterion will be used in determining which access attempt should be allowed or blocked when congestion occurs in the system, as specified in 3GPP TS 22.261 [1]. For example, access control may be applied to restrict access of other UEs for a specific cell in order to achieve better QoS for some UEs. A cell-level, UE-level, or slice-level access control can be applied. Four categories of radio access control are indicated as below:

   - RACH backoff
   - RRC connection reject
   - RRC connection release
   - Access barring

Both RIC POLICY and RIC CONTROL can be used.

4) **Connection mobility control:** For example, a neighbouring cell may be selected for the optimization of QoS of a specific UE. A neighbour handover restriction list may be configured to prevent the UEs from HO to some neighbouring cells in order to guarantee QoS of the UEs served by those neighbouring cells. Or a capacity boosting mechanism can be used to achieve better QoS, e.g., enable CA/DC.

   - Handover from the source cell to the target cell
   - Configuration/reconfiguration of handover restriction list
   - Enable, disable, or modify CA (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])
   - Enable, disable, or modify dual connectivity (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])

Both RIC POLICY and RIC CONTROL can be used. For the specific requirements and related stage-3 E2SM works, please refer to the traffic steering use case defined in clause 4.1.

5) **UE transmit power control:** For example, when the uplink interference is too large, it is difficult to achieve the uplink QoS target. In this case, UE transmit power control will be used to adjust the amount of interference to achieve required QoS. Near-RT RIC configures target value of uplink received quality such as received SINR or power at E2 node. E2 node controls the UE power by executing open-loop/closed-loop power control to UE to achieve target value configured by Near-RT RIC.

   - Configuration or modification of target value of uplink received quality such as received SINR or received power at E2 node.

RIC CONTROL, RIC POLICY can be used.

NOTE: When the target UEs are at the cell edge, their QoS of uplink can be improved by increasing their transmit power and/or allocating additional resources to the UEs. Hence for UEs at the cell edge, the optimization should consider the impact on serving and neighbour cell.

4.2.4.2 UE context information from E2 nodes

The followings are examples of UE context information identified as required:

- UE ID (as specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23])
- Slice level: S-NSSAI
- DRB level: e.g., established DRB ID, mapping with QoS flows, etc.
- QoS related: e.g., E-RAB level QoS parameters (4G, NSA) or QoS flow level QoS parameters (NG-RAN)
- UE capabilities: CA and DC capabilities
- RLC/MAC/PHY level: e.g., logical channel, DRX, scheduling request, SPS configurations

For example, UE ID, S-NSSAI, DRB ID, or QCI/5QI can be used for different granularity of controls over E2; an established DRB level information may be needed to change the mapping of QoS flows to a specific DRB or modify DRB attributes; the UE capabilities may be required to make sure if CA/DC can be enabled.

4.2.4.3 Measurements from E2 nodes

The E2 measurements are necessary for inference and prediction in the Near-RT RIC as the driver for decisions in addition to KPMs. For the QoS based resource optimization use case, the Near-RT RIC can translate an A1 policy (relatively static targets) into a flexible selection of controls over E2 (e.g., RB control, handover, access control) by taking into account the runtime status in the Near-RT RIC. Therefore, it is required to specify those measurement parameters as possible as needed over E2 interface.

The examples of UE-level, cell-level, and slice-level measurement information identified as required are listed in table 4.2.4.3-1 below.

Table 4.2.4.3-1: Measurements from E2 nodes

Measurement Type		Measurement Examples
UE-level	Radio channel info available at DU	1. **CQI** (*)
	Radio channel info available at CU-CP for serving cell	1. **RSRP** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) 2. **RSRQ** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) 3. **SINR** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) See NOTE 1.
	Radio channel info available at CU-CP for neighboring cells	1. **RSRP** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) 2. **RSRQ** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) 3. **SINR** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) See NOTE 2.
	L2	1. **DL/UL UE PRB usage for data traffic** (*) 2. **Average DL UE throughput in gNB** (*) 3. **Distribution of DL UE throughput in gNB** (*) 4. **Percentage of unrestricted DL UE data volume in gNB** (*) 5. **Packet Delay and RAN part packet delay components** (*) 6. **Packet Delay** (*) 7. **Data volume** (per QCI, as specified in 3GPP TS 36.314 [9], clause 4.1.8) 8. **DL PDCP occupied buffer size** (*) 9. **DL unused PDCP buffer size** (*) 10. **Packet Loss Rate per DRB** (as specified in 3GPP TS 38.314 [16], clause 4.2.1.5) and per logical channel (*)

Measurement Type		Measurement Examples
Cell-level	L2	**1. CQI** (available at DU; as specified in 3GPP TS 28.552 [6], clause 5.1.1.11.1) **2. MCS Distribution in PDSCH** (available at DU; as specified in 3GPP TS 28.552 [6], clause 5.1.1.12.1) **3. DL/UL Total PRB usage** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.1 and 5.1.1.2.2 and in 3GPP TS 32.425 [7], clauses 4.5.3 and 4.5.4) **4. Distribution of DL/UL Total PRB usage** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.3 and 5.1.1.2.4 and in 3GPP TS 32.425 [7], clauses 4.5.10 and 4.5.11) **5. DL/UL PRB used for data traffic** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.5 and 5.1.1.2.7) **6. DL/UL PRB usage for traffic** (per QCI, as specified in 3GPP TS 32.425 [7], clauses 4.5.1 and 4.5.2) **7. DL/UL Total available PRB** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.6 and 5.1.1.2.8) **8. DL/UL PRB full utilization** (as specified in 3GPP TS 32.425 [7], clauses 4.5.9.1 and 4.5.9.2) **9. Total number of DL/UL TBs** (available at DU; split into subcounters per layer at MU-MIMO case, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.7.3 and 5.1.1.7.8 and in 3GPP TS 32.425 [7], clauses 4.5.7.1 and 4.5.7.3) **10. Total error number of DL/UL TBs** (available at DU; split into subcounters per layer at MU-MIMO case, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.7.4 and 5.1.1.7.9 and in 3GPP TS 32.425 [7], clauses 4.5.7.2 and 4.5.7.4) **11. Average DL UE throughput in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.1) **12. Distribution of DL UE throughput in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.2) **13. Percentage of unrestricted DL UE data volume in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.5) **14. Packet Delay** (available at DU and CU-UP; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.3) **15. RAN part packet delay components** (as specified in 3GPP TS 38.314 [16], clause 4.2.1.2) **16. Packet Delay** (per QCI, as specified in 3GPP TS 36.314 [9], clause 4.1.4) **17. DL/UL Cell PDCP SDU Data Volume** (available at CU-UP; per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.2.1 for non-split gNB, clause 5.1.3.6.2 for split gNB; per PLMN ID and per E-RAB QoS profile (QCI, ARP and GBR), as specified in 3GPP TS 32.425 [7], clause 4.4.7) **18. Mean number of Active UEs in the DL/UL per cell** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.1 and 5.1.1.23.3) **19. Max number of Active UEs in the DL/UL per cell** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.2 and 5.1.1.23.4) **20. Average number of Active UEs** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.2) **21. Packet Loss Rate** (available at CU-UP or DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6],

Measurement Type		Measurement Examples
		clause 5.1.3.1) **22. Packet Loss Rate** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.4) **23. DL Packet Drop Rate** (available at CU-UP or DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.2) **24. DL Packet Drop Rate** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.3.2)
NOTE 1: Include periodical measurement report and/or RRC event trigger measurement report (A1-A6, B1-B2) (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [12]). NOTE 2: Include periodical measurement report and/or RRC event trigger measurement report (A1-A6, B1-B2) (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]).		

(*) Detailed measurement definition will be provided in E2SM specifications.

4.3 Use case 3: RAN slice SLA assurance

The 3GPP standards architected a sliceable 5G infrastructure which allows creation and management of customized networks to meet specific service requirements that can be demanded by future applications, services and business verticals. Such a flexible architecture needs different requirements to be specified in terms of functionality, performance and group of users which can greatly vary from one service to the other. The 5G standardization efforts have gone into defining specific slices and their Service Level Agreements (SLAs) based on application/service type as specified in 3GPP TS 22.261 [1]. Since network slicing is conceived to be an end-to-end feature that includes the core network, the transport network and the radio access network (RAN), these requirements should be met at any slice subnet during the life-time of a network slice as specified in 3GPP TS 28.530 [4], especially in RAN side. Exemplary slice performance requirements are specified in terms of throughput, energy efficiency, latency and reliability at a high level in SDOs such as 3GPP TS 22.261 [1] and GSMA [22]. These requirements are defined as a reference for SLA/contractual agreements for each slice, which individually need proper handling in NG-RAN.

Although network slicing support is started to be defined with 3GPP Release 15, slice assurance mechanisms in RAN needs to be further addressed to achieve deployable network slicing in an open RAN environment. It is necessary to assure the SLAs by dynamically controlling slice configurations based on slice specific performance information. Existing RAN performance measurements as specified in 3GPP TS 28.552 [6] and information model definitions as specified in 3GPP TS 28.541 [5] are not enough to support RAN slice SLA assurance use cases. This use case is intended to clarify necessary mechanisms and parameters for RAN slice SLA assurance.

In the context of the RAN, the SLA assurance parameters sent over the A1 interface help the Near-RT RIC guide the behavior of the E2 nodes (O-CU-UP, O-CU-CP, O-DU). The Non-RT RIC utilizes the slice SLA information and performance metrics to derive the necessary set of A1 policies and sends those to the Near-RT RICs related to a network slice. Each subtending Near-RT RICs uses these A1 policies for further cell-level and/or UE-level policy guidance and/or control action over the E2 interface that affects the cells and/or UEs, involved in the network slice, served by the respective E2 nodes. The combined guidance is handled as one or more A1 policies and/or E2 policies and/or E2 control actions. The intention of the SLA assurance parameters in the RAN context is to provide guidance to the E2 nodes for assuring SLAs of the network slices in the radio access network.

4.3.1 Background and goal of the use case

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 can 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.

5G core and O-RAN cooperation for SLA enforcement

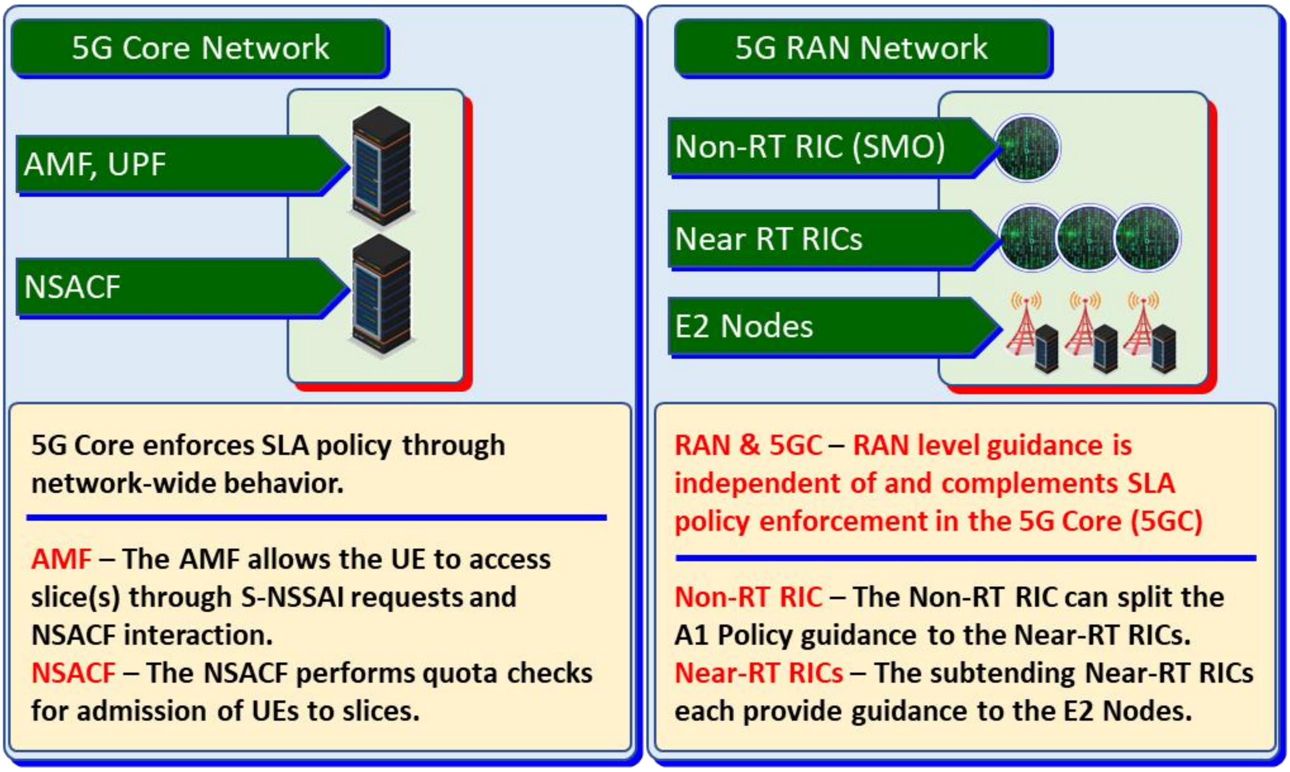

Figure 4.3.1-1: Core & RAN cooperation for SLA enforcement

The network functions and components that are related with SLA enforcement within 5G Core (5GC) and O-RAN are shown in figure 4.3.1-1. Although the 5GC enforces most of the SLA parameters, the components of the 5GC have a comprehensive view of the entire wireless network but from a core perspective. 3GPP Release 17 introduces the concept of a *Network Slice Admission Control Function* (NSACF). This debuted from the 3GPP TR 23.700-40 [i.3], and normative as specified in 3GPP TS 23.501 [31], clause 5.15.11. The purpose of the NSACF is to enforce some of the slice SLA parameters from a 5G core perspective. While NSACF handles slice-specific user admission control into the network as specified in GSMA NG.116 [22] GST criterion, the AMF allows the UE to access slice(s) through S-NSSAI or NSSAI requests through NSACF interaction. Together, they can perform network-level policy enforcement. However, these components do not have the detailed knowledge of RAN, such as RAN resources usage or where specific UEs are geographically located within a gNB. These 5GC components can perform only at a "network view" and they also do not have control over RAN resources.

O-RAN SLA assurance is independent of and complements 5GC SLA policy enforcement. Within the RAN, the Near-RT RIC provides unique SLA policy actions within the scope of E2 nodes based on the A1 policy guidance received from the Non-RT RIC.

Non-RT RIC & Near-RT RIC provide RAN guidance for SLA objectives

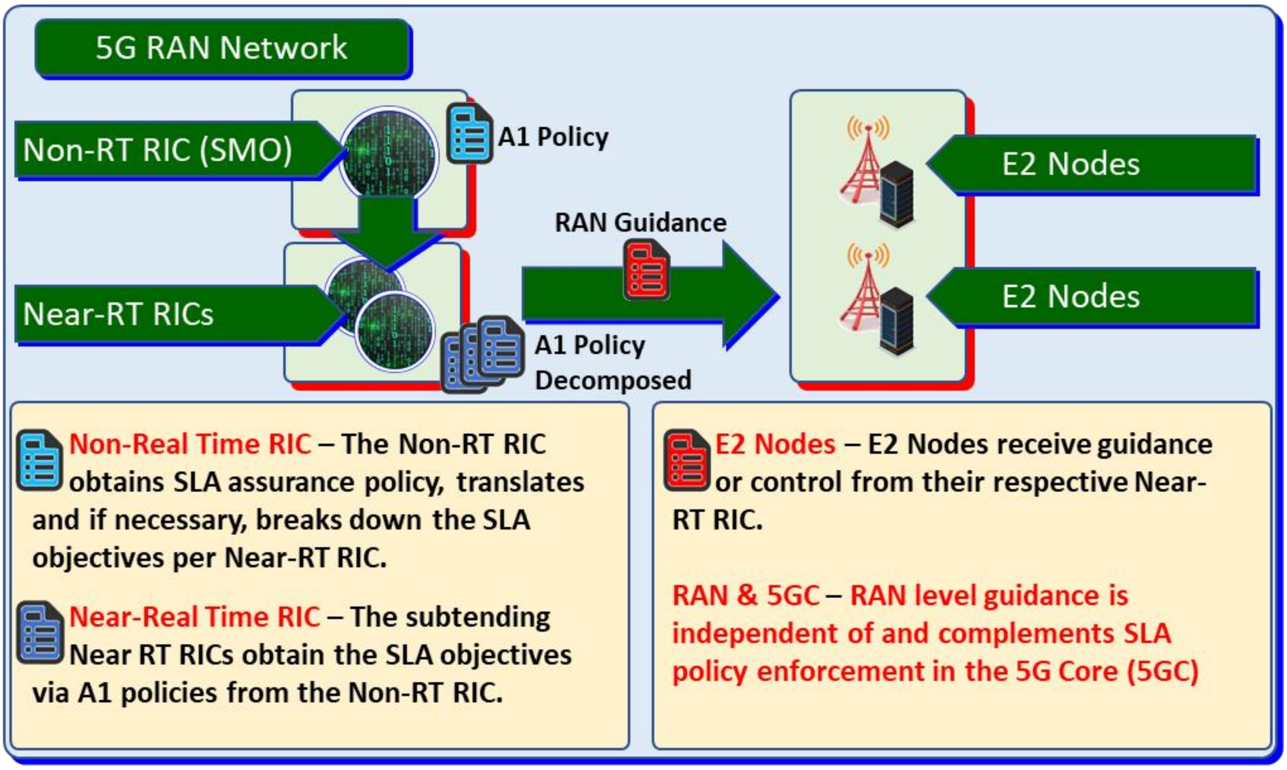

Figure 4.3.1-2: Non-RT RIC & Near-RT RIC RAN guidance

As shown in figure 4.3.1-2, the Non-Real Time RIC obtains the SLA parameters from SMO. The Non-RT RIC has a system level view of RAN topology, configuration and performance, so rApps can provide ongoing guidance and decompose SLA objects to the subtending Near-RT RICs. The Non-RT RIC then translates the SLA parameters into SLA objective A1 policies to its subtending Near-RT RIC(s). In some cases, the SLA parameters are already RAN or UE specific. Those SLA parameters would then not need any change in their values and would be "passed-through" to the Near-RT RIC(s) in A1 policies.

The Near-RT RICs obtain the SLA objectives via A1 policies from the Non-RT RIC. The Near-RT RIC can provide cell-level and/or UE-level guidance or control to the E2 nodes to achieve SLA assurance enforcement at the RAN level. The E2 nodes receive guidance or control from their respective Near-RT RICs. There are parameters as specified in GSMA GST/NEST NG.116 [22], such as the *Downlink and Uplink Throughput Per Network Slice,* that have both core and RAN applicability.

<u>For example</u>, the *Downlink and Uplink Throughput Per Network Slice* can be used by 5GC network functions; and the Non-RT RIC can calculate `maxUlThptPerSlice` and `maxDlThptPerSlice` parameters in an A1 policy which will then be used by the Near-RT RIC as target values via monitoring E2 node performance and, where required, requesting appropriate E2 services (CONTROL and/or POLICY) to provide guidance to the E2 nodes.

4.3.2 Entities/resources involved in the use case

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 Non-RT RIC for slow loop optimization and/or Near-RT RIC for fast loop optimization.
   d) Support deployment and update of AI/ML models into Near-RT RIC.
   e) Receive slice control/slice SLA assurance rApps from SMO.

f) Create and update A1 policies based on RAN intent and A1 feedback.
g) Send A1 policies and enrichment information to Near-RT RIC to drive slice assurance.
h) 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) Receive slice SLA assurance xApps from SMO.
   d) Support interpretation and execution of policies from Non-RT RIC.
   e) Perform optimized RAN (E2) actions to achieve RAN slice requirements based on O1 configuration, A1 policy, and E2 reports.
3) E2 node:
   a) Support slice assurance actions such as slice-aware resource allocation, prioritization, etc. through E2.
   b) Support slice specific performance measurements through O1.
   c) Support slice specific performance reports through E2.

4.3.3 Solutions

4.3.3.1 RAN slice SLA assurance

The context of RAN slice SLA assurance is captured in table 4.3.3.1-1.

Table 4.3.3.1-1: RAN slice SLA assurance

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	RAN slice SLA assurance	
Actors and Roles	SMO functions, Non-RT RIC framework, Near-RT RIC, E2 nodes	
Assumptions	All relevant functions and components are instantiated. A1, O1, E2 interface connectivity is established.	
Pre-conditions	Near-RT RIC and Non-RT RIC are instantiated with A1 interface connectivity being established between them. O1 interfaces are established between SMO and Near-RT RIC, and SMO and E2 nodes. RAN slice SLA assurance applications have been deployed in Non-RT RIC and Near-RT RIC respectively.	
Begins when	A RAN slice is activated, or an operator defined trigger is detected.	
Step 1 (M)	OAM functions may configure baseline slice SLA Assurance parameters in E2 node(s) through O1 interface. OAM functions collects data from E2 node through O1 interface.	
Step 2 (M)	RAN slice SLA assurance rApp retrieves relevant information from Non-RT RIC framework, such as active RAN slices (such as active S-NSSAIs, network slice subnet instances, topology), RAN slice SLA information, NF configuration, etc.	
Step 3 (M)	RAN slice SLA assurance rApp monitors and evaluates performance of RAN slices which may include detection of possible RAN slice SLA violation.	
Step 4 (M)	RAN slice SLA assurance rApp decides to apply A1 policy-based RAN slice SLA assurance considering RAN slice SLA requirements and/or operator-defined RAN intents, EI from external application servers and O1 based long term trends. In addition to these input parameters, A1 feedback from Near-RT RIC, when available, can be utilized for updating existing policies.	
Step 5 (M)	(Start of inner loop control) Near-RT RIC subscribes to a UE context information and measurement metrics via E2 interface.	
Step 6 (M)	E2 nodes report the UE context information and E2 measurements via RIC	

Use Case Stage	Evolution / Specification	<<Uses>> Related use
	REPORT periodically or event-triggered.	
Step 7 (M)	Near-RT RIC evaluates the performance data from E2 nodes (including performance data from different E2 nodes for the same UE) and finds the performance is out of slice SLA targets which are indicated in the A1 policy and/or internal Near-RT RIC slice SLA targets.	
Step 8 (M)	Based on the UE context information, E2 measurement metrics (RIC REPORT), and A1 policy, Near-RT RIC may generate new or modify the existing E2 policies and sends them to E2 nodes. Near-RT RIC may also generate control command(s) and send them to E2 node(s) to trigger re-allocation of radio resources so that slice SLA indicators can move back to the limits outlined in the A1 policies.	
Step 9 (O)	Near-RT RIC may send A1 policy feedback on A1 to the Non-RT RIC.	
Step 10 (O)	Non-RT RIC decides to delete slice SLA assurance policy and sends the related message or following internal trigger, the Near-RT RIC terminates the slice SLA Assurance procedure.	
Ends when	RAN slice(s) is deactivated or an operator defined trigger is detected.	
Exceptions	None identified.	
Post Conditions	SLA assurance for RAN slice(s) over a period of time is achieved.	
Traceability		

```
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Box “Service Management and Orchestration” #gold
    Participant OF  as “OAM Functions”
    Participant non as “Non-RT RIC”
End box

Box “O-RAN” #lightpink
   Participant near as “Near-RT RIC”
   Participant ran  as “E2 Node”
End box

group OUTER LOOP CONTROL

ran <-> OF   : <<O1>> RAN data collection
OF   -> non  : RAN Slice SLA assurance data


non  -> non  : Collected data evaluation and policy creation

non  -> near : <<A1>> SLA Assurance policy setup or update


group INNER LOOP CONTROL
      near -> ran  : <<E2>> RIC SUBSCRIPTION REQUEST (REPORT, UE context & Measurement
metrics)
      ran  -> near : <<E2>> RIC INDICATION (UE context & Measurement metrics)


      near -> near : Evaluation, possible SLA violation prevention
      near -> ran : (opt.) <<E2>> RIC SUBSCRIPTION REQUEST (POLICY)


near -> ran : (opt.) <<E2>> RIC CONTROL REQUEST (Slice SLA assurance RIC CONTROL)
end

non <-- near: (opt.) <<A1>> A1 Policy feedback

end
```



```
non --> near: (opt.) <<A1>> A1 policy delete
near -> near: (opt.)Slice SLA Assurance stopped
near-> ran: (opt.)<<E2>> RIC SUBSCRIPTION DELETE

@enduml
```

The flow diagram of the RAN slice SLA assurance is given in figure 4.3.3.1-1.

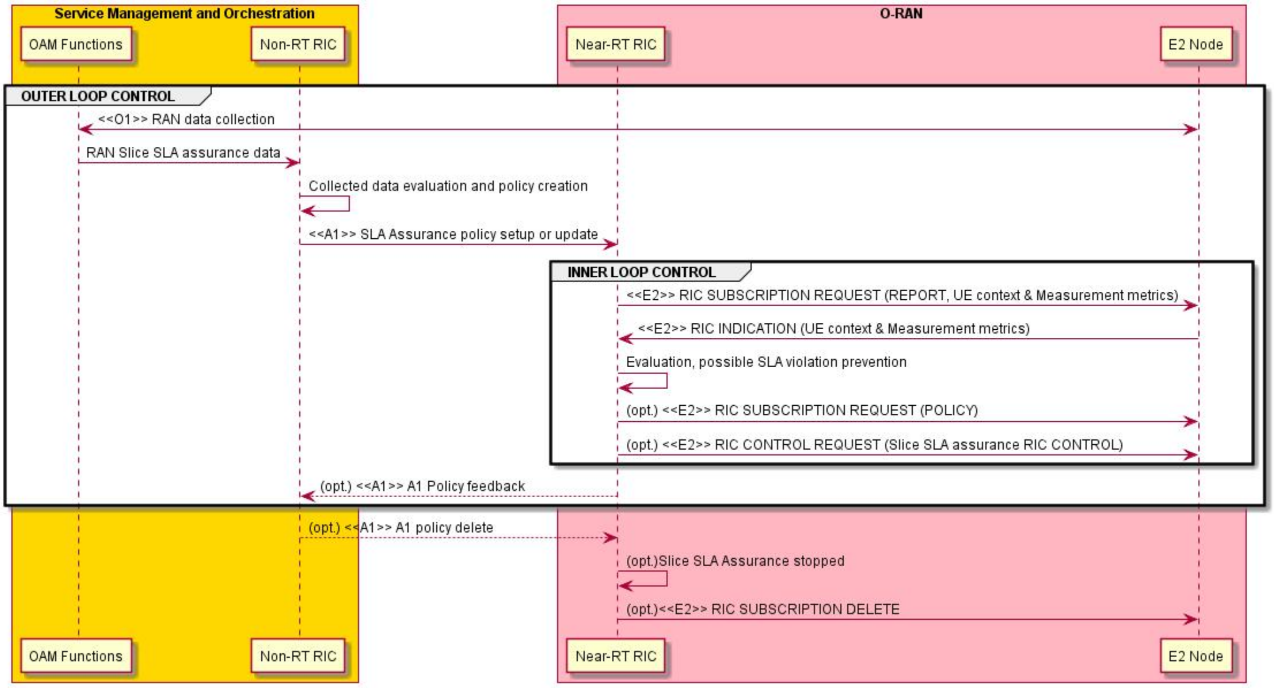

Figure 4.3.3.1-1: RAN slice SLA assurance

4.3.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the slice SLA assurance use case. The requirements are specified in clause 5.

4.3.4.1 Control over E2

1) **Radio resource allocation**, such as configuration of slice level PRB quota or per-cell-per-slice/QoS frequency partitions. For example, based on prediction, an E2 policy or control to reconfigure slice level PRB may be generated. Another example is, based on analysis of slice level interference among cells in terms of the reliability requirement, an E2 control to reconfigure frequency partitions may be generated.

   - Configuration and/or reconfiguration of slice level PRB quota (as specified in 3GPP TS 28.541 [4])
   - Configuration and/or reconfiguration of per-cell-per-slice/QoS frequency partitions

Both RIC POLICY and RIC CONTROL can be used.

2) **Radio access control:** Depending on operator's policies, deployment scenarios, subscriber profiles, available services and SLA of slice, different criterion will be used in determining which access attempt should be allowed or blocked when congestion occurs in the system, as specified in 3GPP TS 22.261 [1]. For example, access control may be applied to restrict access of other UEs for a specific slice in order to achieve better SLA for some slice. A UE-level, or slice-level access control can be applied. Three categories of radio access control are indicated as below:

- RRC connection reject
- RRC connection release
- Access barring

4.3.4.2 UE context information from E2 nodes

The followings are examples of UE context information identified as required:

- UE ID
- Slice level: S-NSSAI
- QoS level: 5QI
- UE-level RAN state information
- UE-level PM data

For example, UE ID, S-NSSAI and 5QI can be used to derive the resource occupation of each slice.

4.3.4.3 Measurements from E2 nodes

The E2 measurements are necessary for inference and prediction in the Near-RT RIC as the driver for decisions in addition to KPMs. For the slice SLA assurance use case, the Near-RT RIC can translate an A1 policy (relatively static targets) into a flexible selection of controls over E2 (e.g., PRB control, access control) by taking into account the runtime status in the Near-RT RIC. Therefore, it is required to specify those measurement parameters as possible as needed over E2 interface.

The examples of cell-level, UE-level, and slice-level measurement information identified as required are listed in table 4.3.4.3-1 below.

Table 4.3.4.3-1: Measurements from E2 nodes

Measurement Type		Measurement Examples
Cell-level	L2	**1. DL/UL Total PRB usage** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.1 and 5.1.1.2.2 and in 3GPP TS 32.425 [7], clauses 4.5.3 and 4.5.4) **2. Distribution of DL/UL Total PRB usage** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.3 and 5.1.1.2.4 and in 3GPP TS 32.425 [7], clauses 4.5.10 and 4.5.11) **3. DL/UL PRB used for data traffic** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.5 and 5.1.1.2.7) **4. DL/UL Total available PRB** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.6 and 5.1.1.2.8) **5. Average DL UE throughput in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.1) **6. Distribution of DL UE throughput in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.2) **7. Packet Delay** (available at DU and CU-UP; optionally split into subcounters

Measurement Type		Measurement Examples
		per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.3) **8. DL/UL Cell PDCP SDU Data Volume** (available at CU-UP; per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.2.1 for non-split gNB, clause 5.1.3.6.2 for split gNB; per PLMN ID and per E-RAB QoS profile (QCI, ARP and GBR), as specified in 3GPP TS 32.425 [7], clause 4.4.7) **9. Mean number of Active UEs in the DL/UL per cell** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.1 and 5.1.1.23.3) **10. Max number of Active UEs in the DL/UL per cell** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.2 and 5.1.1.23.4) **11. Average number of Active UEs** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.2) **12. Packet Loss Rate** (available at CU-UP or DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.1) **13. Packet Loss Rate** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.4) **14. DL Packet Drop Rate** (available at CU-UP or DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.2) **15. DL Packet Drop Rate** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.3.2) **16. Wideband CQI distribution** (as specified in 3GPP TS 28.552 [6], clause 5.1.1.11.1) **17. SS-RSRP distribution per SSB for serving cell** (as specified in 3GPP TS 28.552 [6], clause 5.1.1.22.1) **18. SS-RSRP distribution per SSB for neighbor cell** (as specified in 3GPP TS 28.552 [6], clause 5.1.1.22.1)
Slice-level	L2	**1. DL/UL PRB used for data traffic** (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.5 and 5.1.1.2.7) **2. Average DL UE throughput in gNB** (as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.1) **3. Distribution of DL UE throughput in gNB** (as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.2) **4. Packet Delay** (as specified in 3GPP TS 28.552 [6], clause 5.1.3.3) **5. DL/UL Cell PDCP SDU Data Volume** (as specified in 3GPP TS 32.425 [7], clause 4.4.7) **6. Mean number of Active UEs in the DL/UL per cell** (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.1 and 5.1.1.23.3) **7. Max number of Active UEs in the DL/UL per cell** (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.2 and 5.1.1.23.4) **8. Packet Loss Rate** (as specified in 3GPP TS 28.552 [6], clause 5.1.3.1) **9. DL Packet Drop Rate** (as specified in 3GPP TS 28.552 [6], clause 5.1.3.2)
UE-level	L2	**1. DL/UL PRB used for data traffic** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **2. Average DL UE throughput in gNB** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **3. Distribution of DL UE throughput in gNB** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **4. Packet Delay** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **5. DL/UL Cell PDCP SDU Data Volume** (as specified in 3GPP O-RAN WG3

Measurement Type		Measurement Examples
		E2SM-KPM [36]) **6. Mean number of Active UEs in the DL/UL per cell** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **7. Max number of Active UEs in the DL/UL per cell** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **8. Packet Loss Rate** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **9. DL Packet Drop Rate** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **10. DRB-specific RLC buffer occupancy** (as specified in 3GPP O-RAN WG3 E2SM-RC [37]) **11. Serving cell and neighbor cell RRC measurements** (as specified in 3GPP O-RAN WG3 E2SM-RC [37]) **12. Number of DRBs and PDU sessions** (as specified in 3GPP O-RAN WG3 E2SM-RC [37]) **13. Number of QoS flows and QoS parameters of QoS flows mapped to each DRB** (as specified in 3GPP O-RAN WG3 E2SM-RC [37]) **14. Number of HARQ TBs with specific MCS rates** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **15. CQI** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36]) **16. Serving cell and neighbor cell RSRP** (as specified in 3GPP O-RAN WG3 E2SM-KPM [36])

4.4 Use case 4: Massive MIMO optimization

4.4.1 Background and goal of the use case

Please refer to O-RAN.WG1.mMIMO-Use-Cases-TR-v01.00 [i.2] and to use case 22 in ORAN-WG1.Use Cases Detailed Specification R003 v11.00 [32].

4.4.2 Entities/resources involved in the use case

NOTE: The AI/ML model training, deployment, and inference described below cannot be applicable for some mMIMO optimization features.

1) SMO/Non-RT RIC:
   - Retrieve necessary performance indicators, measurement reports and RAN configurations from E2 nodes via the O1 interface for the purpose of AI/ML model training and performance monitoring.
     - E.g., the number of supported Non-GoB BF modes in O-DU.
   - Collect enrichment information from application servers and associate enrichment information with collected measurements and configurations.
   - Perform AI/ML model training and deployment.
   - Perform AI/ML model performance monitoring and re-training.
   - Send enrichment information to the Near-RT RIC for inference via the A1 interface.

NOTE: The requirements of SMO/Non-RT RIC are under the scope of WG2.

2) Near-RT RIC:
   - Support AI/ML model deployment from the Non-RT RIC via the O1/O2 interface.
   - Subscribe and retrieve necessary performance and failure indicators, measurement reports, UE context information and RAN configurations from E2 nodes via the E2 interface for the purpose of mMIMO optimization.
   - Retrieve enrichment information from Non-RT RIC via the A1 interface, and associate enrichment information with collected measurements and configurations.
   - Perform AI/ML model training and inference.

- Perform AI/ML model performance monitoring and re-training.
- Send control or policy message for massive MIMO optimization to E2 nodes via the E2 interface.

3) E2 nodes:
   - Support reporting of necessary performance indicators, measurement reports, UE context information and RAN configurations with required granularity to SMO/Non-RT RIC via the O1 interface.
   - Support reporting of necessary performance and failure indicators, measurement reports, UE context information collection and RAN configurations with required granularity to Near-RT RIC via the E2 interface.
   - Execute control/policy message received from the Near-RT RIC via the E2 interface.

4.4.3 Solutions

4.4.3.1 AI/ML-assisted Non-Grid-of-Beams beamforming optimization

4.4.3.1.1 Model training in Non-RT RIC

NOTE: The below table 4.4.3.1.1-1 and figure 4.4.3.1.1-1 are under the scope of WG2.

The context of AI/ML-assisted Non-GoB BF mode selection in Non-RT RIC – model training, deployment, and update is captured in table 4.4.3.1.1-1.

Table 4.4.3.1.1-1: AI/ML-assisted Non-GoB BF mode selection in Non-RT RIC – model training, deployment, and update

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	To train an AI/ML model to select the best Non-GoB BF modes given wireless conditions and RAN configuration.	
Actors and Roles	SMO, Non-RT RIC, Near-RT RIC, O-DU, Application server	
Assumptions	- All relevant functions and components are instantiated. - O1 interface connectivity is established.	
Pre-conditions	- O1 interface is established between SMO and O-DU to enable SMO/Non-RT RIC to obtain the number of supported Non-GoB BF modes and to collect performance measurement data and associated RAN configurations. - A1 interface is established between Non-RT RIC and Near-RT RIC to enable enrichment information transfer. - O-DU supports Non-GoB BF.	
Begins when	Operator specified trigger condition or event is satisfied.	
Step 1 (M)	SMO requests the number of supported Non-GoB BF modes in O-DU via the O1 interface.	
Step 2 (M)	SMO collects the number of supported Non-GoB BF modes in O-DU via the O1 interface.	
Step 3 (M)	Non-RT RIC retrieves collected information.	
Step 4 (M)	For each Non-GoB BF mode, SMO requests performance measurement data and associated RAN configurations from O-DU for model training via the O1 interface.	
Step 5 (M)	SMO collects required performance measurement data and RAN configurations from O-DU via the O1 interface.	
Step 6 (M)	SMO collects enrichment information (e.g., UE mobility and location info.) from application server.	
Step 7 (M)	Non-RT RIC retrieves collected data and enrichment information.	
Step 8 (M)	For each Non-GoB BF mode, Non-RT RIC associates received enrichment information with measurement data and RAN configurations.	
Step 9 (M)	Non-RT RIC performs model training.	
Step 10 (M)	Non-RT RIC deploys trained model to the Near-RT RIC via O1 or O2 interface.	
Step 11 (M)	For each Non-GoB BF mode, SMO requests performance measurement data from O-DU for performance monitoring via the O1 interface.	
Step 12 (M)	For each Non-GoB BF mode, SMO collects performance measurement data from O-DU for performance monitoring via the O1 interface.	
Step 13 (M)	SMO collects enrichment information (e.g., UE mobility and location info.) from application server.	
Step 14 (M)	Non-RT RIC retrieves collected performance monitoring data and enrichment information.	
Step 15 (M)	Non-RT RIC evaluates the performance of deployed AI/ML model.	
Step 16 (M)	Non-RT RIC re-trains the model.	
Step 17 (M)	Non-RT RIC updates model in the Near-RT RIC via O1 or O2 interface.	
Ends when	Operator specified trigger condition or event is satisfied.	
Exceptions	None identified.	
Post Conditions	Near-RT RIC executes the deployed model for AI/ML-assisted Non-GoB BF.	
Traceability	REQ-Non-RT-RIC-FUN1, REQ-Non-RT-RIC-FUN4, REQ-Non-RT-RIC-FUN5, REQ-Non-RT-RIC-FUN9, REQ-A1-FUN2, REQ-Near-RT-RIC-MM-FUN2	

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  Participant “Non-RT RIC” as non
End box

Box “O-RAN” #lightpink
  Participant near as “Near-RT RIC”
  Participant ran as “O-DU”
End box

Box “External” #lightcyan
  Participant “Application Server” as app
End box

group Data Collection
  smo -> ran : <<O1>> Request the number of supported Non-GoB BF modes
  ran -> smo : <<O1>> Collect the number of supported Non-GoB BF modes
  smo -> non : Retrieve collected information

  smo -> ran : <<O1>> Request measurement data and RAN configurations for each Non-GoB BF mode
  ran -> smo : <<O1>> Collect measurement data and RAN configurations for each Non-GoB BF mode
  app -> smo : Collect enrichment information (e.g., UE location/mobility, etc.)
  smo -> non : Retrieve collected data
end

group AI/ML workflow
  non -> non : Associate enrichment information with \n measurements and configurations
  non -> non : Train AI/ML models to select \n the best Non-GoB mode
  non -> near: <<O1>> or <<O2>> \n Deploy AI/ML models
end

group Performance evaluation and optimization
  smo -> ran : <<O1>> Request measurement data and RAN configurations for each Non-GoB BF mode
  ran -> smo : <<O1>> Collect measurement data and RAN configurations for each Non-GoB BF mode
  app -> smo : Collect enrichment information (e.g., UE location/mobility, etc.)
  smo -> non : Retrieve collected data
  non -> non : Performance monitoring & evaluation
  non -> non : Re-train AI/ML models
  non -> near: <<O1>> or <<O2>> \n Update AI/ML models
end
@enduml
```

The flow diagram of the AI/ML model training in Non-RT RIC, deployment, and performance monitoring is given in figure 4.4.3.1.1-1.

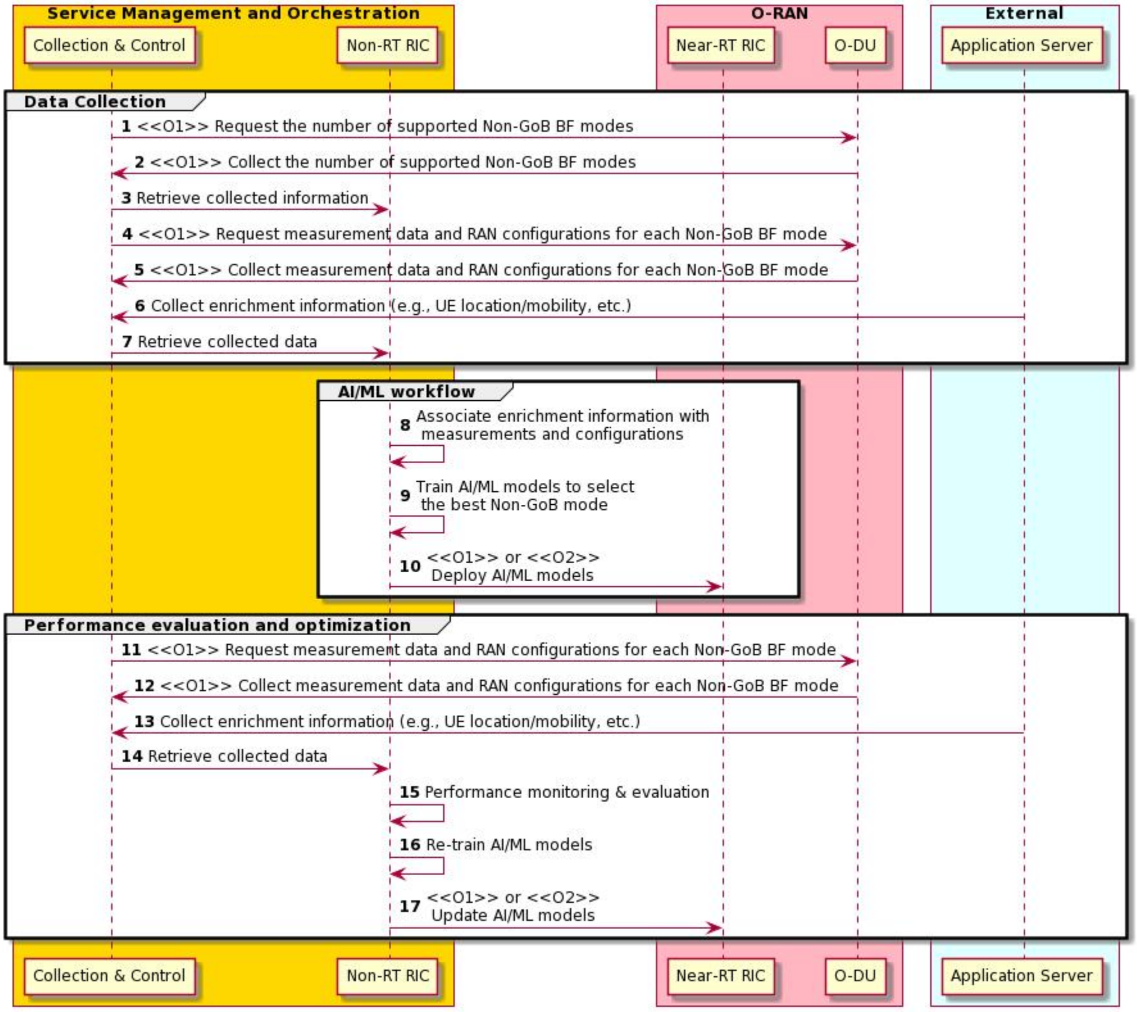

Figure 4.4.3.1.1-1: AI/ML model training in Non-RT RIC, deployment, and performance monitoring

4.4.3.1.2 Model training in Near-RT RIC

The context of AI/ML-assisted Non-GoB BF mode selection – model training in Near-RT RIC, deployment, and update is captured in table 4.4.3.1.2-1.

Table 4.4.3.1.2-1: AI/ML-assisted Non-GoB BF mode selection – model training in Near-RT RIC, deployment, and update

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	To train an AI/ML model to select the best Non-GoB BF modes given wireless conditions and RAN configuration.	
Actors and Roles	SMO, Non-RT RIC, Near-RT RIC, O-DU, Application server	
Assumptions	- All relevant functions and components are instantiated.	
Pre-conditions	- A1 interface is established between Non-RT RIC and Near-RT RIC to enable enrichment information transfer. - O-DU supports Non-GoB BF. - E2 interface is established between Near-RT RIC and O-DU.	
Begins when	Operator specified trigger condition or event is satisfied.	
Step 1 (M)	Near-RT RIC requests the number of supported Non-GoB BF modes in O-DU via the E2 interface.	
Step 2 (M)	Near-RT RIC collects the number of supported Non-GoB BF modes in O-DU via the E2 interface.	
Step 3 (M)	For each Non-GoB BF mode, Near-RT RIC requests performance measurement data and associated RAN configurations from O-DU for model training via the E2 interface.	
Step 4 (M)	Near-RT RIC collects required performance measurement data and RAN configurations from O-DU via the E2 interface.	
Step 5 (M)	Near-RT RIC collects enrichment information (e.g., UE mobility and location info) from Non-RT RIC via the A1 interface.	
Step 6 (M)	For each Non-GoB BF mode, Near-RT RIC associates received enrichment information with measurement data and RAN configurations.	
Step 7 (M)	Near-RT RIC performs model training.	
Step 8 (M)	For each Non-GoB BF mode, Near-RT RIC requests performance measurement data from O-DU for performance monitoring/training updates via the E2 interface.	
Step 9 (M)	For each Non-GoB BF mode, Near-RT RIC collects performance measurement data from O-DU for performance monitoring/training updates via the E2 interface.	
Step 10 (M)	Near-RT RIC collects enrichment information (e.g., UE mobility and location info) from Non-RT RIC via the A1 interface.	
Step 11 (M)	Near-RT RIC evaluates the performance of deployed AI/ML model.	
Step 12 (M)	Near-RT RIC re-trains the model.	
Ends when	Operator specified trigger condition or event is satisfied.	
Exceptions	None identified.	
Post Conditions	Near-RT RIC executes the deployed model for AI/ML-assisted Non-GoB BF.	
Traceability	REQ-Non-RT-RIC-FUN9, REQ-A1-FUN3, REQ-Near-RT-RIC-MM-FUN1, REQ-Near-RT-RIC-MM-FUN3, REQ-E2-MM-FUN2, REQ-E2-MM-FUN3, REQ-E2-MM-FUN5, REQ-E2-MM-FUN6, REQ-E2-MM-FUN9, REQ-E2-MM-FUN10	

```
@startuml
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12
autonumber

Box “Service Management and Orchestration” #gold
  Participant “Collection & Control” as smo
  Participant “Non-RT RIC” as non
End box

Box “O-RAN” #lightpink
  Participant near as “Near-RT RIC”
  Participant ran as “O-DU”
```

```
End box

Box "External" #lightcyan
  Participant "Application Server" as app
End box

group Data Collection
  near -> ran : <<E2>> Request the number of supported Non-GoB BF modes
  ran -> near : <<E2>> Collect the number of supported Non-GoB BF modes

  near -> ran : <<E2>> Request measurement data and RAN configurations for each Non-GoB BF
mode
  ran -> near : <<E2>> Collect measurement data and RAN configurations for each Non-GoB BF
mode
  non -> near : <<A1>> Collect enrichment information (e.g., UE location/mobility, etc.)
end

group AI/ML workflow
  near -> near: Associate enrichment information with \n measurements and configurations
  near -> near: Train AI/ML models to select \n the best Non-GoB mode
end

group Performance evaluation and optimization
  near -> ran : <<E2>> Request measurement data and RAN configurations for each Non-GoB BF
mode
  ran -> near: <<E2>> Collect measurement data and RAN configurations for each Non-GoB BF mode
  non -> near : <<A1>> Collect enrichment information (e.g., UE location/mobility, etc.)
  near -> near: Performance monitoring & evaluation
  near -> near: Re-train AI/ML models
end
@enduml
```

The flow diagram of the AI/ML model training in Near-RT RIC, deployment, and performance monitoring is given in figure 4.4.3.1.2-1.

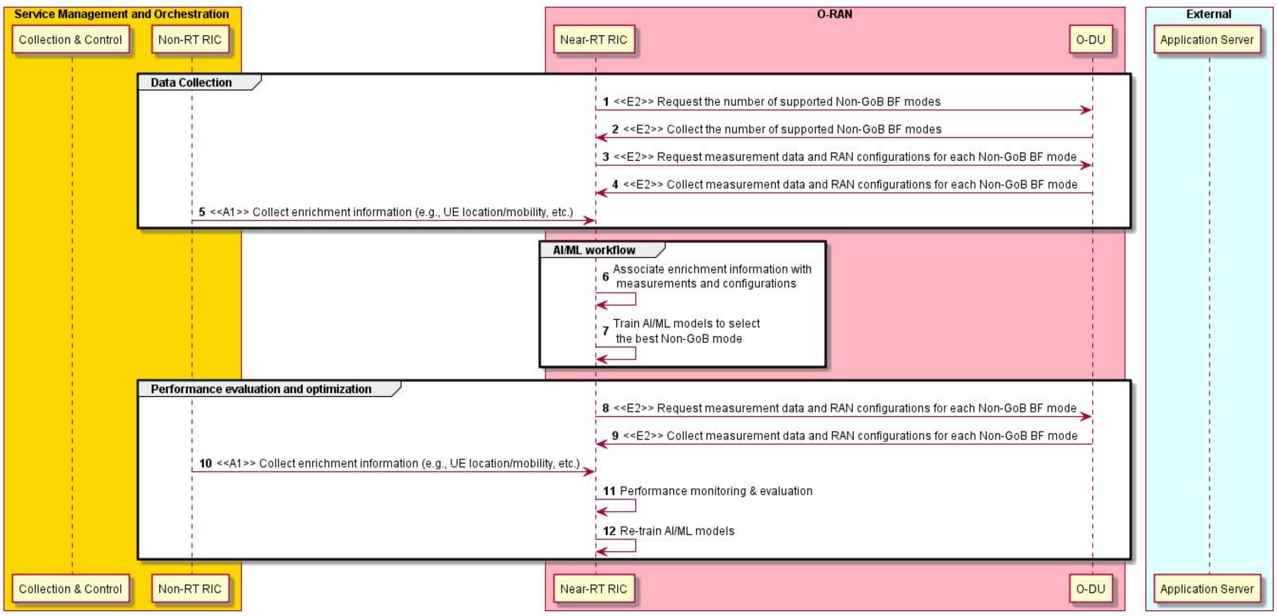

Figure 4.4.3.1.2-1: AI/ML model training in Near-RT RIC, deployment, and performance monitoring

4.4.3.1.3 Model inference

The context of AI/ML-assisted Non-GoB BF mode selection – model inference is captured in table 4.4.3.1.3-1.

Table 4.4.3.1.3-1: AI/ML-assisted Non-GoB BF mode selection – model inference

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	To generate Non-GoB control/policy message.	
Actors and Roles	SMO, Non-RT RIC, Near-RT RIC, O-DU, Application server	
Assumptions	- All relevant functions and components are instantiated. - A1 and E2 interface connectivity are established.	
Pre-conditions	- A1 interface is established between Non-RT RIC and Near-RT RIC to enable enrichment information transfer. - E2 interface is established between Near-RT RIC and O-DU to enable Non-GoB BF mode selection via E2 control/policy message. - O-DU supports Non-GoB BF.	
Begins when	Operator specified trigger condition or event is satisfied.	
Step 1 (M)	SMO collects enrichment information (e.g., UE mobility/location info) from application server.	
Step 2 (M)	Non-RT RIC retrieves collected enrichment information.	
Step 3 (M)	Non-RT RIC sends collected enrichment information to the Near-RT RIC via the A1 interface.	
Step 4 (M)	Near-RT RIC requests measurement data and UE context information (e.g., SRS periodicity) from O-DU via the E2 interface.	
Step 5 (M)	Near-RT RIC collects measurement data and UE context information (e.g., SRS periodicity) from O-DU via the E2 interface.	
Step 6 (M)	Near-RT RIC associates received enrichment information with collected measurement data and UE context information.	
Step 7 (M)	Near-RT RIC performs model inference.	
Step 8 (M)	Near-RT RIC generates Non-GoB control/policy message based on inferred Non-GoB BF mode selection.	
Step 9 (M)	Near-RT RIC sends Non-GoB control/policy message to O-DU via the E2 interface.	
Ends when	Operator specified trigger condition or event is satisfied.	
Exceptions	None identified.	
Post Conditions	Non-RT RIC monitors the performance of AI/ML-assisted Non-GoB BF mode selection in the Near-RT RIC.	
Traceability	REQ-Non-RT-RIC-FUN9, REQ-A1-FUN3, REQ-Near-RT-RIC-MM-FUN2, REQ-Near-RT-RIC-MM-FUN3, REQ-E2-MM-FUN2, REQ-E2-MM-FUN3, REQ-E2-MM-FUN5, REQ-E2-MM-FUN6	

```
@startuml
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12
autonumber

Box "Service Management and Orchestration" #gold
  Participant "Collection & Control" as smo
  Participant "Non-RT RIC" as non
End box

Box "O-RAN" #lightpink
  Participant near as "Near-RT RIC"
  Participant ran as "O-DU"
End box
```



```
Box "External" #lightcyan
  Participant "Application Server" as app
End box

app -> smo : Collect enrichment information (e.g., UE location/mobility, etc.)
smo -> non : Retrieve collected data
non -> near : <<A1>> Enrichment information

group E2 control & Policy
  near -> ran : <<E2>> Request measurement data \n and UE context information (e.g., SRS 
periodicity)
  ran -> near : <<E2>> Collect measurement data \n and UE context information (e.g., SRS 
periodicity)
  near -> near: Associate enrichment information with \n collected measurements and 
configurations
  near -> near : Perform AI/ML model inference
  near -> near : Generate Non-GoB control/policy message
  near -> ran : <<E2>> Non-GoB control/policy message
end

@enduml
```

The flow diagram of the AI/ML inference is given in figure 4.4.3.1.3-1.

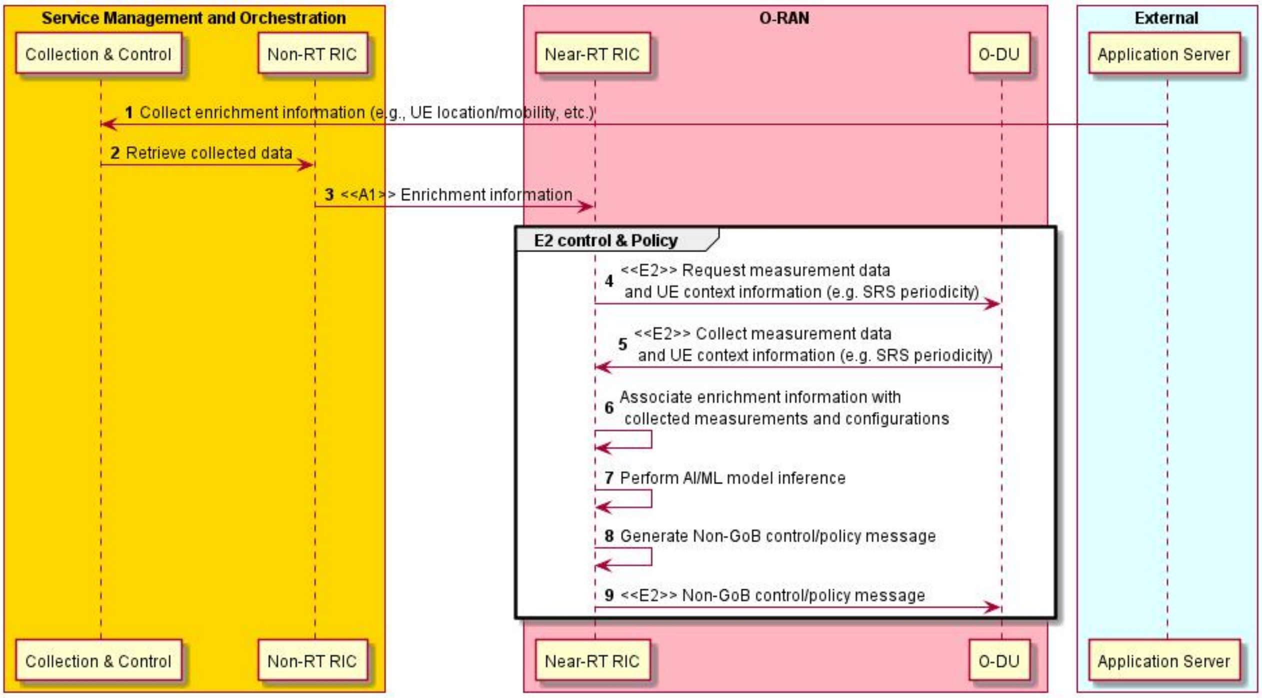

Figure 4.4.3.1.3-1: AI/ML Inference

4.4.3.2 Beam-based Mobility Robustness Optimization (bMRO)

Beam-based Mobility Robustness Optimization (bMRO) is an autonomous self-optimizing algorithm that improves beam-based inter-cell mobility performance by applying beam-specific HO parameters including Cell Individual Offsets (CIO), Time to Trigger (TTT), T310 counter, etc. on the handover configuration between neighbor cells, based on the analysis of beam-specific mobility-related counters and/or mobility failure events. bMRO is capable to reduce the number of unnecessary handovers, handover failures as well as ping-pong handovers particularly in cells that cover areas with different mobility characteristics. Performance, complexity and gain analysis has been provided in O-RAN.WG1.mMIMO-Use-Cases-TR-v01.00 [i.2], clause 3.3. Signaling overhead and complexity (RRC re-configuration, mobility reporting and O-CU reconfiguration messages) can be further reduced by beam grouping in which case beams with similar mobility characteristics comprise a beam group (e.g., group 1: low mobility pedestrian area, group 2: high mobility street). Mobility reports consist of aggregated mobility KPI/PMs (e.g., number of too early HOs, number of too late HOs, number of HO to wrong cell) or individual failure reports with root cause (e.g., to early HO, too late HO, HO to wrong cell) or a combination of the two. Reports are sent per each SSB beam or SSB beam group towards each neighbor cell. Individual mobility failure reports will also be reported per UE to allow UE or UE group-based optimization (besides beam or beam group specific reporting). While aggregated mobility KPIs/PMs are used for slow adaptations (e.g., 5 min), individual failure reports are used for faster adaptations (e.g., 100 ms) or for AI/ML based analysis of failure patterns. Measurement reporting periodicity and measurement type are configurable on a per cell basis considering the tradeoff between gain in mobility performance and associated signaling overhead. Mobility KPIs and failure events are forwarded from the O-CU to the Near-RT RIC, and the Near-RT RIC configures the CIO and the measurement reporting in the O-CUs. CIOs might be beam- or beam group-based and can also be configurable per UE group (e.g., UE type, UE mobility or UE mode such as energy saving mode).

While AI/ML based approaches are not mandated, AI/ML methods/models can be used i) to build beam groups, to ii) decide on cell individual measurement configuration, to iii) detect changes in mobility characteristics (e.g., traffic jam) that trigger optimization, to iv) group UEs in UE groups as well as v) for the bMRO optimization algorithm itself to calculate the optimal cell individual offsets. In case of dynamic beam pattern optimization, relevant mMIMO beam pattern information shall be available at the Near-RT RIC, e.g., mobility reports might indicate a specific beam pattern.

The context of Near-RT RIC beam-based mobility robustness optimization – model training and beam grouping is captured in table 4.4.3.2-1.

Table 4.4.3.2-1: Near-RT RIC beam-based mobility robustness optimization – model training and beam grouping

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	To obtain beam pattern optimization in case of Grid-of-Beam optimization, to train the ML models and to decide on the beam grouping.	
Actors and Roles	SMO, Near-RT RIC, E2 node (O-CU)	
Assumptions	- All relevant functions and components are instantiated. - O1 and E2 interface connectivity are established.	
Pre-conditions	- Network is operational with default configuration. - (optional) OAM functions have configured bMRO targets in Near-RT RIC through O1 interface. - OAM functions have configured baseline mobility parameters in O-CUs through O1 interface. - O-CUs support reporting of beam-based mobility performance and/or instantaneous mobility failure event reporting. - Near-RT RIC has access to the beam-based mobility performance and/or failure reporting from the E2 node.	
Begins when	Operator specified trigger condition or event is satisfied.	
Step 1 (M)	OAM provides ML model to the Near-RT RIC via O1 or O2 interface (e.g., to perform beam grouping, to identify a change in mobility characteristics, to derive optimized mobility reporting configuration and/or to calculate the optimized mobility settings).	
Step 2 (M)	Near-RT RIC subscribes to cell change configuration reports from E2 node (O-CU) to obtain mMIMO beam pattern information.	
Step 3 (M)	Near-RT RIC obtains cell change configuration reports from E2 node (O-CU) including mMIMO beam pattern information.	
Step 4 (M)	Near-RT RIC subscribes to beam based mobility performance and failure reporting via E2 interface.	
Step 5 (M)	Near-RT RIC obtains to beam based mobility performance and failure reporting via E2 interface.	
Step 6 (M)	Near-RT RIC performs model training.	
Step 7 (M)	Near-RT RIC obtains to beam based mobility performance and failure reporting via E2 interface.	
Step 8 (M)	Near-RT RIC performs AI/ML based beam grouping algorithm to group beams with similar mobility characteristics based on received mobility reports.	
Step 9 (M)	Near-RT RIC generates beam grouping policy message and send policy message to O-CUs via E2 interfaces.	
Exceptions	None identified.	
Post Conditions	None identified.	
Traceability	REQ-Near-RT-RIC-TS-FUN1, REQ-Near-RT-RIC-TS-FUN2, REQ-E2-MM-FUN1, REQ-E2-MM-FUN4, REQ-E2-MM-FUN5, REQ-E2-MM-FUN7, REQ-E2-MM-FUN8	

```
@startuml
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12
Autonumber

Box “SMO” #gold
   Participant SMO as “Operator/SMO”
   Participant NON as “Non-RT RIC”
end box

Box “O-RAN” #lightpink
```

```
    Participant NearRTRIC as "Near-RT RIC"
    Participant ORANnodes as "E2 Nodes"
End box

group AI/ML Model Training
      SMO -> NearRTRIC: <<O1>> Initialize/Provide ML Model
      NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (cell configuration report)
      ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (cell configuration)
      Hnote over NearRTRIC
            mMIMO Beam Pattern Information is available
      Endhnote
      NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (mobility reports)
      ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (mobility reports)
      NearRTRIC -> NearRTRIC: AI/ML model training
end

group Beam grouping
      ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (mobility reports)
      NearRTRIC -> NearRTRIC: AI/ML model inference(beam grouping)
      NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (beam grouping policy)
end

@enduml
```

The flow diagram of the procedure for Near-RT RIC beam-based mobility robustness optimization – model training and initial beam grouping is given in figure 4.4.3.2-1.

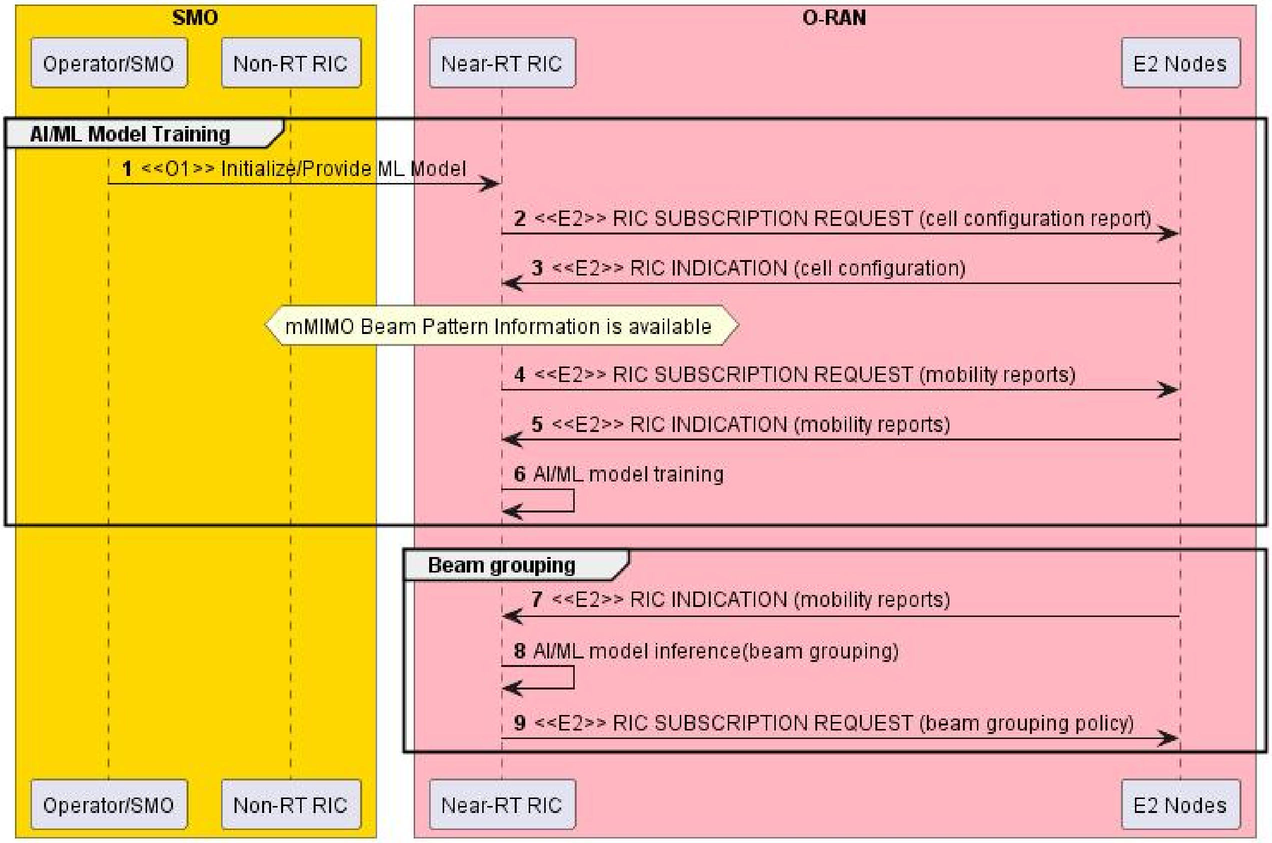

Figure 4.4.3.2-1: Procedure for Near RT RIC beam-based mobility robustness optimization – model training and initial beam grouping

The context of Near-RT RIC beam-based mobility robustness optimization – model inference and mobility optimization is captured in table 4.4.3.2-2.

Table 4.4.3.2-2: Near-RT RIC beam-based mobility robustness optimization – model inference and mobility optimization

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Based on evaluation of mobility performance and failure reporting, identify changes in mobility characteristics and derive optimized mobility settings such as CIO, TTT, T310, etc. to optimize beam-based mobility performance between neighbor cells.	
Actors and Roles	SMO, Near-RT RIC, E2 node (O-CU)	
Assumptions	- All relevant functions and components are instantiated. - O1 and E2 interface connectivity are established. - ML models are trained, and beam groups are defined.	
Pre-conditions	- Network is operational with default configuration. - (optional) OAM functions have configured bMRO targets in Near-RT RIC through O1 interface. - OAM functions have configured baseline mobility parameters in O-CUs through O1 interface. - Near-RT RIC has up-to-date beam pattern information. - O-CUs support reporting of beam-based mobility performance and/or instantaneous mobility failure event reporting. - Near-RT RIC has access to the beam-based mobility performance and/or failure reporting from the E2 node.	
Begins when	Operator specified trigger condition or event is satisfied.	
Step 1 (M)	Near-RT RIC subscribes to beam- or beam-group based mobility performance and/or failure reporting via E2 interface for mobility optimization.	
Step 2 (M)	Near-RT RIC subscribes to cell configuration reports via E2 interface to get informed about mMIMO beam pattern changes.	
Step 3,4,5,6,7 (M)	SMO may trigger mobility optimization by configuration of a new GoB beam pattern in the E2 node (O-CU). Near-RT RIC obtains the cell configuration from E2 node via E2 interface and detects a mMIMO beam pattern change. Based on obtained mobility reports from E2 nodes, AI/ML model inference in the Near-RT RIC derives an updated beam grouping. Near-RT RIC requests to apply an updated beam grouping policy at E2 node (O-CU).	
Step 8 (M)	Alternatively, OAM may trigger mobility optimization by operator specified trigger or a new optimization target.	
Step 9 (M)	Near-RT RIC obtains to beam- or beam-group based mobility performance and failure reporting via E2 interface for mobility optimization.	
Step 10 (M)	Near-RT RIC performs AI/ML based mobility report analysis to detect a change in mobility characteristics and to trigger reconfiguration of mobility reporting and mobility parameter settings.	
Step 11 (M)	Near-RT RIC subscribes to updated beam- or beam-group based mobility performance and failure reporting via E2 interface.	
Step 12 (M)	Near-RT RIC obtains to beam-or beam-group based mobility performance and failure reporting via E2 interface.	
Step 13 (M)	Near-RT RIC performs mobility robustness optimization to update mobility parameter settings.	
Step 14 (M)	Near-RT RIC requests to apply an updated beam- or beam-group based mobility parameter policy (e.g., CIO, TTT, T310, etc.) at E2 node (O-CU).	
Ends when	Operator specified trigger condition or event is satisfied.	
Exceptions	None identified.	
Post Conditions	Near-RT RIC monitors the performance of mobility robustness optimization in the Near-RT RIC and initiates ML model retraining if required.	
Traceability	REQ-Near-RT-RIC-TS-FUN1, REQ-Near-RT-RIC-TS-FUN2, REQ-Near-RT-RIC-TS-FUN3, REQ-E2-MM-FUN1, REQ-E2-MM-FUN4, REQ-E2-MM-FUN5, REQ-E2-MM-FUN7, REQ-E2-MM-FUN8	


```
@startuml
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12
Autonumber

Box “SMO” #gold
   Participant SMO as “Operator/SMO”
   Participant NON as “Non-RT RIC”
end box

Box “O-RAN” #lightpink
   Participant NearRTRIC as “Near-RT RIC”
   Participant ORANnodes as "E2 Nodes"
End box

group OUTER LOOP CONTROL
          NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (mobility reports)
          NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (cell configuration report)
     group alt 1
          SMO -> ORANnodes: <<O1>> Optimization Trigger:\nNew GoB configuration
          ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (cell configuration)
          Hnote over NearRTRIC
               mMIMO Beam Pattern Change
          Endhnote
          ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (mobility reports)
          NearRTRIC -> NearRTRIC: AI/ML model inference (beam grouping)
          NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (beam grouping policy)
     end
     group alt 2
          SMO -> NearRTRIC: <<O1>> Optimization Trigger:\nNew optimization target
     end
     group INNER LOOP CONTROL
          ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (mobility reports)
          NearRTRIC -> NearRTRIC: AI/ML model inference (optimization trigger)
          Hnote over NearRTRIC
               Change in mobility characteristics
          Endhnote
          NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (mobility reports)
          ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (mobility reports)
          NearRTRIC -> NearRTRIC: Mobility Robustness Optimization
          Hnote over NearRTRIC
               Update mobility parameters
          Endhnote
          NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (mobility parameter policy)
     end
end

group Performance Monitoring
     NearRTRIC -> ORANnodes: <<E2>> RIC SUBSCRIPTION REQUEST (mobility reports)
     ORANnodes -> NearRTRIC: <<E2>> RIC INDICATION (mobility reports)
     NearRTRIC -> NearRTRIC: Performance monitoring and evaluation
     NearRTRIC -> NearRTRIC: Model retraining and update
end


@enduml
```

The flow diagram of the procedure for Near-RT RIC beam-based mobility robustness optimization – optimization trigger, model inference and mobility optimization is given in figure 4.4.3.2-2.

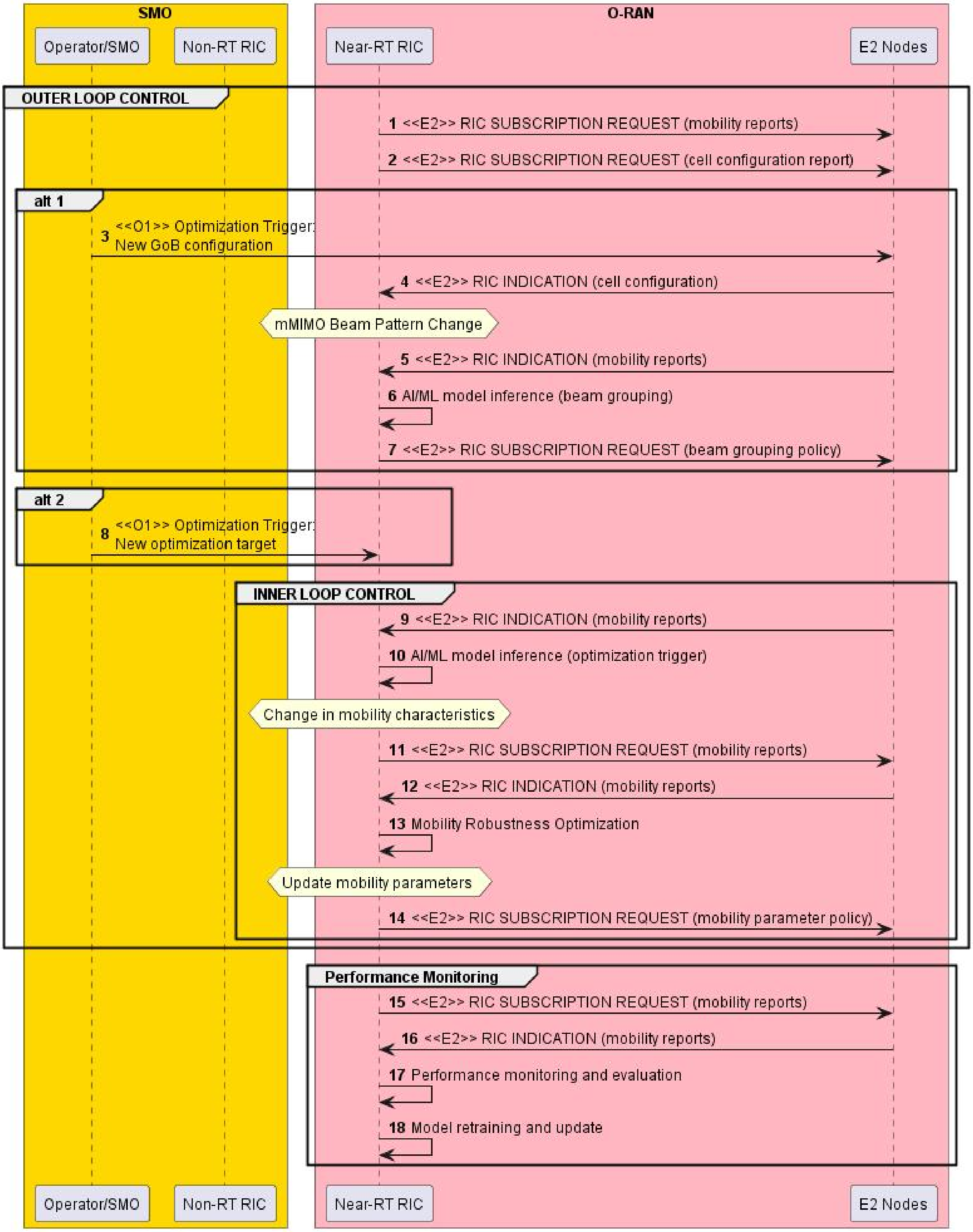

Figure 4.4.3.2-2: Procedure for Near-RT RIC beam-based mobility robustness optimization – optimization trigger, model inference and mobility optimization

4.4.3.3 MU-MIMO optimization

The context of MU-MIMO optimization is captured in table 4.4.3.3-1.

Table 4.4.3.3-1: MU-MIMO optimization

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	MU-MIMO optimization using Near-RT RIC control loop.	
Actors and Roles	Near-RT RIC: Configures E2 nodes' measurements, collects data from E2 nodes, performs MU-MIMO optimization function, and sends MIMO information to E2 nodes. E2 nodes: Report measurements to Near-RT RIC and execute received MU-MIMO information.	
Assumptions	E2 connectivity is established between Near-RT RIC and E2 nodes. Network is operational.	
Pre-conditions	All relevant functions and components are instantiated. MU-MIMO optimization xApp is deployed with initial configuration. All relevant subscriptions established on E2 interface.	
Begins when	Operator specified trigger condition or event is satisfied.	
Step 1 (M)	Near-RT RIC requests cell and UE capabilities and configuration information from E2 node (O-CU).	
Step 2 (M)	Near-RT RIC obtains cell and UE capabilities and configuration information from E2 node (O-CU).	
Step 3 (M)	Near-RT RIC requests UE connections and RRC states information from E2 node (O-CU).	
Step 4 (M)	Near-RT RIC obtains UE connections and RRC states information from E2 node (O-CU).	
Step 5 (M)	Near-RT RIC requests reference signals and resource allocation information from E2 node (O-DU).	
Step 6 (M)	Near-RT RIC obtains reference signals and resource allocation information from E2 node (O-DU).	
Step 7 (M)	Near-RT RIC requests channel measurement and reporting configuration information from E2 node (O-DU).	
Step 8 (M)	Near-RT RIC obtains channel measurement and reporting configuration information from E2 node (O-DU).	
Step 9 (O)	Near-RT RIC may configure reference signals.	
Step 10 (O)	Near-RT RIC may configure channel measurement and reporting.	
Step 11 (M)	Near-RT RIC requests served radio bearers configuration information from E2 node (O-CU).	
Step 12 (M)	Near-RT RIC requests traffic and channel information from E2 nodes (O-CU, O-DU).	
Step 13 (M)	(Start of outer loop control) Near-RT RIC obtains UE connections and RRC states update from E2 node (O-CU).	
Step 14 (M)	Near-RT RIC obtains reference signals and resource allocation update from E2 node (O-CU).	
Step 15 (M)	Near-RT RIC obtains channel measurement and reporting configuration update from E2 Node (O-CU)	
Step 16 (M)	Near-RT RIC obtains DRB/SRB configuration information from E2 node (O-CU).	
Step 17 (O)	Near-RT RIC coordinates scheduling control of active DRB/SRB with E2 node (O-DU).	
Step 18 (M)	(Start of inner loop control) Near-RT RIC obtains traffic and channel information from E2 nodes (O-CU, O-DU).	
Step 19 (M)	Near-RT RIC uses the collected information to estimate channels and select UE groupings per ranges of frequency and time resources.	
Step 20 (M)	Near-RT RIC calculates scheduling and MIMO parameters (MCS and precoding coefficients for each selection of UEs).	
Step 21 (M)	Near-RT RIC sends scheduling and optimized MIMO parameters per	

	slot per UE to E2 node (O-DU). Steps 18 to Step 21 may repeat. (End of inner loop control)	
Step 22 (M)	E2 node (O-DU) schedules transmissions using the parameters received from the Near-RT RIC.	
Step 23 (O)	Near-RT RIC sends updated reference signals configuration to E2 node (O-DU).	
Step 24 (O)	Near-RT RIC sends updated DL channel measurement and reporting configuration to E2 node (O-DU). Step 13 to Step 24 may repeat. (End of outer loop control)	
Ends when	MU-MIMO optimization is deactivated.	
Exceptions	None identified.	
Post Conditions	The E2 nodes operate using the newly received parameters.	
Traceability	REQ-E2-MM-FUN1, REQ-E2-MM-FUN2, REQ-E2-MM-FUN5, REQ-E2-MM-FUN11, REQ-E2-MM-FUN12, REQ-E2-MM-FUN13, REQ-E2-MM-FUN14, REQ-E2-MM-FUN15	

```
@startuml
skin rose
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12
Autonumber

Box “O-RAN” #lightpink
  Participant NearRTRIC as “Near-RT RIC”
  Participant OCU as “O-CU”
  Participant ODU as “O-DU”
End box

NearRTRIC->OCU: <<E2>> Request cell and UE capabilities and configuration information
OCU->NearRTRIC: <<E2>> Cell and UE capabilities and configuration information
NearRTRIC->OCU: <<E2>> Request UE connections and RRC states information
OCU->NearRTRIC: <<E2>> UE connections and RRC states information
NearRTRIC->ODU: <<E2>> Request reference signals and resource allocation configuration
information
ODU->NearRTRIC: <<E2>> Reference signals and resource allocation configuration information
NearRTRIC->ODU: <<E2>> Request channel measurement and reporting configuration information
ODU->NearRTRIC: <<E2>> Channel measurement and reporting configuration information

group #white opt
  NearRTRIC->ODU: <<E2>> Configure reference signals
  NearRTRIC->ODU: <<E2>> Configure channel measurement and reporting
end

NearRTRIC->OCU: <<E2>> Request Served Radio Bearers configuration information
NearRTRIC->ODU: <<E2>> Request traffic and channel information

group #white MU-MIMO Optimization Loop
  OCU->NearRTRIC: <<E2>> UE states and RRC connections update
  ODU->NearRTRIC: <<E2>> Reference signals and resource allocation configuration update
  ODU->NearRTRIC: <<E2>> Channel measurement and reporting configuration update
  OCU->NearRTRIC: <<E2>> DRB/SRB configuration information
  group opt
    NearRTRIC<->ODU: <<E2>> Coordinate scheduling control of active DRB/SRB
  end
  group #white Scheduling and MIMO Parameters Calculation Loop
    ODU->NearRTRIC: <<E2>> Traffic and channel information
```



```
    NearRTRIC->NearRTRIC: UE selections and Channel estimation
    NearRTRIC->NearRTRIC: Scheduling and MIMO parameters calculations
    NearRTRIC->ODU: <<E2>> Scheduling and optimized MIMO parameters per slot per UE
    ODU->ODU: Schedule transmissions using\n received parameters
  end
  group opt
    NearRTRIC->ODU: <<E2>> Updated reference signal configuration
    NearRTRIC->ODU: <<E2>> Updated channel measurement and reporting configuration
  end
end@enduml
```

The flow diagram of the MU-MIMO optimization is given in figure 4.4.3.3-1.

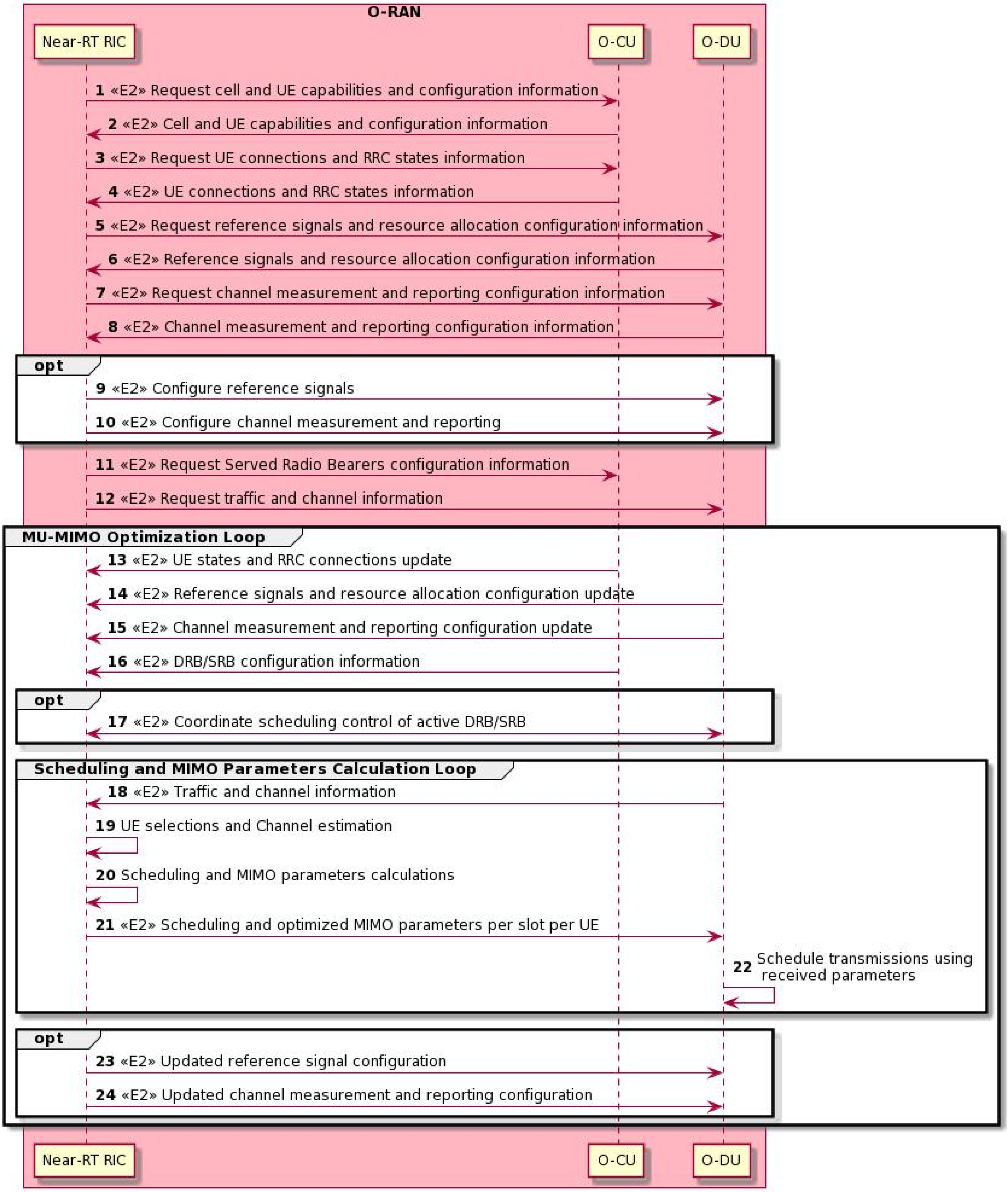

Figure 4.4.3.3-1: MU-MIMO optimization flow

4.4.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the massive MIMO optimization use case. The requirements are specified in clause 5.

4.4.4.1 Control over E2

Non-Grid-of-Beams beamforming optimization

Table 4.4.4.1-1: Output data

Output data					
Interface	**Source → Target**	**Name/Description**	**Units**	**Config. Period, granularity**	**New or existing config**
E2	Near-RT RIC → O-DU	Non-GoB control/policy (non-GoB beamforming mode)	index	~per N x 100ms, per UE	New

Beam-based mobility robustness optimization

Table 4.4.4.1-2: Output data

Output data					
Interface	**Source → Target**	**Name/Description**	**Units**	**Config. Period, granularity**	**New or existing config**
E2	Near-RT RIC → O-CU	Cell Individual Offset (CIO) to a given neighbor cell	dB	~per N x 100ms, per beam or beam group, per UE group (optional)	As specified in 3GPP TS 38.331 [18], clauses 5.3.5 and 5.5.4 New: beam or beam group, per UE group configuration of CIOs
E2	Near-RT RIC → O-CU	Time To Trigger (TTT)	ms	~per N x 100ms, per beam or beam group, per UE group (optional)	As specified in 3GPP TS 38.331 [18], clauses 5.3.5 and 6.3.2 New: beam or beam group, per UE group configuration of TTTs
E2	Near-RT RIC → O-CU	UE Timer 310 (T310)	ms	~per N x 100ms, per beam or beam group, per UE group (optional)	As specified in 3GPP TS 38.331 [18], clauses 5.8.8 and 6.3.2 New: beam or beam group, per UE group configuration of TTTs

MU-MIMO optimization

Table 4.4.4.1-3: Output data

Output data					
Interface	**Source → Target**	**Name/Description**	**Units**	**Config. Period, granularity**	**New or existing config**
E2	Near-RT RIC → O-DU	CSI resource configuration	message	~per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2

Output data					
Interface	Source → Target	Name/Description	Units	Config. Period, granularity	New or existing config
E2	Near-RT RIC → O-DU	CSI report configuration	message	~ per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2
E2	Near-RT RIC → O-DU	SRS resource configuration	message	~ per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2
E2	Near-RT RIC → O-DU	PDSCH configuration	message	~ per N x 100ms, per UE per BWP	As specified in 3GPP TS 38.331 [18], clause 6.3.2
E2	Near-RT RIC → O-DU	MU-MIMO parameters per slot per UE	message	~ per Nx1ms, per slot per SMG	New

4.4.4.2 UE context information from E2 nodes

<From O-DU>

Table 4.4.4.2-1: Input data

Input data						
Interface	Source → Target	Name/Description	Units	Reporting Period, granularity	New or existing definition, Existing Specification (Clause)	Applicable sub-features
E2	O-DU → Near-RT RIC	UE ID		~per N x 100ms, per UE	As specified in O-RAN.WG3.E2SM-v02.00 [25] New reporting	**Non-GoB**
E2	O-DU → Near-RT RIC	SRS configuration periodicity	slots	~per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 “SRS-Config >periodicityAndOffset” New reporting	**Non-GoB**
E2	O-DU → Near-RT RIC	CSI measurement configuration	message	~per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	SRS configuration	message	~per N x 100ms, per UE	As specified in O-RAN.WG3.E2SM-RC-R003-v05.00 [42], clause 8.1.1.17	**mUMO**
E2	O-DU → Near-RT RIC	BWP configurations	message	~per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	PDSCH of serving cell configuration	message	Infrequent, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**

<From O-CU>

Table 4.4.4.2-2: Input data

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
E2	O-CU → Near-RT RIC	UE ID and cell ID of RRC connected UEs		~per N x 100ms, per UE	As specified in O-RAN.WG3.E2SM-RC-R003-v05.00 [42]	**mUMO**
E2	O-CU → Near-RT RIC	RRC state change		~per N x 100ms, per UE	As specified in O-RAN.WG3.E2SM-RC-R003-v05.00 [42], clause 9.3.37	**mUMO**
E2	O-CU → Near-RT RIC	MeasGapConfig	message	~per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**
E2	O-CU → Near-RT RIC	Served radio bearer configuration	message	~per N x 100ms, per UE	As specified in 3GPP TS 38.473 [21], clause 9.2.2.1 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**
E2	O-CU → Near-RT RIC	DRX configuration	message	~per N x 100ms, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**
E2	O-CU → Near-RT RIC	UE capabilities	message	Infrequent, per UE	As specified in 3GPP TS 38.331 [18], clause 6.3.2 Existing reporting	**mUMO**

4.4.4.3 Measurements from E2 nodes

<From O-DU>

Table 4.4.4.3-1: Input data

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
E2	O-DU → Near-RT RIC	RSRP L1 measurement (based on synchronization signal)	dBm	~per N x 100ms, per UE	As specified in 3GPP TS 38.133 [26], clause 10.1.6 3GPP TS 38.215 [27], clause 5.1.1 New reporting	**Non-GoB L1/L2 BM**
E2	O-DU → Near-RT RIC	DL L1 SINR measurement (based on synchronization signal)	dB	~per N x 100ms, per UE	As specified in 3GPP TS 38.133 [26], clause 10.1.16 3GPP TS 38.215 [27], clause 5.1.5 New reporting	**Non-GoB L1/L2 BM**
E2	O-DU → Near-RT RIC	UL SRS RSRP measurement	dBm	~per N x 100ms, per UE	As specified in 3GPP TS 38.133 [26], clause 13.3.1	**Non-GoB**

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
					3GPP TS 38.215 [27], clause 5.2.5 New reporting	
E2	O-DU → Near-RT RIC	Average DL UE throughput in gNB with associated non-GoB BF mode and MIMO mode	Kb/s + index	(non real-time for training)	As specified in 3GPP TS 28.552 [6], clause 5.1.1.3.1 New reporting New component is associated non-GoB BF mode index and MIMO mode (SU/MU)	**Non-GoB**
E2	O-DU → Near-RT RIC	Average UL UE throughput in gNB with associated non-GoB BF mode and MIMO mode	Kb/s + index	(non real-time for training)	As specified in 3GPP TS 28.552 [6], clause 5.1.1.3.3 New reporting New component is associated non- GoB BF mode index and MIMO mode (SU/MU)	**Non-GoB**
E2	O-DU → Near-RT RIC	SRS samples		~per N x 1ms, per SRS RE per antenna port	As specified in O-RAN.WG4.CUS.0-R003-v13 [34], clause 8.3.5.2 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	DL channel quality information (PMi, RI, CQI)	message	~per N x 10ms, per UE	As specified in 3GPP TS 38.212 [43], clause 6.3 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	HARQ ACK/NACK/DTX counts	count	~per N x 10ms, per UE	As specified in 3GPP TS 38.212 [43], clause 6.3 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	DL RLC buffer status	count	~per N x 1ms, per DRB per UE	As specified in 3GPP TS 25.321 [41], clause 8.2.2 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	MAC timestamped slot number	message	~per N x 100ms	As specified in 3GPP TS 38.473 [21], clause 9.3.1.171 New reporting	**mUMO**

<From O-CU>

Table 4.4.4.3-2: Input data

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
E2	O-CU → Near-RT RIC	Number of too early HOs to a given neighbor cell	count	~ 1 min, per beam or beam group	As specified in 3GPP TS 28.552 [6], clause 5.1.1.25	**bMRO**
E2	O-CU → Near-RT RIC	Number of too late HOs to a given neighbor	count	~ 1 min, per beam or beam group	As specified in 3GPP TS 28.552 [6], clause 5.1.1.25	**bMRO**

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
		cell				
E2	O-CU → Near-RT RIC	Number of HO to wrong cell to a given neighbor cell	count	~ 1, per beam or beam group	As specified in 3GPP TS 28.552 [6], clause 5.1.1.25	**bMRO**
E2	O-CU → Near-RT RIC	Number of requested legacy HO executions (HO attempts) to a given neighbor cell	count	~ 1 min, per beam or beam group	As specified in 3GPP TS 28.552 [6], clause 5.1.1.6	**bMRO**
E2	O-CU → Near-RT RIC	Number of successful legacy HO executions to a given neighbor cell	count	~ 1 min, per beam or beam group	As specified in 3GPP TS 28.552 [6], clause 5.1.1.6	**bMRO**
E2	O-CU → Near-RT RIC	Number of failed legacy HO executions to a given neighbor cell	count	~ 1 min, per beam or beam group	As specified in 3GPP TS 28.552 [6], clause 5.1.1.6	**bMRO**
E2	O-CU → Near-RT RIC	Mobility failure indication with root cause (too early HO, too late HO, HO to wrong cell; ping-pong HO) and number of requested or number of successful HO executions at the time of failure	message	Instantaneous at failure event, per beam or beam group, per UE	New measurement and new reporting	**bMRO**
E2	O-CU → Near-RT RIC	PDCP buffer status	count	~per N x 1ms, per DRB per UE	As specified in 3GPP TS 38.323 [40], clause 5.6 New reporting	**mUMO**

NOTE: Measurements for bMRO to be associated with active beam pattern in case of GoB optimization.

4.4.4.4 E2 node configuration

<From O-DU>

Table 4.4.4.4-1: Input data

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
E2	O-DU → Near-RT RIC	Number of supported non-GoB beamforming modes	count	infrequent event (> hours)	New	**Non-GoB**
E2	O-DU → Near-RT RIC	O-RU antenna information	message	Infrequent (~hours)	As specified in O-RAN.WG4.MP.0-R003-v13 [35], clause D.3.8 New reporting	**mUMO**
E2	O-DU → Near-RT RIC	O-DU supported compression methods	message	Infrequent (~hours)	As specified in O-RAN.WG4.CUS.0-R003-v13 [34], clause 7.7.1.2 New reporting	**mUMO**

<From O-CU>

Table 4.4.4.4-2: Input data

Input data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Reporting Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
E2	O-CU → Near-RT RIC	Served cell information	message	Infrequent (~hours)	As specified in 3GPP TS 38.473 [21], clause 9.3.1.10	**mUMO**
E2	O-CU → Near-RT RIC	MIB	message	Infrequent (~hours)	As specified in 3GPP TS 38.331 [18], clause 6.2.2 New reporting	**mUMO**
E2	O-CU → Near-RT RIC	Serving cell SSB information	message	Infrequent (~hours)	As specified in 3GPP TS 38.331 [18], clause 6.3.2 New reporting	**mUMO**

<To O-CU>

Table 4.4.4.4-3: Output data

Output data						
Interface	**Source → Target**	**Name/Description**	**Units**	**Config. Period, granularity**	**New or existing definition, Existing Specification (Clause)**	**Applicable sub-features**
E2	Near-RT RIC → O-CU	Beam grouping info (list of beam group IDs with associated beam IDs)	list	infrequent event (> hours)	New	**bMRO**

4.5 Use case 5: QoE optimization

Based on the end-to-end requirements for the QoE optimization use case specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23], clause 3.4 and in O-RAN.WG2.UCR [28], clause 3.2, some high-level functional description and requirements over Near-RT RIC and E2 interface are introduced.

4.5.1 Background and goal of the use case

The highly demanding 5G native applications like cloud VR are both bandwidth consuming and latency sensitive. However, for such traffic-intensive and highly interactive applications, current semi-static QoS framework can be insufficient to satisfy diversified QoE requirements especially taking into account potentially significant fluctuation of radio transmission capability. It is expected that QoE estimation/prediction can help deal with such uncertainty and improve the efficiency of radio resources, and eventually improve user experience. RAN Analytics Information (RAI) as RAN service can be exposed to RAI service consumers for specific UE (as specified in O-RAN.WG1.O-RAN-Architecture-Description-v06.00 [30], clause 4.5) or for groups of UE (per slice, per cell, per PLMN, etc.). RAI is envisioned to be helpful for the applications to improve the user experience.

Near-RT RIC and E2 interface are leveraged to support this use case. Measurement data through E2 interface, e.g., cell level data, UE level data, can be acquired and processed via ML algorithms to support traffic recognition, QoE prediction, and QoS enforcement decisions. When requested, the analytics information, e.g., traffic rate, latency, packet loss rate, is exposed to the RAI service consumers to help applications execute logical control.

4.5.2 Entities/resources involved in the use case

1) Near-RT RIC:
   a) Support receiving request or subscription messages from RAI service consumer.
   b) Support receiving network state and UE performance report from RAN.
   c) Support data analysis and executing the AI/ML models to infer RAN analytics information, e.g., QoE prediction, and available bandwidth prediction.
   d) Support exposure RAN analytics information to RAI service consumer.
2) RAN:
   a) Support network state and UE performance report with required granularity to Near-RT RIC over E2 interface.
3) RAI service consumer:
   a) Request or subscribe to RAN analytics information from the Near-RT RIC.
   b) Support UE identification using data structure as specified in O-RAN.WG1.O-RAN-Architecture-Description-v06.00 [30], clause 4.

4.5.3 Solutions

4.5.3.0 Introduction

This clause specifies solution components that can be combined into different solutions. A solution based on E2 control/policy consists of clause 4.5.3.1 and clause 4.5.3.2. Another solution based on RAN analytics information exposure consists of clause 4.5.3.1 and clause 4.5.3.3.

4.5.3.1 AI/ML model training and distribution

Overall process shall be as specified in O-RAN.WG2.UCR [28], clause 3.2.3.1, however step 3 would be performed over O2 when and if "image based" ML model deployment option is selected (as specified in O-RAN.WG2.AIML [29], clause 7).

4.5.3.2 Policy generation and performance evaluation

Editor's note: to be defined based on requirements as specified in O-RAN.WG2.UCR [28], clause 3.2.4.1.

4.5.3.3 RAN performance analytics assisted QoE optimization

RAN performance analytics can be requested by the RAI service consumer using either a request/response solution or a subscription-based solution.

The context of RAN performance analytics assisted QoE optimization using request/response is captured in table 4.5.3.3-1.

Table 4.5.3.3-1: RAN performance analytics assisted QoE optimization using request/response

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Expose RAN analytics information to RAI service consumer for QoE optimization.	
Actors and Roles	Near-RT RIC, RAI service consumer, E2 nodes	
Assumptions	All relevant functions and components are instantiated. RAI service consumer has obtained the necessary information to initiate request for QoE related RAI from the Near-RT RIC.	
Pre-conditions	QoE related ML models have been deployed in Near-RT RIC. E2 interface is established to enable collection of measurements from E2 nodes.	
Begins when	RAI service consumer decides to request RAN analytics information for QoE optimization.	
Step 1 (M)	RAI service consumer requests for QoE related RAN analytics information from Near-RT RIC.	
Step 2 (O)	Near-RT RIC initiates measurement data collection from E2 nodes via RIC subscription procedure. See NOTE 1.	
Step 3-4 (M)	E2 node sends periodic measurement data to Near-RT RIC, received data is processed and stored.	
Step 5 (M)	Near-RT RIC generates the RAN analytics information, using QoE related AI/ML models and collected measurement data.	
Step 6 (M)	Near-RT RIC sends the RAN analytics information to RAI service consumer.	
Ends when	RAI service consumer receives the RAN analytics information response.	
Exceptions	None identified.	
Post Conditions	RAI service consumer obtains RAI necessary for QoE optimization. Near-RT RIC may stop data collection.	
NOTE 1: Near-RT RIC may be configured to start collection of measurement data before requested by RAI service consumer.		

```
@startuml
Skin rose
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12

Box “O-RAN” #lightpink
  Participant near as “Near-RT RIC”
  Participant ran as “E2 Nodes”
End box
Box “External” #lightcyan
  Participant “RAI service consumer” as app
End box

app -> near : 1. RAI Request for QoE optimization
near <--> ran: 2. <<E2>> RIC Subscription procedure(Report: Measurements)

Loop Data collection
  ran -> near : 3. <<E2>> RIC Indication (Report)
    near -> near : 4. Process and store data
```

```
end
near -> near: 5. RAN analytics information generation
near -> app: 6. RAI Response (RAN analytics information)
near <--> ran: <<E2>> RIC Subscription Delete procedure(Report: Measurements)

@enduml
```

The flow diagram of the RAN performance analytics assisted QoE optimization using request/response is given in figure 4.5.3.3.-1.

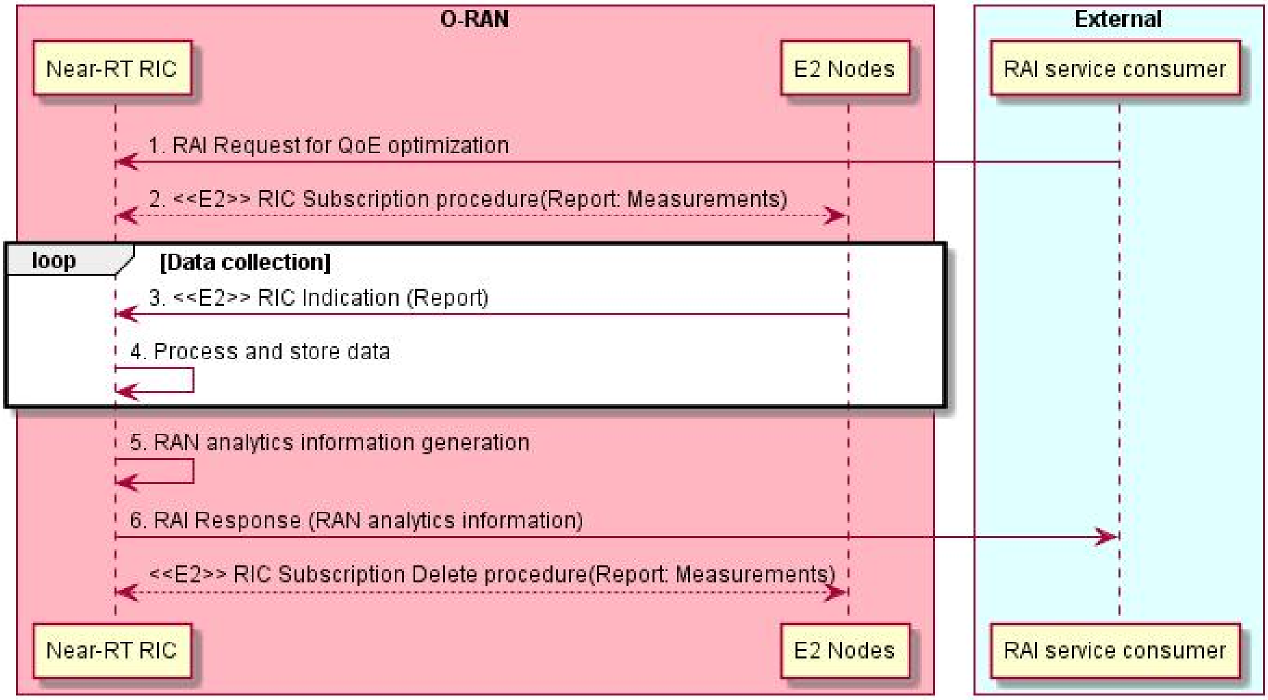

Figure 4.5.3.3-1: RAN performance analytics assisted QoE optimization using request/response

The context of RAN performance analytics assisted QoE optimization using subscription-based solution is captured in table 4.5.3.3-2.

Table 4.5.3.3-2: RAN performance analytics assisted QoE optimization using subscription-based solution

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Expose RAN analytics information to RAI service consumer for QoE optimization.	
Actors and Roles	Near-RT RIC, RAI service consumer, E2 nodes	
Assumptions	All relevant functions and components are instantiated. RAI service consumer has obtained the necessary information to initiate request for QoE related RAI from the Near-RT RIC.	
Pre-conditions	QoE related ML models have been deployed in Near-RT RIC. E2 interface is established to enable collection of measurements from E2 nodes.	
Begins when	RAI service consumer decides to subscribe to reports of RAN analytics information for QoE optimization.	
Step 1 (M)	RAI service consumer initiates RAI subscription procedure for QoE related RAN analytics information from Near-RT RIC.	
Step 2 (O)	Near-RT RIC may initiate measurement data collection from E2 nodes via RIC subscription procedure. See NOTE 1.	
	Steps 3-5 loop with RAI service consumer receiving requested subscription-based reports.	
Step 3-4 (M)	E2 node sends periodic measurement data to Near-RT RIC, received data is processed and stored.	
Step 5 (M)	Near-RT RIC generates the RAN analytics information, using QoE related AI/ML models and collected measurement data.	
Step 6 (M)	Near-RT RIC sends the RAN analytics information to RAI service consumer.	
Ends when	RAI service consumer initiates RAI subscription delete procedure.	
Exceptions	None identified.	
Post Conditions	RAI service consumer obtains RAI necessary for QoE optimization. Near-RT RIC may stop E2 node data collection.	
NOTE 1: Near-RT RIC may be configured to start collection of measurement data before requested by RAI service consumer.		

```
@startuml
Skin rose
skinparam ParticipantPadding 5
skinparam BoxPadding 10
skinparam defaultFontSize 12

Box "O-RAN" #lightpink
  Participant near as "Near-RT RIC"
  Participant ran as "E2 Nodes"
End box
Box "External" #lightcyan
  Participant "RAI service consumer" as app
End box

app <-> near : 1. RAI Subscription procedure for QoE optimization
near <--> ran: 2. <<E2>> RIC Subscription procedure(Report: Measurements)

Loop Until subscription terminated
  Loop Data collection
    ran -> near : 3. <<E2>> RIC Indication (Report)
    near -> near : 4. Process and store data
  end
  near -> near: 5. RAN analytics information generation
  near -> app: 6. RAI Report (RAN analytics information)
end
app <-> near : RAI Subscription Delete procedure
near <--> ran: <<E2>> RIC Subscription Delete procedure(Report: Measurements)
```



```
@enduml
```

The flow diagram of the RAN performance analytics assisted QoE optimization using subscription-based solution is given in figure 4.5.3.3-2.

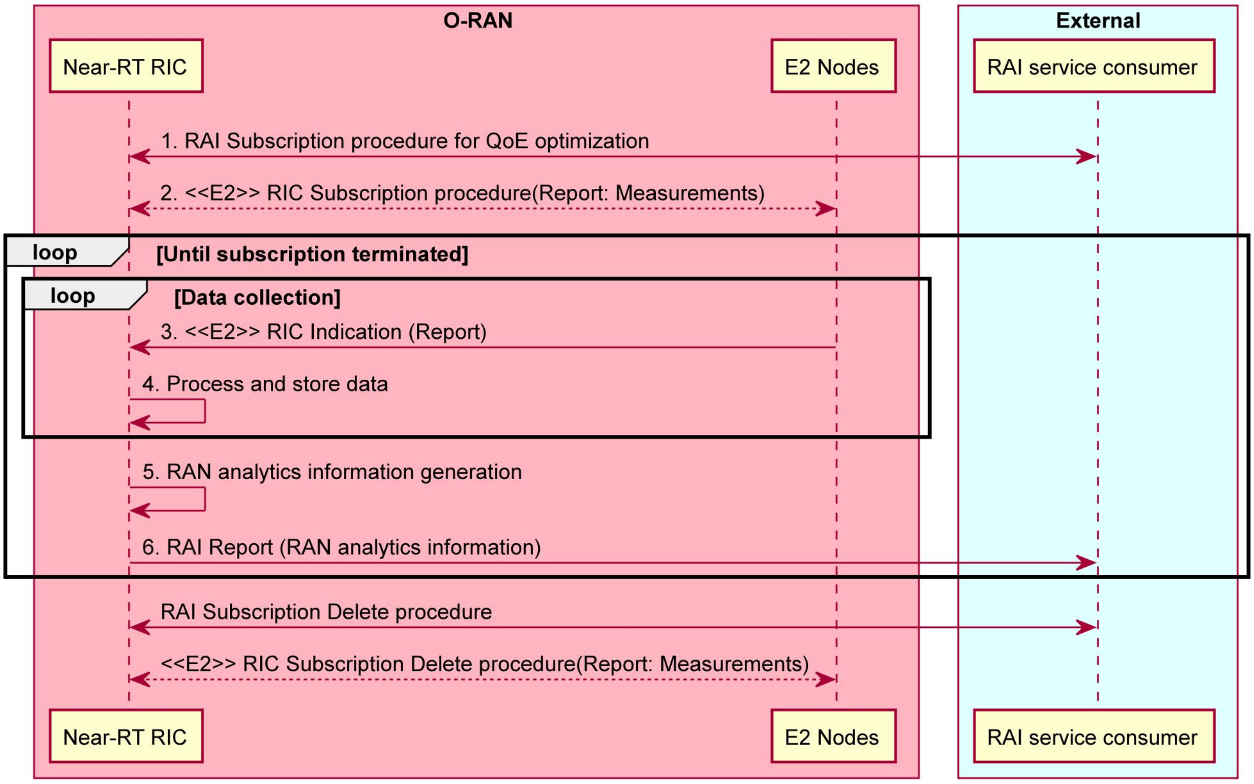

Figure 4.5.3.3-2: RAN performance analytics assisted QoE optimization using subscription-based solution

4.5.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the QoE optimization use case, especially for RAN performance analytics. The requirements are specified in clause 5.

4.5.4.1 UE context information from E2 nodes

The followings are examples of UE context information identified as required:

- UE ID
- List of S-NSSAI
- List of QoS related ID, eg., 5QI, QFI

For example, UE ID, S-NSSAI or QoS related ID can be used to collect, analysis and predict the resource occupation of each user, slice or service, eg. maximum/average throughput, maximum/average latency, average packet loss rate.

4.5.4.2 Measurements from E2 nodes

The E2 measurements are necessary for inference and prediction in the Near-RT RIC as the driver for decisions in addition to KPMs. For the QoE optimization use case, especially for RAN performance analytics, the Near-RT RIC receives the request or subscription from RAI service consumer and subscribes and receives the measurement data from O-CU/O-DU through E2 interface. Based on it, with QoE related AI/ML models, the Near-RT RIC infers the RAN analytics information, and exposes it to RAI service consumer.

The examples of cell-level, UE-level, and slice-level measurement information are listed in table 4.5.4.2-1 below.

Table 4.5.4.2-1: Measurements from E2 nodes

Measurement Type		Measurement Examples
Cell-level	L2	**1. MCS Distribution in PDSCH** (available at DU; as specified in 3GPP TS 28.552 [6], clause 5.1.1.12.1) **2. DL/UL Total PRB usage** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.1 and 5.1.1.2.2 and in 3GPP TS 32.425 [7], clauses 4.5.3 and 4.5.4) **3. Distribution of DL/UL Total PRB usage** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.3 and 5.1.1.2.4 and in 3GPP TS 32.425 [7], clauses 4.5.10 and 4.5.11) **4. DL/UL PRB used for data traffic** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.5 and 5.1.1.2.7) **5. DL/UL PRB usage for traffic** (per QCI, as specified in 3GPP TS 32.425 [7], clauses 4.5.1 and 4.5.2) **6. DL/UL Total available PRB** (available at DU; as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.6 and 5.1.1.2.8) **7. DL/UL PRB full utilization** (as specified in 3GPP TS 32.425 [7], clauses 4.5.9.1 and 4.5.9.2) **8. Total number of DL/UL TBs** (available at DU; split into subcounters per layer at MU-MIMO case, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.7.3 and 5.1.1.7.8 and in 3GPP TS 32.425 [7], clauses 4.5.7.1 and 4.5.7.3) **9. Total error number of DL/UL TBs** (available at DU; split into subcounters per layer at MU-MIMO case, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.7.4 and 5.1.1.7.9 and in 3GPP TS 32.425 [7], clauses 4.5.7.2 and 4.5.7.4) **10. Average DL UE throughput in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.1) **11. Distribution of DL UE throughput in gNB** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.2) **12. Packet Delay** (available at DU and CU-UP; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.3) **13. RAN part packet delay components** (as specified in 3GPP TS 38.314 [16], clause 4.2.1.2) **14. Packet Delay** (per QCI, as specified in 3GPP TS 36.314 [9], clause 4.1.4) **15. DL/UL Cell PDCP SDU Data Volume** (available at CU-UP; per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.2.1 for non-split gNB, clause 5.1.3.6.2 for split gNB; per

Measurement Type		Measurement Examples
		PLMN ID and per E-RAB QoS profile (QCI, ARP and GBR), as specified in 3GPP TS 32.425 [7], clause 4.4.7) **16. Mean number of Active UEs in the DL/UL per cell** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.1 and 5.1.1.23.3) **17. Max number of Active UEs in the DL/UL per cell** (available at DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.2 and 5.1.1.23.4) **18. Average number of Active UEs** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.2) **19. Packet Loss Rate** (available at CU-UP or DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.1) **20. Packet Loss Rate** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.4) **21. DL Packet Drop Rate** (available at CU-UP or DU; optionally split into subcounters per QoS level (mapped 5QI or QCI in NR option 3) and subcounters per supported S-NSSAI, as specified in 3GPP TS 28.552 [6], clause 5.1.3.2) **22. DL Packet Drop Rate** (per QCI, as specified in 3GPP TS 32.425 [7], clause 4.4.3.2)
UE-level	Radio channel info in CU-CP	**1. SINR** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) **2.RSRP** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) **3.RSRQ** (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])
	L2	**CQI, MCS** **DL/UL UE throughput** **DL/UL UE PRB usage** **RLC buffer size** **RLC occupied buffer** **RLC unused buffer** **UL/DL MAC rate** **Packet Delay** **Packet Interval** **Packet Jitter, eg. Packet Interval Jitter, Packet Size Jitter** **Data volume** (per UE, as specified in 3GPP TS 36.314 [9], clause 4.1.8) Data volume (per UE) **Packet Loss Rate per DRB per UE** (as specified in 3GPP TS 38.314 [16], clause 4.2.1.5)

Measurement Type		Measurement Examples
		Block Error Rate **DL Packet Drop Rate** **Total number of RLC SDUs/PDUs**
Slice-level	L2	**DL/UL UE PRB usage** **RLC buffer size** **RLC occupied buffer** **RLC unused buffer** **UL/DL MAC rate** **Packet Delay** **Packet Interval** **Packet Jitter, eg. Packet Interval Jitter, Packet Size Jitter** **Data volume** (per QCI, as specified in 3GPP TS 36.314 [9], clause 4.1.8) **Data volume** (per 5QI) **Packet Loss Rate per DRB per UE** **Block Error Rate** **DL Packet Drop Rate** (as specified in 3GPP TS 28.552 [6], clause 5.1.3.2) **Total number of RLC SDUs/PDUs**

4.5.5 RAN analytics information exposed by Near-RT RIC

Based on the measurements from E2 nodes, with QoE related AI/ML models, the Near-RT RIC infers the RAN analytics information and expose it to RAI service consumer. The exposed RAN analytics information will be helpful for the applications to evaluate network status and execute logic control, e.g., TCP transmission window adjustment, video coding rate selection to improve QoE.

The examples of RAN analytics information are listed in table 4.5.5-1 below.

Table 4.5.5-1: RAN analytics information

Measurement Type		Measurement Examples
UE-level	Predicted RAN performance	**1. Minimum/maximum/average throughput** **2. Minimum/maximum/average latency** **3. Average packet loss rate** **4. QoE prediction**
	Prediction related information	**1. Confidence** **2. Validity period**

4.6 Use case 6: Network energy saving

This use case provides the motivation, description, and requirements for Near RT RIC and E2 interface to support network energy saving, whose end-to-end requirements are specified in ORAN-WG1.Use Cases Detailed Specification R003 v11.00 [32].

The RAN is responsible for the majority of the Energy Consumption (EC) of a mobile network, and the O-RU consumes the largest part of the energy consumption of the RAN. The rarefication of fossil fuel-based energy resources and the urgent need to reduce CO_2 emissions make energy saving a strategic goal for network operators, in addition to the significant energy related OPEX reduction requirement.

Energy consumption can be reduced by improving the Energy Efficiency (EE) of the network, and by introducing different Energy Saving (ES) mechanisms. Several ES mechanisms are related to switching off certain components in the network and differ from one another by their time scale. In a longer time-scale of minutes, hours and above, and when the cell load is low, ES can be achieved by switching off one or more carriers or the cell itself. At the same or shorter time-scale, from seconds to minutes, ES can be achieved by switching off RF channels (including possibly array of antennas) of a Massive-MIMO (mMIMO) system. At a shorter time-scale corresponding to a symbol, subframe and frame, Advanced Sleep Modes (ASM) can be considered (see ORAN-WG1.Use Cases Energy Saving Technical Report R003 v02.00 [i.4], 3GPP TR 28.813 [i.5] and 3GPP TS 28.310 [33]).

The ES use cases are divided into three sub-use cases, which have different properties, the time scale of the control and the controlled system involved:

1. Carrier and cell switch off/on
2. RF channel reconfiguration
3. Advanced Sleep Modes

4.6.1 Carrier and cell switch off/on

4.6.1.1 Background and goal of the use case

Carrier and cell switch off/on control by the Non-RT or Near-RT RIC can consider overall network energy efficiency instead of local optimization. In addition to the ES optimization in the SMO/Non-RT RIC, optimizing network EC in the Near-RT RIC brings significant gains due to more UE centric, near-real-time intelligent control capabilities with finer granularity. The AI/ML models' functionality in the Near-RT RIC can include prediction of future traffic, user mobility, resource usage, QoS and QoE on a per UE basis and may also predict expected energy efficiency enhancements, resource usage, and network performance for different carrier and cell switching off/on options. Based on the predicted results, optimized ES control actions or policies can be given by the Near-RT RIC to E2 nodes in near-real-time manner to track the dynamic network conditions. ES control also includes preparation actions (before carrier and cells are switched off) and post control actions (after carrier and cells are switched on) such as checking ongoing emergency calls and warning messages, enabling/disabling/modifying carrier aggregation and/or dual connectivity, steering traffic and handing over UEs from source cells/carriers to other cells/carriers, changing MU-MIMO layers, beam scheduling policies and SSB burst configurations etc, which can be handled in the Near-RT RIC by the intelligent and UE centric RAN control capabilities coordinated with the SMO/Non-RT RIC.

The goal of Near-RT RIC energy saving is to interpret the policies received over A1 and to determine the optimum changes it can make according to these policies. More specifically, Near-RT RIC triggers E2 procedure and related control/policies so as to obtain network performance that would fulfill the criteria identified in the A1 policies. It may also leverage the A1 enrichment information to make more informed decisions. Traffic steering may reuse mechanisms provided by other use cases to affect the changes necessary to achieve its goals. The Near-RT RIC may also work in background processing without the A1 policy guidance from the Non-RT RIC.

4.6.1.2 Entities/resources involved in the use case

1) Near-RT RIC:
   a) Near-real-time monitoring of energy saving related performance measurements.
   b) Receive energy saving xApps from SMO.

c) Support interpretation and enforcement of A1 policies from Non-RT RIC.
d) Support enrichment information via the A1 interface.
e) Perform optimized RAN (E2) actions to achieve ES requirements based on O1 configuration, A1 policy, A1 enrichment information and E2 reports.

2) E2 node:
a) Support ES optimization actions or policy enforcements via E2.
b) Support ES related performance measurements through O1.
c) Support ES related performance reports through E2.

4.6.1.3 Solution

There are three general ES processing modes and the transitions between them. The three processing modes, baseline, background and A1 policy-based, as described in clause 4.1.3 for traffic steering use case applies to the energy saving use case as is except that the modes represent the way the Near-RT RIC operates on a given E2 node rather than UE specific.

The context of ES optimization by carriers and cell switching off/on is captured in table 4.6.1.3-1.

Table 4.6.1.3-1: ES optimization by carriers and cell switching off/on

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Drive energy saving cell switching off/on optimization in accordance with RAN OAM configured background behavior (mode 1) or policies information from the Non-RT RIC using A1 interface (mode 2).	
Actors and Roles	- Non-RT RIC in SMO domain: Creates and updates A1 policies, provide A1 enrichment information. - Near-RT RIC: Enforces A1 policies and generates RIC CONTROL and/or POLICY. - E2 node: RIC CONTROL and POLICY execution and RIC REPORT creation. Refer to 4.6.1.2 for more details.	
Assumptions	- All relevant functions and components are instantiated. - A1, O1 and E2 interface connectivity is established. - A1 policy scope defined.	
Pre-conditions	- Network is operational with default configuration. - OAM functions have configured a baseline measurement configuration and the Non-RT RIC has access to this data. - OAM functions have configured baseline traffic steering parameters in E2 node(s) through O1 interface. - (optional) If ES mode 1, OAM functions have configured background ES behavior to the Near-RT RIC through O1 interface. - Non-RT RIC analyzes the historical data from RAN for training the relevant AI/ML models to be deployed or updated in the Near-RT RIC, as well as AI/ML models required for non-real-time optimization of configuration and policies.	
Begins when	Energy saving optimization by cell switching off/on is activated or an operator defined trigger is detected.	
Step 1 (O)	(Start of outer loop control) If ES mode 1, OAM functions collect data from E2 node through O1 interface.	
Step 2 (O)	Non-RT RIC retrieve ES related performance data from OAM function.	
Step 3 (O)	Non-RT RIC evaluates the collected data and A1 policy feedback, if required, and generates or updates the appropriate ES optimization policy, such as ES targets and carrier/cell switching off/on guidance, etc.	
Step 4 (O)	Non-RT RIC sends the ES optimization policy to Near-RT RIC via A1 interface.	
Step 5 (O)	Non-RT RIC sends optional ES related A1 enrichment information.	
Step 6 (O)	If ES mode 2, Near-RT RIC collects data from E2 node through E2 interface.	

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Step 7 (O)	Near-RT RIC evaluates the collected data, if required, generates or updates the internal background mode ES optimization targets or policies.	
Step 8 (M)	(Start of inner loop control) Near-RT RIC subscribes to a UE context information and measurement metrics via E2 interface.	
Step 9 (M)	E2 nodes report the UE context information and E2 measurements via RIC REPORT periodically or event-triggered.	
Step 10 (M)	Near-RT RIC evaluates the performance data from E2 nodes and finds potential improvements to energy efficiency which are indicated in the A1 policy and/or internal Near-RT RIC TS targets.	
Step 11 (O)	Based on the UE context information, E2 measurement metrics (RIC REPORT), and A1 policy, Near-RT RIC may generate new or modify the existing E2 policies and sends them to E2 nodes. E2 node functions target of E2 policy may be: - E-UTRAN-NR dual connectivity - Carrier aggregation - Connected mode mobility - Idle mode mobility - Radio access control - Cell switching off/on control	
Step 12 (O)	Near-RT RIC may also generate control command(s) and send them to E2 node(s) to trigger re-allocation of radio resources and switching off/on carrier and cells so that the overall network energy efficiency can be improved. E2 node functions target of E2 control command may be: - Same as Step 11 (End of inner loop control)	
Step 13 (O)	For ES mode 2, Near RT-RIC may send A1 policy feedback on A1 to the Non-RT RIC. (End of outer loop control)	
Step 14 (O)	Non-RT RIC decides to delete ES optimization policy in case of ES mode 2 and sends the related messages.	
Step 15,16 (M)	Following A1 policy deletion (mode 2) or internal trigger (mode 1), the Near-RT RIC terminates the ES optimization procedure and delete the related RIC subscriptions.	
Ends when	ES optimization is deactivated, or an operator defined trigger is detected.	
Exceptions	None.	
Post Conditions	Energy saving over a period of time is achieved.	
Traceability	REQ-E2-ES-FUN1, REQ-E2-ES-FUN2, REQ-Near-RT-RIC-ES-FUN1, REQ-Near-RT-RIC-ES-FUN2, REQ-Near-RT-RIC-ES-FUN3	

```
@startuml
autonumber
skinparam ParticipantPadding 4
skinparam BoxPadding 8
skinparam defaultFontSize 12

Box "Service Management and Orchestration" #gold
    Participant OAM as "OAM Functions"
    Participant non as "Non-RT RIC"
End box

Box "O-RAN" #lightpink
```



```
   Participant near as "Near-RT RIC"
   Participant ran as "E2 Node"
End box



group OUTER LOOP CONTROL

   OAM <--> ran : (Mode 2) <<O1>> RAN Data collection
   OAM --> non: (Mode 2) ES related performance information
   non --> non: (Mode 2) Collected data evaluation and policy creation

   non --> near : (Mode 2) <<A1>> A1 policy setup or update
   non --> near: (opt.) <<A1-EI>> ES related A1 enrichment information
   near <--> ran: (Mode 1) <<E2>> RAN Data collection
   near --> near: (Mode 1) Collected data evaluation and policy creation

   group INNER LOOP CONTROL
      near -> ran : <<E2>> RIC SUBSCRIPTION REQUEST(UE context & measurement metrics)
      ran -> near: <<E2>> RIC INDICATION (UE context & E2 measurement metrics)
      near -> near: Evaluation, potential improvement to energy efficiency
      near -> ran : (opt.) <<E2>> RIC SUBSCRIPTION REQUEST (ES optimisation POLICY)
      near -> ran : (opt.) <<E2>> RIC CONTROL REQUEST (ES optimisation RIC CONTROL)
   end

   non <-- near: (Mode 2) <<A1>> A1 policy feedback

end
non --> near: (Mode 2) <<A1>> A1 policy delete
near -> near: ES optimization stopped
near-> ran: <<E2>> RIC SUBSCRIPTION DELETE
@enduml
```

The flow diagram of the ES optimization by carriers and cell switching off/on is given in figure 4.6.1.3-1.

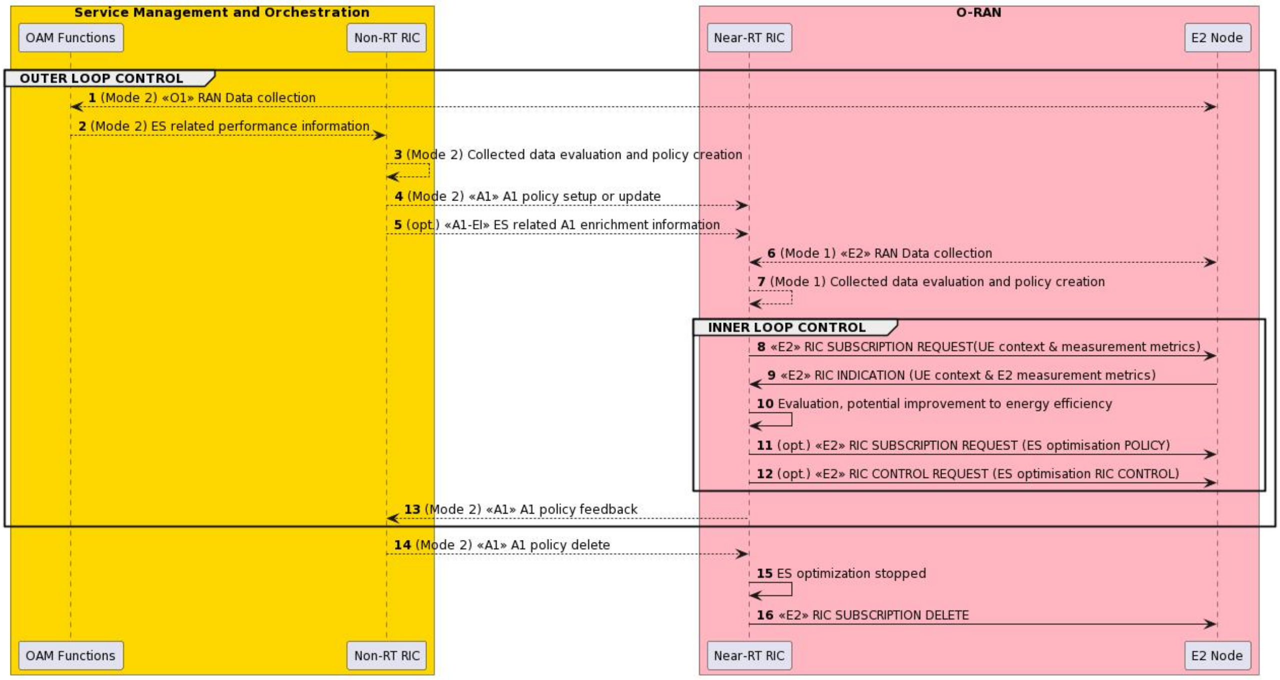

Figure 4.6.1.3-1: ES optimization by carriers and cell switching off/on

4.6.1.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the ES carrier and cell switch off/on use case. The requirements are specified in clause 5.

4.6.1.4.1 Control over E2

1) **Radio access control:** Access control may be applied to restrict access of other UEs for a specific cell in order to prepare for switching off the cell to save energy. A cell-level, UE-level, or slice-level access control can be applied. Four categories of radio access control are indicated as below:

    - RACH backoff
    - RRC connection reject
    - RRC connection release
    - Access barring

Both RIC POLICY and RIC CONTROL can be used.

2) **Mobility control:** For example, a neighbouring cell may be selected in order to switch off the current serving cell. A neighbour handover restriction list may be configured to prevent the UEs from HO to some neighbour cells in order to reduce traffic load of the neighbour cells and switch them off.

    - Handover from the source cell to the target cell
    - Configuration/reconfiguration of handover restriction list
    - Configuration of idle mode mobility parameters
    - Enable, disable, or modify CA (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])
    - Enable, disable, or modify dual connectivity (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])

Both RIC POLICY and RIC CONTROL can be used.

3) **Carriers and cell switch off/on control:** Depending on the traffic condition, certain number of carriers and cells can be switched off by the Near-RT RIC by sending guidance to the E2 node when the traffic is low in order to save energy. When the network conditions deteriorate (e.g., congested traffic, frequent handover failure and/or RA failure), carrier/cell switch-on control command could be sent to E2 node in E2 policy/control to activate the cell/carrier from energy saving and hence ensure network performance.

    NOTE: Once E2 node receives the guidance from Near-RT RIC for switching off/on a cell/carrier, it is not expected that the cell/carrier can be switched off immediately. The E2 node can take time to do all necessary actions to prepare for switching off/on the carrier/cell and there is also a delay in O-RU and open fronthaul interface for switching off/on the cell/carrier. However, it is still expected, as specified in ORAN-WG1.Use Cases Detailed Specification R003 v11.00 [32], that the Near-RT RIC to send this intent to the E2 node to start the process for cell/carrier switching off/on after the network performance and energy efficiency are jointly optimized through for example traffic steering and QoS/QoE optimisation by the Near-RT RIC through 1) and 2). The E2 node (e.g., O-CU-CP) can optionally do traffic steering and OoS optimisation upon receiving this command from the Near-RT RIC before triggering the cell/carrier switching off/on.

Either RIC POLICY or RIC CONTROL can be used which is not addressed in the present document.

4.6.1.4.2 UE context information from E2 nodes

The followings are examples of UE context information identified as required:

- UE ID (as specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23])
- Slice level: S-NSSAI
- DRB level: e.g., established DRB ID, mapping with QoS flows, etc.
- QoS related: e.g., E-RAB level QoS parameters (4G, NSA) or QoS flow level QoS parameters (NG-RAN)
- UE capabilities: CA and DC capabilities

For example, UE ID, S-NSSAI, DRB ID, or QCI/5QI can be used to derive the QoS requirements and the resource occupation; the UE capabilities may be required to select the appropriate RRM action (e.g., CA/DC configuration).

4.6.1.4.3 Measurements from E2 nodes

The E2 measurements are necessary for inference and prediction in the Near-RT RIC as the driver for decisions in addition to KPMs. For the energy saving carrier and cell switch off/on use case, the Near-RT RIC can translate an A1 policy (relatively static targets) into a flexible selection of controls over E2 (e.g., handover control, DC, CA, idle mode mobility, carrier and cell switching off/on) by taking into account the RAN resource utilization, cell level and the UE level performance, the radio and traffic conditions, QoS and QoE requirements and energy consumption and efficiency etc.

The examples of measurement information identified as required are listed in table 4.6.1.4.3-1.

Table 4.6.1.4.3-1: Measurements from E2 nodes

Measurement Type	Measurement Examples
Cell/SSB area related measurements	- DL/UL Total PRB Usage, Distribution of DL/UL Total PRB Usage, DL/UL GBR PRB Usage, DL/UL non-GBR PRB Usage, RRC Connection Number, Available RRC Connection Capacity Value, Mean and Maximum Number of Active UEs per DRB in the DL/UL, DL/UL Scheduling PDCCH CCE Usage, DL/UL Composite Available Capacity, DL/UL Cell PDCP SDU Data Volume (including secondary RAT usage for EN-DC/MR-DC), Handover success ratio - DL/UL SSB Area Total PRB Usage, DL/UL SSB Area GBR PRB Usage, DL/UL SSB Area non-GBR PRB Usage, SSB Area Capacity Value - DL/UL PRB usage per QCI, DL/UL PRB usage per 5QI, DL/UL PRB usage per slice, Slice Available Capacity Value *As specified in 3GPP TS 32.425 [7], 3GPP TS 28.552 [6], 3GPP TS 36.314 [9], 3GPP TS 38.314 [16], 3GPP TS 38.423 [19], 3GPP TS 38.463 [20] and 3GPP TS 38.473 [21]*
E2 node user plane measurements per-UE/UE group	- Average DL/UL throughput - DL/UL PRB usage - DL/UL Scheduled IP throughput - Buffer Status Information (e.g., UL BSR) *As specified in 3GPP TS 32.425 [7], 3GPP TS 28.552 [6], 3GPP TS 36.314 [9], 3GPP TS 38.314 [16], 3GPP TS 38.423 [19], 3GPP TS 38.473 [21], 3GPP TS 38.463 [20], 3GPP TS 36.321 [10], 3GPP TS 38.321 [17]*
UE L1/L2/L3 measurements	- RSRP and RSRQ measurements - SINR measurements - CQI/MCS measurements - Location and Velocity measurements *As specified in 3GPP TS 36.331 [11] and 3GPP TS 38.331 [18]*
Energy consumption measurement	Energy consumption measurement of O-RU - PNF Power Consumption (average/min/max) - PNF Energy Consumption (average/min/max) *As specified in 3GPP TS 28.552 [6]*
Mobility and RA related KPIs/measurements of UE/UE group	Mobility and RA related KPIs/measurements from the E2 nodes hosting the target NES cell(s) and/or the neighbour cell(s) to the target NES cell(s) - Handover failure related, e.g., number of handover failures related to MRO - RACH failure related, e.g., distribution of RACH access delay - Radio link failure reports - UE context release related, e.g., number of UE context release requests *As specified in 3GPP TS 36.331 [11], 3GPP TS 38.331 [18], 3GPP 32.425 [7], 3GPP 28.552 [6]*

4.6.1.4.4 E2 node configuration

Cell level configuration parameters in order to configure UE measurements required for traffic steering and QoS/QoE optimization (see clause 4.1.4.4) for optionally preparing for and optimizing network performance and efficiency before cell/carrier switching off/on.

4.6.2 Advanced sleep mode

4.6.2.1 Background and goal of the use case

During DL transmission or UL reception, certain O-RU components (e.g., PA, LNA and baseband etc) can be powered off during blank OFDM symbols and slots. For power saving at the symbol level, PA and LNA can be turned off since their transition period (on to off and off to on) can be in a few microseconds (micro sleep). For power saving at slot level, additional HW can be turned off to save more energy if the transition time allowed is in a few milliseconds (light sleep). For power saving at frame level, even more HW can be turned off (e.g., only maintain O-RU M-plane processing) however higher transition delay, in 100 msec, is expected. For micro and light sleeps, Near-RT RIC can play important roles which based on AI/ML solutions can help to create more sleeping opportunities in the E2 nodes to save energy by e.g., steering traffic, influencing traffic shaping/scheduling, and adjusting common channel (SS/RS) configurations etc. For deep sleeps, where traffic prediction and more capacity, coverage, accessibility and QoS/QoE impacts awareness is needed because of the long-term traffic interruption (e.g., >100ms), Near-RT RIC is the sensible place to guide the system into deep mode due to the rich UE centric data and AI/ML solutions available in the Near-RT RIC.

The goal of Near-RT RIC energy saving is to interpret the policies received over A1 and to determine the optimum changes it can make according to these policies. More specifically, Near-RT RIC triggers E2 procedure and related control/policies so as to obtain network performance that would fulfill the criteria identified in the A1 policies. It may also leverage the A1 enrichment information to make more informed decisions. Traffic steering may reuse mechanisms provided by other use cases to affect the changes necessary to achieve its goals. The Near-RT RIC may also work in background processing without the A1 policy guidance from the Non-RT RIC.

4.6.2.2 Entities/resources involved in the use case

See clause 4.6.1.2.

4.6.2.3 Solution

The three processing modes, baseline (mode 0), background (mode 1) and A1 policy-based (mode 2), as described in clause 4.1.3 for traffic steering use case applies to this use case also as is except that the modes represent the way the Near-RT RIC operates on a given E2 node rather than UE specific.

The context of energy saving ASM optimization is captured in table 4.6.2.3-1.

Table 4.6.2.3-1: Energy saving ASM optimization

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Goal	Drive energy saving Advanced Sleep Mode (ASM) optimization in accordance with RAN OAM configured background behavior (ES mode 1) or policies information from the Non-RT RIC using A1 interface (ES mode 2).	
Actors and Roles	- Non-RT RIC in SMO domain: Creates and updates A1 policies, provide A1 enrichment information. - Near-RT RIC: Enforces A1 policies and generates RIC CONTROL and/or POLICY. - E2 node: RIC CONTROL and POLICY execution and RIC REPORT creation. Refer to 4.6.2.2 for more details.	

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Assumptions	- All relevant functions and components are instantiated. - A1, O1 and E2 interface connectivity is established. - A1 policy scope defined.	
Pre-conditions	- Network is operational with default configuration. - OAM functions have configured a baseline measurement configuration and the Non-RT RIC has access to this data. - OAM functions have configured baseline ES parameters in E2 node(s) through O1 interface. - (optional) If ES mode 1, OAM functions have configured background ES behavior to the Near-RT RIC through O1 interface. - Non-RT RIC analyzes the historical data from RAN for training the relevant AI/ML models to be deployed or updated in the Near-RT RIC, as well as AI/ML models required for non-real-time optimization of configuration and policies.	
Begins when	Energy saving ASM optimization is activated, or an operator defined trigger is detected.	
Step 1 (O)	(Start of outer loop control) If ES mode 2, OAM functions collects data from E2 node through O1 interface.	
Step 2 (O)	Non-RT RIC retrieve ES related performance data from OAM function.	
Step 3 (O)	Non-RT RIC evaluates the collected data and A1 policy feedback, if required, and generates or updates the appropriate ES optimization policy, such as energy saving and performance targets and ASM guidance, etc.	
Step 4 (O)	Non-RT RIC sends the ES optimization policy to Near-RT RIC via A1 interface.	
Step 5 (O)	Non-RT RIC sends optional ES related A1 enrichment information.	
Step 6 (O)	If ES mode 1, Near-RT RIC collects data from E2 node through E2 interface.	
Step 7 (O)	Near-RT RIC evaluates the collected data, if required, generates, or updates the internal background mode ES optimization targets or policies.	
Step 8 (M)	(Start of inner loop control) Near-RT RIC subscribes to a UE context information and measurement metrics via E2 interface.	
Step 9 (M)	E2 nodes report the UE context information and E2 measurements via RIC REPORT periodically or event triggered.	
Step 10 (M)	Near-RT RIC evaluates the performance data from E2 nodes and finds potential improvements to energy efficiency which are indicated in the A1 policy and/or internal Near-RT RIC TS targets.	
Step 11 (O)	Based on the UE context information, E2 measurement metrics (RIC REPORT), and A1 policy, Near-RT RIC may generate new or modify the existing E2 policies and sends them to E2 nodes. E2 node functions target of E2 policy may be: - Mobility control - Radio access control - ASM scheduler policy setting - Common channel configurations - Sleep mode configurations	
Step 12 (O)	Near-RT RIC may also generate control command(s) and send them to E2 node(s) to trigger the reconfiguration of radio resources, traffic steering, reconfiguration of common channels and entering/leaving deep sleep mode. E2 node functions target of E2 control command may be: - Same as Step 11 (End of inner loop control)	
Step 13 (O)	For ES mode 2, Near RT-RIC may send A1 policy feedback on A1 to the Non-RT RIC. (End of outer loop control)	

Use Case Stage	Evolution / Specification	<<Uses>> Related use
Step 14 (O)	Non-RT RIC decides to delete ES optimization policy in case of ES mode 2 and sends the related messages.	
Step 15,16 (M)	Following A1 policy deletion (mode 2) or internal trigger (mode 1), the Near-RT RIC terminates the ES optimization procedure and delete the related RIC subscriptions.	
Ends when	ES optimization is deactivated, or an operator defined trigger is detected.	
Exceptions	None.	
Post Conditions	Energy saving over a period of time is achieved.	
Traceability	REQ-Near-RT-RIC-ES-FUN1, REQ-Near-RT-RIC-ES-FUN2, REQ-Near-RT-RIC-ES-FUN4, REQ-E2-ES-FUN2, REQ-E2-ES-FUN3, REQ-E2-ES-FUN4, REQ-E2-ES-FUN5	

```
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skinparam BoxPadding 8
skinparam defaultFontSize 12

Box "Service Management and Orchestration" #gold
    Participant OAM as "OAM Functions"
    Participant non as "Non-RT RIC"
End box

Box "O-RAN" #lightpink
   Participant near as "Near-RT RIC"
   Participant ran as "E2 Node"
End box



group OUTER LOOP CONTROL

   OAM <--> ran : (Mode 2) <<O1>> RAN Data collection
   OAM --> non: (Mode 2) ES related performance information
   non --> non: (Mode 2) Collected data evaluation and policy creation

   non --> near : (Mode 2) <<A1>> A1 policy setup or update
   non --> near: (opt.) <<A1-EI>> ES related A1 enrichment information
   near <--> ran: (Mode 1) <<E2>> RAN Data collection
   near --> near: (Mode 1) Collected data evaluation and policy creation

   group INNER LOOP CONTROL
      near -> ran : <<E2>> RIC SUBSCRIPTION REQUEST(UE context & measurement metrics)
      ran -> near: <<E2>> RIC INDICATION (UE context & E2 measurement metrics)
      near -> near: Evaluation, potential improvement to energy efficiency
      near -> ran : (opt.) <<E2>> RIC SUBSCRIPTION REQUEST (ES optimisation POLICY)
      near -> ran : (opt.) <<E2>> RIC CONTROL REQUEST (ES optimisation RIC CONTROL)
   end

   non <-- near: (Mode 2) <<A1>> A1 policy feedback

end
non --> near: (Mode 2) <<A1>> A1 policy delete
near -> near: ES optimization stopped
near-> ran: <<E2>> RIC SUBSCRIPTION DELETE
@enduml
```

The flow diagram of the energy saving ASM optimization is given in figure 4.6.2.3-1.

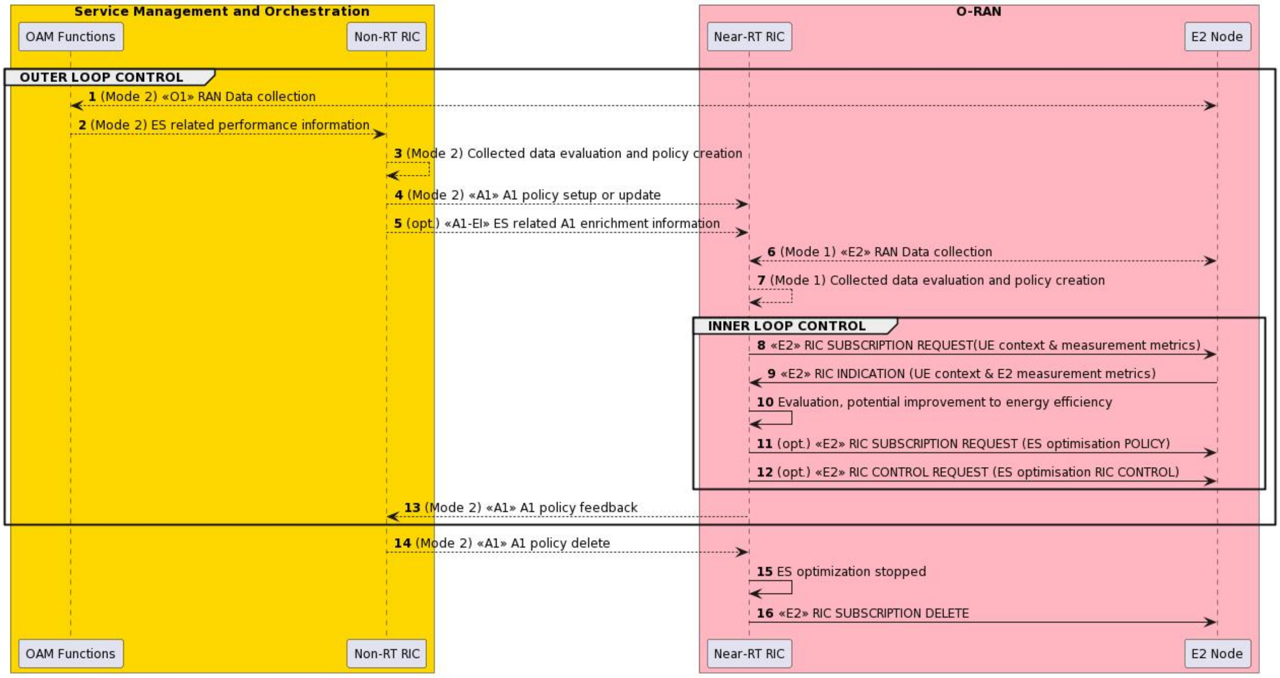

Figure 4.6.2.3-1: Energy saving ASM optimization

4.6.2.4 Required Data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the ES ASM use case. The requirements are specified in clause 5.

4.6.2.4.1 Control over E2

1) **Radio access control:** Access control may be applied to restrict access of other UEs for a specific cell in order to create more sleeping opportunities for the cell. A cell-level, UE-level, or slice-level access control can be applied. Four categories of radio access control are indicated as below:

    - RACH backoff
    - RRC connection reject
    - RRC connection release
    - Access barring

Both RIC POLICY and RIC CONTROL can be used.

2) **Mobility control:** In order to reduce traffic load to create more sleeping opportunities on the targeted cells, serving cell can be chosen based on the resource status and QoS of the UE(s) and a neighbour handover restriction list may be configured to prevent the UEs from HO to some neighbour cells. The following procedures can be used for mobility control:
    - Handover from the source cell to the target cell
    - Configuration/reconfiguration of handover restriction list
    - Configuration of idle mode mobility parameters
    - Enable, disable, or modify CA (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])
    - Enable, disable, or modify dual connectivity (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])

Both RIC POLICY and RIC CONTROL can be used.

3) **NES related radio resource control,** such as configuration common channel periodicities and semi-persistent scheduling (SPS) to create more sleep opportunities including the following types of configurations:

- SR periodicity reconfiguration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Both *sr-ProhibitTimer* and *sr-TransMax* can be treated.
- SPS configuration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Both *SPS-Config* (DL) and *ConfiguredGrantConfig* (UL) can be treated.
- CSI-RS periodicity configurations.
- Common channel periodicity configurations.

NOTE: UE DTX/DRX slots overwrite the SR and SPS configurations since during DTX/DRX, SR and SPS transmission will be deactivated. SSB periodicity may be reconfigured by the Near-RT RIC (if the capability is exposed by the E2 node) on some cells such that the O-RU can have longer sleep duration which enables deeper sleep (more hardware components can be switched off) to save energy, however, the performance impact to UEs needs to be taken care by the operator and xApp/E2 node vendors.

Both RIC POLICY and RIC CONTROL can be used.

4) **ASM mode objectives:** Configuration of ASM mode objectives to the E2 node which can include:

- Energy saving target, e.g., targeted energy saving in percentage of current average energy consumption or energy saving levels (e.g., maximum energy saving, medium energy saving, maximum performance etc.).
- UE or cell level performance targets, e.g., throughput cap, throughput drop tolerance, latency target.
- Preferred sleep mode, as specified in O-RAN.WG4.MP.0-R003-v13 [35], clause 20.4.1, sleep-mode-type of asm-capability-info.

Either RIC POLICY or RIC CONTROL can be used.

NOTE: After the objectives are configured, the E2 node shall try to achieve the objectives, however, whether the objectives can be met depends on the real traffic conditions and E2 node implementations. The E2 node reports if the ASM performance objective is applied and taken into operation. The E2 node also reports the related KPIs, as defined in clause 4.6.1.4.3, for Near-RT RIC to assess the performance changes comparing against the objectives and make further optimisation actions.

5) **Sleep mode configuration:** Depending on the current and predicted future traffic conditions, the Near-RT RIC may guide O-DU to move the carriers into sleep mode. Following the guidance, O-DU may decide to disable ("move to sleep mode") array carriers, tx-arrays or rx-arrays or the whole O-RU accordingly via the O-FH C-plane in order to save energy (see O-RAN.WG4.CUS.0-R003-v13 [34], table 7.4.6-7). The guided configurations can include:

- Indication of the slot numbers, symbol numbers and the conditions for the sleep mode configuration to be applied.
- The sleep mode (as specified in O-RAN.WG4.MP.0-R003-v13 [35], clause 20.4.1, sleep-mode-type of asm-capability-info) to be applied during the sleep period indicated in 1 above.

Either RIC POLICY or RIC CONTROL can be used.

NOTE: After the configuration, the E2 node shall try to achieve the configured sleep mode behaviour if the conditions are met, however, it is up to the E2 node to decide when and whether the configuration can be applied depending on the on-going traffic conditions within the E2 node. The E2 node reports if the sleep mode configuration is applied. The E2 node also report the related KPIs, as defined in clause 4.6.1.4.3, for Near-RT RIC to assess the performance changes comparing against the objectives and make further optimisation actions.

4.6.2.4.2 UE context information from E2 nodes

See clause 4.6.1.4.2.

4.6.2.4.3 Measurements from E2 nodes

See clause 4.6.1.4.3

4.6.2.4.4 E2 node configuration

Cell level configuration parameters in order to configure UE measurements required for traffic steering and QoS/QoE optimization (see clause 4.1.4.4) for creating more sleeping opportunities to save energy while maintaining acceptable performance.

O-RU and O-DU advanced sleep mode capabilities, as specified in O-RAN.WG4.MP.0-R003-v13 [35], clause 20.4.1, asm-capability-info, along with information about the mapping from cells to sector carriers and to O-RU are retrieved from O-DU in order to generate applicable and optimized energy saving related policies and controls.

4.6.3 RF channel reconfiguration

4.6.3.1 Background and goal of the use case

In mobile networks, massive-MIMO array antennas are used to implement beamforming techniques, which boost the cell coverage, capacity, and spectrum efficiency for enhanced mobile broadband services. Due to the massive number of the active antenna elements and RF channels used in the massive-MIMO array, it can consume significantly more energy than conventional antenna solution. The goal of the RF channel reconfiguration energy saving use case is to reduce the power consumption of O-RUs for massive-MIMO by dynamically reconfiguring the number of active Tx/Rx array antenna elements. When the traffic load is low, fewer beams or MU-MIMO spatial layers are needed, therefore, fewer Tx/Rx array antenna elements can be active which can be reconfigured from Near-RT RIC dynamically leading to significant power savings. The number of active antenna element and the antenna element layout also have an impact to the signal coverage and spatial channel orthogonality translating to impact to the UE service of quality, which need to be handled by the Near-RT RIC to avoid the impact to the performance or finding the trade-off between energy saving and performance.

The goal of Near-RT RIC energy saving is to interpret the policies received over A1 interface. Based on policy and the current or predicted traffic and channel conditions, the Near-RT RIC then derive the best choices for O-RU Tx/Rx array configurations including e.g. number of active antenna element, antenna element layout, SU/MU MIMO layers etc and provide guided configurations to the O-DU. Following the guidance, O-DU may decide to disable (“putting to sleep”) some or all array elements in a tx-array or rx-array (or both) accordingly via the O-FH C-plane in order to save energy (see O-RAN.WG4.CUS.0-R003-v14 [38], clause 7.2.9.2.3).

4.6.3.2 Entities/resources involved in the use case

See clause 4.6.1.2.

4.6.3.3 Solution

The context of energy saving RF channel reconfiguration optimization is captured in table 4.6.3.3-1.

Table 4.6.3.3-1: Energy saving RF channel reconfiguration optimization

Use Case Stage	Evolution / Specification
Goal	Drive energy saving RF channel reconfiguration optimization in accordance with RAN OAM configured background behavior (ES mode 1) or policies information from the Non-RT RIC using A1 interface (ES mode 2).
Actors and Roles	- Non-RT RIC in SMO domain: Creates and updates A1 policies, provide A1 enrichment information. - Near-RT RIC: Enforces A1 policies and generates RIC CONTROL and/or POLICY. - E2 node: RIC CONTROL and POLICY execution and RIC REPORT creation. Refer to 4.6.3.2 for more details.

Use Case Stage	Evolution / Specification
Assumptions	- All relevant functions and components are instantiated. - A1, O1 and E2 interface connectivity is established. - A1 policy scope defined.
Pre-conditions	- Network is operational with default configuration. - OAM functions have configured a baseline measurement configuration and the Non-RT RIC has access to this data. - OAM functions have configured baseline ES parameters in E2 node(s) through O1 interface. - (optional) If ES mode 1, OAM functions have configured background ES behavior to the Near-RT RIC through O1 interface. - Non-RT RIC analyzes the historical data from RAN for training the relevant AI/ML models to be deployed or updated in the Near-RT RIC, as well as AI/ML models required for non-real-time optimization of configuration and policies.
Begins when	Energy saving RF channel reconfiguration optimization is activated, or an operator defined trigger is detected.
Step 1 (O)	(Start of outer loop control) If ES mode 2, OAM functions collects data from E2 node through O1 interface.
Step 2 (O)	Non-RT RIC retrieve ES related performance data from OAM function.
Step 3 (O)	Non-RT RIC evaluates the collected data and A1 policy feedback, if required, and generates or updates the appropriate ES optimization policy, such as energy saving and performance, etc.
Step 4 (O)	Non-RT RIC sends the ES optimization policy to Near-RT RIC via A1 interface.
Step 5 (O)	Non-RT RIC sends optional ES related A1 enrichment information.
Step 6 (O)	If ES mode 1, Near-RT RIC collects data from E2 node through E2 interface.
Step 7 (O)	Near-RT RIC evaluates the collected data, if required, generates or updates the internal background mode ES optimization targets or policies.
Step 8 (M)	(Start of inner loop control) Near-RT RIC subscribes to a UE context information and measurement metrics via E2 interface.
Step 9 (M)	E2 nodes report the UE context information and E2 measurements via RIC REPORT periodically or event-triggered.
Step 10 (M)	Near-RT RIC evaluates the performance data from E2 nodes and finds potential improvements to energy efficiency or potential gap to A1 policy and/or internal Near-RT RIC ES targets.
Step 11 (O)	Based on evaluation in Step 10, Near-RT RIC may generate new or modify the existing E2 policies and sends them to E2 nodes. E2 node functions target of E2 policy may be: - Connected mode mobility - Idle mode mobility - Radio access control - RF channel reconfiguration policy setting - Common channel configurations (SSB, CSI-RS) - TX/RX array configuration change
Step 12 (O)	Near-RT RIC may also generate control command(s) and send them to E2 node(s) to trigger the reconfiguration of radio resources, traffic steering, reconfiguration of common channels and entering/leaving deep sleep mode. E2 node functions target of E2 control command may be: - Same as Step 11 (End of inner loop control)
Step 13 (O)	For ES mode 2, Near RT-RIC may send A1 policy feedback on A1 to the Non-RT RIC. (End of outer loop control)
Step 14 (O)	Non-RT RIC decides to delete ES optimization policy in case of ES mode 2 and sends the related messages.
Step 15,16 (M)	Following A1 policy deletion (mode 2) or internal trigger (mode 1), the Near-RT

Use Case Stage	Evolution / Specification
	RIC terminates the ES optimization procedure and delete the related RIC subscriptions.
Ends when	ES optimization is deactivated, or an operator defined trigger is detected.
Exceptions	None.
Post Conditions	Energy saving over a period of time is achieved.
Traceability	REQ-Near-RT-RIC-ES-FUN1, REQ-Near-RT-RIC-ES-FUN2, REQ-Near-RT-RIC-ES-FUN3, REQ-Near-RT-RIC-ES-FUN5, REQ-Near-RT-RIC-ES-FUN6, REQ-E2-ES-FUN2, REQ-E2-ES-FUN4, REQ-E2-ES-FUN6, REQ-E2-ES-FUN7

```
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    Participant non as "Non-RT RIC"
End box

Box "O-RAN" #lightpink
   Participant near as "Near-RT RIC"
   Participant ran as "E2 Node"
End box



group OUTER LOOP CONTROL

   OAM <--> ran : (Mode 2) <<O1>> RAN Data collection
   OAM --> non: (Mode 2) ES related performance information
   non --> non: (Mode 2) Collected data evaluation and policy creation

   non --> near : (Mode 2) <<A1>> A1 policy setup or update
   non --> near: (opt.) <<A1-EI>> ES related A1 enrichment information
   near <--> ran: (Mode 1) <<E2>> RAN Data collection
   near --> near: (Mode 1) Collected data evaluation and policy creation

   group INNER LOOP CONTROL
      near -> ran : <<E2>> RIC SUBSCRIPTION REQUEST(UE context & measurement metrics)
      ran -> near: <<E2>> RIC INDICATION (UE context & E2 measurement metrics)
      near -> near: Evaluation, potential improvement to energy efficiency
      near -> ran : (opt.) <<E2>> RIC SUBSCRIPTION REQUEST (ES optimisation POLICY)
      near -> ran : (opt.) <<E2>> RIC CONTROL REQUEST (ES optimisation RIC CONTROL)
   end

   non <-- near: (Mode 2) <<A1>> A1 policy feedback

end
non --> near: (Mode 2) <<A1>> A1 policy delete
near -> near: ES optimization stopped
near-> ran: <<E2>> RIC SUBSCRIPTION DELETE
@enduml
```

The flow diagram of the energy saving RF channel reconfiguration optimization is given in figure 4.6.3.3-1.

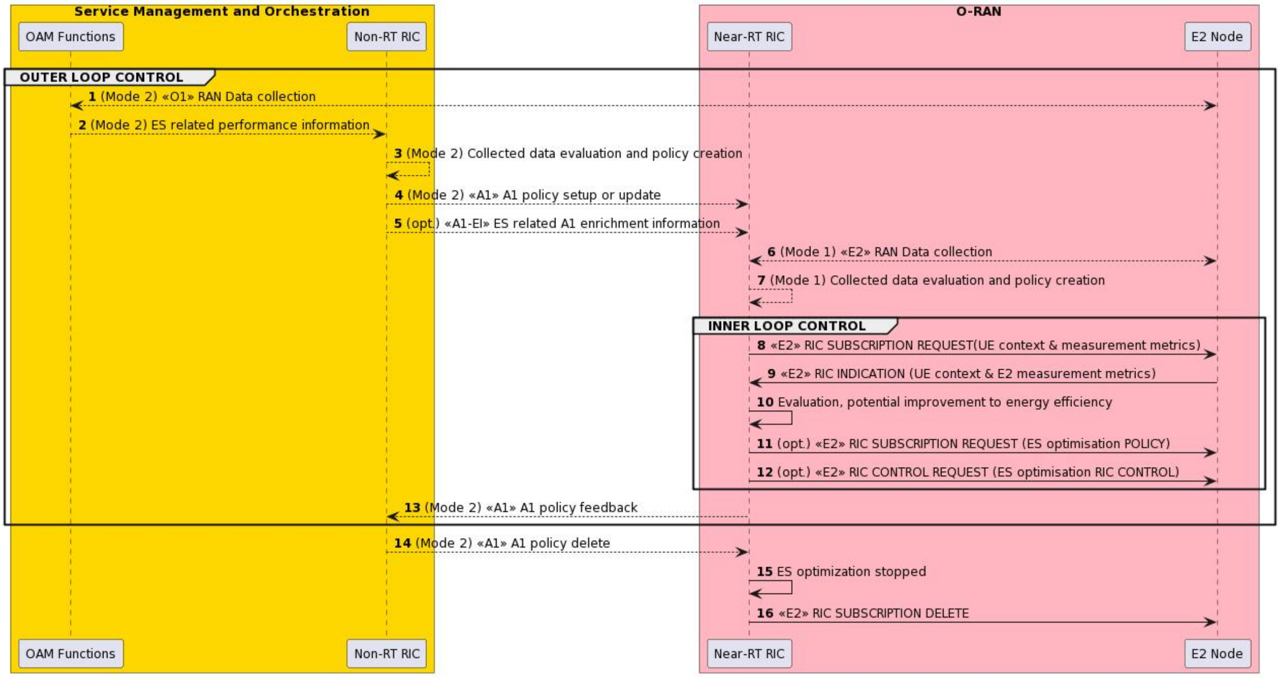

Figure 4.6.3.3-1: Energy saving RF channel reconfiguration optimization

4.6.3.4 Required data

This clause elaborates the Near-RT RIC and the E2 node capabilities necessary for implementation of the ES RF channel reconfiguration use case. The requirements are specified in clause 4.

4.6.3.4.1 Control over E2

1) **Radio access control:** See clause 4.6.2.4.1.

2) **Mobility control:** See clause 4.6.2.4.1.

3) **NES related radio resource control:** See clause 4.6.2.4.1

4) **TRX control performance objectives:** Configuration of TRX control performance objectives to the E2 node which can include:

   - Energy saving target, e.g. targeted energy saving in percentage of current average energy consumption or energy saving levels (e.g., maximum energy saving, medium energy saving, maximum performance, etc.).
   - UE or cell level performance targets, e.g., throughput cap, throughput drop tolerance, latency target.

Either RIC POLICY or RIC CONTROL can be used.

NOTE: After the objectives are configured, the E2 node shall try to achieve the objectives, however, whether the objectives can be met depends on the real traffic conditions and E2 node implementations. The E2 node reports if the TRX control objective is applied and taken into operation. The E2 node also reports the related KPIs, as defined in clause 4.6.1.4.3, for Near-RT RIC to assess the performance changes comparing against the objectives and make further optimisation actions.

5) **TRX control configuration:** Depending upon the current and future traffic predictions, the Near-RT-RIC may guide the O-DU to perform O-RU RF channel reconfigurations to reduce the overall power consumption of the O-RU. Following the guidance, O-DU may decide to disable ("putting to sleep") some or all array elements in a tx-array or rx-array (or both)

accordingly via the O-FH C-plane in order to save energy (O-RAN.WG4.CUS.0-R003-v14 [38], Table 7.4.6-7). The guided configurations can include:

- Indication of the slot numbers, symbol numbers and the conditions for the TRX control configuration to be applied.
- Indication of the array elements to be switched off during the period indicated above based on the TRX control capability information reported by the E2 node (O-DU), see clause 4.6.3.4.4. The capability information includes antenna mask values supported by the O-RU, see O-RAN.WG4.MP.0-R003-v14 [39], clause 20.3.1, trx-control-capability-info, for more details.
- The sleep mode (see O-RAN.WG4.MP.0-R003-v14 [39], clause 20.3.1, sleep-mode-type of trx-control-capability-info) to be applied during the sleep period indicated above.

Either RIC POLICY or RIC CONTROL can be used.

NOTE: After the configuration, the E2 node shall try to achieve the configured behaviour if the conditions are met, however, it is up to the E2 node to decide when and whether the configuration can be applied depending on the on-going traffic conditions within the E2 node. The E2 node reports if the TRX control configuration is applied. The E2 node also report the related KPIs, as defined in clause 4.6.1.4.3, for Near-RT RIC to assess the performance changes comparing against the objectives and make further optimisation actions.

Both RIC POLICY and RIC CONTROL can be used.

4.6.3.4.2 UE context information from E2 nodes

See clause 4.6.1.4.2.

4.6.3.4.3 Measurements from E2 nodes

See clause 4.6.1.4.3.

4.6.3.4.4 E2 node configuration

Cell level configuration parameters in order to configure UE measurements required for traffic steering and QoS/QoE optimization (see clause 4.1.4.4) for creating more RF channel reconfiguration opportunities to save energy while maintaining acceptable performance.

O-RU and O-DU TRX control capabilities, see O-RAN.WG4.MP.0-R003-v14 [39], clause 20.3.1, trx-control-capability-info, along with information about the mapping from cells to sector carriers and to O-RU are retrieved from O-DU in order to generate applicable and optimized energy saving related policies and controls.

5 Requirements

5.1 Functional requirements

5.1.1 Near-RT RIC generic functional requirements

The Near-RT RIC functional requirements are captured in table 5.1.1-1.

Table 5.1.1-1: Near-RT RIC functional requirements

REQ	Description	Note
REQ-Near-RT-RIC-TS-FUN1	Near-RT RIC shall be able to use traffic steering-related A1 policies to determine and execute appropriate E2 actions.	
REQ-Near-RT-RIC-TS-FUN2	Near-RT RIC shall be able to use traffic steering-related A1 enrichment information, e.g., the radio finger print information, to determine and execute appropriate E2 actions.	
REQ-Near-RT-RIC-MM-FUN1	Near-RT RIC shall support training of massive MIMO-related models in xApps.	
REQ-Near-RT-RIC-MM-FUN2	Near-RT RIC shall support deployment of massive MIMO-related trained models in xApps .	
REQ-Near-RT-RIC-MM-FUN3	Near-RT RIC shall be able to use massive MIMO-related A1 enrichment information, e.g., location and mobility information, to determine and execute appropriate E2 actions.	
REQ-Near-RT-RIC-QOE-FUN1	Near-RT RIC shall be able to generate QoE related RAN analytics information and expose it to RAI service consumer.	
REQ-Near-RT-RIC-ES-FUN1	Near-RT RIC shall be able to use energy saving-related A1 policies and enrichment information, e.g., the radio finger print information, to determine and execute appropriate E2 actions.	
REQ-Near-RT-RIC-ES-FUN2	Near-RT RIC shall be able to trigger necessary energy saving related actions based on the configuration from O1 interface.	
REQ-Near-RT-RIC-ES-FUN3	Near-RT RIC shall be able to handle mobility of users to account for potential coverage loss directly or indirectly via guidance to the E2 node.	
REQ-Near-RT-RIC-ES-FUN4	Near-RT RIC shall be able to handle radio access and mobility controls as described in clause 4.6.2.4.1 to create more ASM sleep opportunities on the targeted cells.	
REQ-Near-RT-RIC-ES-FUN5	Near-RT RIC shall support handling radio access to restrict access of UEs for a specific cell.	
REQ-Near-RT-RIC-ES-FUN6	Near-RT RIC shall support handling mobility control to reduce traffic load.	

5.1.2 E2 interface functional requirements

The E2 interface functional requirements are captured in table 5.1.2-1.

Table 5.1.2-1: E2 interface functional requirements

REQ	Description	Note
REQ-E2-TS-FUN1	E2 shall support retrieval over E2 (read or receive via REPORT) of the following: - Cell level configuration parameters, such as PCI, neighbor relations and related offsets for measurement, cell reselection and handover, etc. Supported REPORT triggers shall include: - Modification of the configuration parameters	

REQ	Description	Note
REQ-E2-TS-FUN2	E2 shall support the configuration (including range and granularity) and retrieval of cell/SSB area or slice related measurements in the nomenclature as specified in 3GPP TS 28.552 [6], 3GPP TS 32.425 [7], 3GPP TS 36.314 [9], 3GPP TS 36.423 [12], 3GPP TS 38.314 [16], 3GPP TS 38.423 [19], 3GPP TS 38.463 [20] and 3GPP TS 38.473 [21]. These include: - DL/UL Total PRB Usage, Distribution of DL/UL Total PRB Usage, DL/UL GBR PRB Usage, DL/UL total available PRB, DL/UL non-GBR PRB Usage, RRC Connection Number, Available RRC Connection Capacity Value, Mean and Maximum Number of Active UEs in the DL/UL per DRB, DL/UL Scheduling PDCCH CCE Usage, DL/UL Composite Available Capacity, DL/UL Cell PDCP SDU Data Volume (including secondary RAT usage for EN-DC/MR-DC), Handover success ratio - DL/UL SSB Area Total PRB Usage, DL/UL SSB Area GBR PRB Usage, DL/UL SSB Area non-GBR PRB Usage, SSB Area Capacity Value - DL/UL PRB usage per QCI, DL/UL PRB usage per 5QI, DL/UL PRB usage per slice, Slice Available Capacity Value See NOTE 1. Supported REPORT triggers shall include: - Availability of new information e.g., new load measurement generated - Threshold crossing	
REQ-E2-TS-FUN3	E2 shall support the configuration and retrieval of E2-node user plane measurements per-UE / UE group, in the nomenclature as specified in 3GPP TS 28.552 [6], 3GPP TS 32.425 [7], 3GPP TS 36.314 [9], 3GPP TS 36.321 [10], 3GPP TS 38.314 [16], 3GPP TS 38.321 [17], 3GPP TS 38.423 [19], 3GPP TS 38.463 [20] and 3GPP TS 38.473 [21], e.g.: - Average DL/UL throughput - DL/UL PRB usage - Buffer Status Information (e.g., UL BSR) Supported REPORT triggers shall include: - Availability of new information e.g., new load measurement generated - Threshold crossing	
REQ-E2-TS-FUN4	E2 shall support the configuration and retrieval of UE L1/L2/L3 measurements reported by individual UE, e.g.: - RSRP and RSRQ measurements - SINR measurements - CQI/MCS measurements Supported REPORT triggers shall include: - Availability of new information e.g., reception of RRC measurement reports.	
REQ-E2-TS-FUN5	E2 shall support the control of EN-DC/MR-DC function in E2 nodes, including the configuration of the relevant parameters for EN-DC/MR-DC procedures, e.g. - X2 SgNB addition - X2 SgNB modification - X2 SgNB release - X2 SgNB change - PSCell change - Inter-master node handover and UE level cell preference guidance for EN-DC/MR-DC, e.g.: - Ordered list of target cells for sgNB addition and change.	

REQ	Description	Note
	INSERT/CONTROL and POLICY shall be supported in order to trigger the operation by a RAN event, as well as REPORT/CONTROL for Near-RT RIC to trigger the operation asynchronously where appropriate	
REQ-E2-TS-FUN6	E2 shall support the control of handover function in E2 nodes, including the configuration of the relevant parameters for handover procedures, e.g.: - Intra-frequency/inter-frequency/inter-RAT handover - Intra/inter-eNB/gNB handover and UE level cell preference guidance for handover, e.g.: - Ordered list of target cells for handover INSERT/CONTROL and POLICY shall be supported in order to trigger the operation by a RAN event, as well as REPORT/CONTROL for Near-RT RIC to trigger the operation asynchronously where appropriate	
REQ-E2-TS-FUN7	E2 shall support the control of carrier aggregation function in E2 nodes, including the configuration of the relevant parameters for CA procedures (e.g., addition, modification and release of a component carrier) and UE level cell preference guidance for CA (e.g., ordered list of target cells for Scell addition/modification) INSERT/CONTROL and POLICY shall be supported in order to trigger the operation by a RAN event, as well as REPORT/ CONTROL for Near-RT RIC to trigger the operation asynchronously	
REQ-E2-TS-FUN8	E2 shall support the control of idle mode mobility function in E2 nodes, including the configuration of the relevant parameters for idle mode procedures (e.g., intra-frequency/inter-frequency/inter-RAT cell reselection priority) INSERT/CONTROL and POLICY shall be supported in order to trigger the operation by a RAN event, as well as REPORT/CONTROL for RIC to trigger the operation asynchronously	
REQ-E2-TS-FUN9	E2 shall support the fetching of UE information including e.g.: - UE ID as specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23] - S-NSSAI - QCI/5QI, - UE capabilities (DC/CA) - Active DRBs/QoS flows	
REQ-E2-TS-FUN10	E2 shall support the configuration and retrieval of measurements related to UE location and velocity that are reported by an individual UE, e.g.: - LocationInfo, CommonLocationInfo Supported REPORT triggers shall include: - Availability of new information e.g., reception of RRC measurement reports.	
REQ-E2-QoS-FUN1	E2 interface shall support retrieval of the UE context related information from E2 nodes: • UE ID as specified in O-RAN.WG1.Use-Cases-Detailed-Specification-v05.00 [23] • Slicing info, such as S-NSSAI • QoS info, such as E-RAB level QoS parameters (4G, NSA) or QoS flow level QoS parameters (NG-RAN) • Radio bearers related info, such as established DRB ID, flow-to-DRB mapping	Applicable RIC services: REPORT

REQ	Description	Note
	• RLC/MAC/PHY related info, such as LCID, scheduling related parameters • UE capability info, such as CA (carrier aggregation) and DC (dual connectivity) capabilities	
REQ-E2-QoS-FUN2	E2 interface shall support retrieval of the following measurements info from E2 nodes: • UE-level - **Radio channel info available at DU:** CQI (as specified in 3GPP TS 28.552 [6]) - **Radio channel info available at CU-CP for serving cell:** RSRP, RSRQ, SINR (as specified in 3GPP TS 36.331 [11] and 3GPP TS 38.331 [18]), including from periodical and/or event triggered measurement report (A1-A6, B1-B2). - **Radio channel info available at CU-CP for neighboring cells:** RSRP, RSRQ, SINR (as specified in 3GPP TS 36.331 [11] and 3GPP TS 38.331 [18]), including from periodical and/or event triggered measurement report (A1-A6, B1-B2). - **Layer-2:** DL/UL UE PRB used for data traffic, Average DL UE throughput in gNB, Distribution of DL UE throughput in gNB, Percentage of unrestricted DL UE data volume in gNB, Packet Delay and RAN part packet delay components, Packet Delay, Data Volume (as specified in 3GPP TS 36.314 [9]), DL PDCP occupied buffer size, DL unused PDCP buffer size, Packet Loss Rate per DRB (as specified in 3GPP TS 38.314 [16]) and per logical channel • Cell-level - **Layer-2:** CQI, MCS Distribution in PDSCH, DL/UL Total PRB usage, Distribution of DL/UL Total PRB usage, DL/UL PRB used for data traffic, DL/UL Total available PRB, Total number of DL/UL TBs, Total error number of DL/UL TBs, Average DL UE throughput in gNB, Distribution of DL UE throughput in gNB, Percentage of unrestricted DL UE data volume in gNB, Packet Delay, Mean number of Active UEs in the DL/UL per cell, Max number of Active UEs in the DL/UL per cell (as specified so far in 3GPP TS 28.552 [6]), DL/UL PRB usage for traffic, DL/UL Total PRB usage, Distribution of DL/UL Total PRB usage, DL/UL PRB full utilization, Total number of DL/UL TBs, Total error number of DL/UL TBs, Average number of Active UEs (as specified so far in 3GPP TS 32.425 [7]), RAN part packet delay components (as specified in 3GPP TS 38.314 [16]), Packet Delay (as specified in 3GPP TS 36.314 [9]), DL/UL Cell PDCP SDU Data Volume, Packet Loss Rate, DL Packet Drop Rate (as specified in 3GPP TS 28.552 [6] and 3GPP TS 32.425 [7])	Applicable RIC services: REPORT
REQ-E2-QoS-FUN3	E2 interface shall support the control of radio bearer related functions in E2 nodes, including configuration/modification of the following: • DRB QoS (as specified in 3GPP TS 38.473 [21] and 3GPP TS 23.501 [3]) • QoS flow mapping (as specified in 3GPP TS 38.473 [21]) • Logical channel configuration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) • Radio admission control (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) • Change of bearer termination point (MN or SN) and/or bearer types (MCG/SCG/split) (as specified in 3GPP TS	Applicable RIC services: CONTROL POLICY

REQ	Description	Note
	37.340 [13]); Control of split ratio for a split bearer; Control of packet duplication and number of legs (as specified in 3GPP TS 36.300 [8] and 3GPP TS 38.300 [14])	
REQ-E2-QoS-FUN4	E2 interface shall support the control of resource allocation function in E2 nodes, including configuration/modification of the following: • DRX parameters (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) such as long DRX cycle, short DRX cycle, short DRX timer. • SR (scheduling request) periodicity (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) such as *sr-ProhibitTimer, sr-TransMax*. • SPS (semi-persistent scheduling) parameters (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]), such as *SPS-Config* (DL) and *ConfiguredGrantConfig* (UL) • Slice level PRB quota (as specified in 3GPP TS 28.541 [4]) • CQI table (as specified in 3GPP TS 38.214 [15]) with target block error rate	Applicable RIC services: CONTROL POLICY
REQ-E2-QoS-FUN5	E2 interface shall support the control of radio access related functions in E2 nodes, including configuration/modification of the following: • Access control (cell-level, UE-level, slice-level), such as RACH backoff, RRC connection reject, RRC connection release, access barring, etc.	Applicable RIC services: CONTROL POLICY
REQ-E2-QoS-FUN6	E2 interface shall support the control of mobility management function in E2 nodes, including configuration/modification of the following: • Handover • Handover restriction list • Carrier aggregation (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) • MR-DC, including (NG)EN-DC, NE-DC, NR-DC (as specified in 3GPP TS 38.473 [21], 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11])	Applicable RIC services: CONTROL POLICY
REQ-E2-QoS-FUN7	E2 interface shall support the control of uplink power control function in E2 nodes, including configuration/modification of the following: • Target value of uplink received quality such as received SINR or received power at E2 node	Applicable RIC services: CONTROL POLICY
REQ-E2-QoS-FUN8	E2 interface shall support retrieval of configuration of uplink transmit power from E2 node: • Cell specific transmit power (TS38.331 [19]), *PUSCH-ConfigCommon*. • UE specific transmit power (TS 38.331 [19]), *PUSCH-PowerControl*. Target value of uplink received quality such as received SINR or received power at E2 node	Applicable RIC services: REPORT QUERY
REQ-E2-SLA-FUN1	E2 shall support retrieval over E2 (read or receive via REPORT) of the following: - Cell level and/or slice level configuration parameters Supported REPORT triggers shall include: - Modification of cell level and/or slice configuration parameters	
REQ-E2-SLA-FUN2	E2 shall support the configuration (including range and	Applicable

REQ	Description	Note
	granularity) and retrieval of cell or slice related measurements in the nomenclature as specified in 3GPP TS 28.552 [6], 3GPP TS 32.425 [7], 3GPP TS 36.314 [9], 3GPP TS 36.423 [12], 3GPP TS 38.314 [16], 3GPP TS 38.423 [19], 3GPP TS 38.463 [20] and 3GPP TS 38.473 [21]. These include: - DL/UL Total PRB Usage, Distribution of DL/UL Total PRB Usage, DL/UL total available PRB, RRC Connection Number, Available RRC Connection Capacity Value, Mean and Maximum Number of Active UEs in the DL/UL per DRB - DL/UL PRB usage per slice, Slice Available Capacity Value Supported REPORT triggers shall include: - Availability of new information e.g., new load measurement generated - Threshold crossing	RIC services: REPORT
REQ-E2-SLA-FUN3	E2 shall support the fetching of UE information including e.g.: - UE ID - PLMN, S-NSSAI(s) - DRB related information	Applicable RIC services: REPORT
REQ-E2-SLA-FUN4	E2 interface shall support the configuration and retrieval of individual UE measurements, including the following: - RSRP, RSRQ - CQI	Applicable RIC services: REPORT
REQ-E2-SLA-FUN5	E2 interface shall support the control of slice resource allocation in E2 nodes, including configuration/modification of the following: - Per-slice dedicated PRB allocation percentages for downlink and uplink - Per-slice maximum PRB allocation percentages for downlink and uplink - Per-UE-per-slice maximum PRB allocation percentages for downlink and uplink - Per-slice indication of resource sharing allowance to achieve utilization of unused slice resources by other network slices - Per-slice priority values to achieve scheduling prioritization among network slices with different priorities	Applicable RIC services: REPORT CONTROL
REQ-E2-SLA-FUN6	E2 interface shall support the slice-level control of radio resource management related functions in E2 nodes, including the following: - Slice based radio admission control - Slice based radio bearer control	Applicable RIC services: CONTROL POLICY
REQ-E2-MM-FUN1	E2 shall support retrieval over E2 of the following: - Beam level configuration parameters, such as beam pattern information (as specified in 3GPP TS 28.541 [5], clause 4.3.40) - O-RU antenna information (as specified in O-RAN.WG4.MP.0-R003-v13 [35], clause D.3.8) - O-DU supported compression methods (as specified in O-RAN.WG4.CUS.0-R003-v13 [34], clause 7.7.1.2) - Served cell information (as specified in 3GPP TS 38.473 [21], clause 9.3.1.10) - MIB (as specified in 3GPP TS 38.331 [18], clause 6.2.2) - SSB information of the serving cell (as specified in 3GPP TS 38.331 [18], clause 6.2.2) Supported REPORT triggers shall include: Modification of the configuration parameters	Applicable RIC services: REPORT, QUERY
REQ-E2-MM-FUN2	E2 shall support retrieval from E2 node of DL L1 measurements reported by individual UE, e.g.: - RSRP-SS measurements (as specified in 3GPP TS 38.133 [26] and 3GPP TS 38.215 [27]) - SINR-SS measurements (as specified in 3GPP TS 38.133	Applicable RIC services: REPORT

REQ	Description	Note
	[26] and 3GPP TS 38.215 [27]) - PMI, RI, CQI (as specified in 3GPP TS 38.212 [43], clause 6.3) Supported REPORT triggers shall include: Availability of new information	
REQ-E2-MM-FUN3	E2 shall support retrieval from E2 node of UL L1 measurements reported for individual UE, e.g.: - SRS RSRP measurements (as specified in 3GPP TS 38.133 [26] and 3GPP TS 38.215 [27]) Supported REPORT triggers shall include: Availability of new information	Applicable RIC services: REPORT
REQ-E2-MM-FUN4	E2 shall support retrieval from E2 node of L3 mobility measurements reported per beam/beam group, e.g.: - Number of too early HOs (as specified in 3GPP TS 28.552 [6]) - Number of too late HOs (as specified in 3GPP TS 28.552 [6]) - Number of HOs to wrong cell (as specified in 3GPP TS 28.552 [6]) - Number of requested legacy HO executions (HO attempts) (as specified in 3GPP TS 28.552 [6]) - Number of successful legacy HO executions (as specified in 3GPP TS 28.552 [6]) - Number of failed legacy HO executions (as specified in 3GPP TS 28.552 [6]) - Per UE event mobility failure indication with root cause (too early HO, too late HO, HO to wrong cell) and number of requested or number of successful HO executions at the time of failure Supported REPORT triggers shall include - For mobility KPIs, periodic reporting For mobility failure indication, message event trigger	Applicable RIC services: REPORT
REQ-E2-MM-FUN5	E2 shall support retrieval of UE context information from E2 node for individual UE, e.g.: - UE ID - UE capabilities (as specified in 3GPP TS 38.331 [18], clause 6.2.2) - SRS Configuration (as specified in 3GPP TS 38.331 [18], clause 6.2.2) - RRC State - CSI Measurement configuration (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - Measurement Gap configuration (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - BWP DL/UL configurations (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - DRB related info, such as established DRB ID, flow-to-DRB mapping, RLC Mode, LCID (as specified in 3GPP TS 38.473 [21], clause 9.2.2.1) - PDSCH of serving cell configuration (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - DRX Configuration (as specified in 3GPP TS 38.331 [18], clause 6.3.2) Supported REPORT triggers shall include: Configuration or reconfiguration of the UE context information	Applicable RIC services: REPORT, QUERY
REQ-E2-MM-FUN6	E2 interface shall support the control of beamforming in E2 nodes, including the following: - Configuration of non-Grid of beams beamforming mode, separately for single user- and multi-user MIMO, on a per-	Applicable RIC services: CONTROL

REQ	Description	Note
	UE basis	POLICY
REQ-E2-MM-FUN7	E2 interface shall support the control of L3 mobility configuration in E2 nodes, including the following: Cell Individual Offset (CIO), Time To Trigger (TTT), UE Timer 310 (T310) on a per beam/beam group, per UE/UE group basis (as specified in 3GPP TS 38.331 [18])	Applicable RIC services: POLICY
REQ-E2-MM-FUN8	E2 interface shall support the configuration of beam grouping information in E2 nodes, including the following: List of beam group IDs with associated beam IDs	Applicable RIC services: POLICY
REQ-E2-MM-FUN9	E2 shall support request and reporting of the number of supported non-GoB BF modes in O-DU	Applicable RIC services: QUERY
REQ-E2-MM-FUN10	E2 shall support retrieval from E2 node of average DL/UL per-UE throughput in gNB with associated non-GoB BF mode and MIMO mode (SU/MU)	Applicable RIC services: REPORT
REQ-E2-MM-FUN11	E2 shall support retrieval from E2 node of DL L1 and L2 information reported for individual UE, e.g.: - PDCP buffer status (as specified in 3GPP TS 38.323 [40], clause 5.6) - RLC buffer status (as specified in 3GPP TS 25.321 [41], clause 8.2.2) - HARQ ACK/NACK/DTX counts - SRS samples Supported REPORT triggers shall include: Periodic with a configured period	Applicable RIC services: REPORT
REQ-E2-MM-FUN12	E2 interface shall support the configuration of individual UE operation, including the following: - CSI resources (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - CSI reports (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - SRS resources (as specified in 3GPP TS 38.331 [18], clause 6.3.2) - PDSCH (as specified in 3GPP TS 38.331 [18], clause 6.3.2)	Applicable RIC services: CONTROL
REQ-E2-MM-FUN13	E2 shall support retrieval over E2 of the following: - Timestamped slot numbers (as specified in 3GPP TS 38.473 [21], clause 9.3.1.171) - Received time and processing time margin of the scheduling control message Supported REPORT triggers shall include: Periodic with a configured period	Applicable RIC services: REPORT
REQ-E2-MM-FUN14	E2 interface shall support the configuration of the active bearers for which the Near-RT RIC will be providing the scheduling parameters	Applicable RIC services: CONTROL
REQ-E2-MM-FUN15	E2 interface shall support the control of scheduling parameters that enable MU-MIMO transmissions and the relevant MIMO parameters, of latency tolerant traffic per slot per UE.	Applicable RIC services: CONTROL
REQ-E2-QoE-FUN1	E2 shall support UE context information including e.g.: - UE ID - List of S-NSSAI List of QoS related ID, e.g., 5QI, QFI	

REQ	Description	Note
REQ-E2-QoE-FUN2	E2 interface shall support retrieval of UE-level or cell-level measurement, including e.g.: • Cell-level: - **Layer-2:** MCS Distribution in PDSCH (as specified in 3GPP TS 28.552 [6], clause 5.1.1.12.1), DL/UL Total PRB usage (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.1 and 5.1.1.2.2 and in 3GPP TS 32.425 [7], clauses 4.5.3 and 4.5.4), Distribution of DL/UL Total PRB usage (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.3 and 5.1.1.2.4 and in 3GPP TS 32.425 [7], clauses 4.5.10 and 4.5.11), DL/UL PRB used for data traffic (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.5 and 5.1.1.2.7), DL/UL PRB usage for traffic (as specified in 3GPP TS 32.425 [7], clauses 4.5.1 and 4.5.2), DL/UL Total available PRB (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.2.6 and 5.1.1.2.8), DL/UL PRB full utilization (as specified in 3GPP TS 32.425 [7], clauses 4.5.9.1 and 4.5.9.2), Total number of DL/UL TBs (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.7.3 and 5.1.1.7.8 and in 3GPP TS 32.425 [7], clauses 4.5.7.1 and 4.5.7.3), Total error number of DL/UL TBs (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.7.4 and 5.1.1.7.9 and in 3GPP TS 32.425 [7], clauses 4.5.7.2 and 4.5.7.4), Average DL UE throughput in gNB (as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.1), Distribution of DL UE throughput in gNB (as specified in 3GPP TS 28.552 [6], clause 5.1.1.3.2), Packet Delay (as specified in 3GPP TS 28.552 [6], clause 5.1.3.3), RAN part packet delay components (as specified in 3GPP TS 38.314 [16], clause 4.2.1.2), Packet Delay (as specified in 3GPP TS 36.314 [9], clause 4.1.4), DL/UL Cell PDCP SDU Data Volume (as specified in 3GPP TS 28.552 [6], clause 5.1.2.1 for non-split gNB, clause 5.1.3.6.2 for split gNB; per PLMN ID and per E-RAB QoS profile (QCI, ARP and GBR), as specified in 3GPP TS 32.425 [7], clause 4.4.7), Mean number of Active UEs in the DL/UL per cell (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.1 and 5.1.1.23.3), Max number of Active UEs in the DL/UL per cell (as specified in 3GPP TS 28.552 [6], clauses 5.1.1.23.2 and 5.1.1.23.4), Average number of Active UEs (as specified in 3GPP TS 32.425 [7], clause 4.4.2), Packet Loss Rate (as specified in 3GPP TS 28.552 [6], clause 5.1.3.1), Packet Loss Rate (as specified in 3GPP TS 32.425 [7], clause 4.4.4), DL Packet Drop Rate (as specified in 3GPP TS 28.552 [6], clause 5.1.3.2), DL Packet Drop Rate (as specified in 3GPP TS 32.425 [7], clause 4.4.3.2) • UE-level - **Radio channel info:** SINR (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]), RSRP (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]), RSRQ (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]) - **Layer-2:** CQI, MCS, DL/UL UE throughput, DL/UL UE PRB usage, RLC buffer size, RLC occupied buffer, RLC unused buffer, UL/DL MAC rate, Packet Delay, Data volume (per UE, as specified in 3GPP TS 36.314 [9], clause 4.1.8 and 3GPP TS 38.314 [16]), Packet Loss Rate per DRB (as specified in 3GPP TS 38.314 [16], clause 4.2.1.5) and per UE, DL Packet Drop Rate, Total number of RLC SDUs/PDUs • Slice-level - **Layer-2:** DL/UL UE PRB usage, RLC buffer size, RLC	

REQ	Description	Note
	occupied buffer, RLC unused buffer, UL/DL MAC rate, Packet Delay, Data volume (per QCI/5QI, as specified in 3GPP TS 36.314 [9], clause 4.1.8 and 3GPP TS 38.314 [16]), Packet Loss Rate per DRB (as specified in 3GPP TS 38.314 [16], clause 4.2.1.5) and per UE, DL Packet Drop Rate (as specified in 3GPP TS 28.552 [6], clause 5.1.3.2), Total number of RLC SDUs/PDUs	
REQ-E2-ES-FUN1	E2 interface shall support forwarding the guidance of cell and carrier switching off/on from the Near-RT RIC to the E2 node. REPORT/CONTROL shall be supported for Near-RT RIC to trigger the operation asynchronously where appropriate	
REQ-E2-ES-FUN2	E2 interface shall support the configuration and retrieval of energy saving related measurement and cell state information from the E2 Node.	
REQ-E2-ES-FUN3	E2 interface shall support forwarding the guidance of sleep mode configurations as described in 4.6.2.4.1 from the Near-RT RIC to the E2 node.	
REQ-E2-ES-FUN4	E2 interface shall support the control of NES related resource allocation function in E2 nodes including configuration/modification of the following: • SR periodicity reconfiguration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Both *sr-ProhibitTimer* and *sr-TransMax* can be treated. • SPS configuration (as specified in 3GPP TS 38.331 [18] and 3GPP TS 36.331 [11]): Both *SPS-Config* (DL) and *ConfiguredGrantConfig* (UL) can be treated. • CSI-RS periodicity configuration. • Common channel periodicity configurations.	
REQ-E2-ES-FUN5	E2 interface shall support the configuration of energy saving mode objectives from the Near-RT RIC to the E2 node as described in clause 4.6.2.4.1.	
REQ-E2-ES-FUN6	E2 interface shall support configuration of RF channel reconfiguration related NES parameters from the Near-RT RIC to the E2 node which includes: - Indication of the array elements to be switched off during sleep periods based on the TRX control capability information (see O-RAN.WG4.MP.0-R003-v14 [39], clause 20.3.1) reported by the E2 node (O-DU). - Indication of the sleep mode (see O-RAN.WG4.MP.0-R003-v14 [39], clause 20.3.1, sleep-mode-type of trx-control-capability-info) to be applied during sleep periods. - Indication of the sleep periods, e.g. slot numbers, symbol numbers and the conditions for triggering the sleep period.	
REQ-E2-ES-FUN7	E2 interface shall support the configuration of RF channel reconfiguration related performance objectives from the Near-RT RIC to the E2 node. The performance objectives can include: - Energy saving target, e.g. targeted energy saving in percentage of current average energy consumption or energy saving levels defined by operator (e.g. maximum energy saving, medium energy saving, maximum performance etc.). - UE or cell level performance targets e.g. throughput cap, throughput drop tolerance, latency target.	
NOTE 1: Time granularity of the measurements is not defined in the present document.		

5.1.3 RAI exposure interface functional requirements

The RAI exposure interface functional requirements are captured in table 5.1.3-1.

Table 5.1.3-1: RAI exposure interface functional requirements

REQ	Description	Note
REQ-RAI-QoE-FUN1	RAI exposure interface shall support request for QoE related analytics from RAI service consumers, with request scopes including: - List of UE ID	
REQ-RAI-QoE-FUN2	RAI exposure interface shall support exposure to RAI service consumers the following QoE related information: Predicted RAN performance - Minimum/maximum/average throughput - Minimum/maximum/average latency - Average packet loss rate - QoE prediction Prediction related information - Confidence - Validity period	

5.2 Non-functional requirements

5.2.1 Near-RT RIC non-functional requirements

Void

5.2.2 E2 interface non-functional requirements

Void

Annex A (informative): Example use cases

A.1 Example use cases for RAN slice SLA assurance

A.1.1 Downlink and uplink throughput per slice

The *Downlink and Uplink Throughput Per Network Slice* are NG.116 attributes used in the definition and deployment of a network slice. They become `maxDlThptPerSlice` and `maxUlThptPerSlice` parameters in A1 polic(ies). The maximum downlink throughput per slice defines the aggregated data rate in the downlink for all UEs together in the network slice. This parameter is defined in GSMA GST NEST NG.116 Downlink throughput per network slice [22], clause 3.4.5. See also 3GPP TS 28.541 [5], clause 6.3.4 which defines the `SliceProfile` that captures some of the parameters from GSMA depending on the slice type. The parameter places an upper limit on the capacity of the slice so that the slice does not over-utilize available network resources and thereby provides a target to guide resource utilization.

The following explanation describes the relevance to the Near-RT RIC. These attributes are sent by the Non-RT RIC to the Near-RT RIC(s) together with the scope identifier (S-NSSAI) and optional cell list or tracking area list. The Near-RT RICs split the A1 policy guidance from the Non-RT RIC. Thus, the subtending Near-RT RICs each provide guidance to the cells of their E2 nodes (O-DU, O-CU-UP, O-CU-CP) involved in the slice.

For example, suppose there is an SLA parameter, *Downlink throughput per network slice*, with a value of 600,000 kilobits per second (kbps). The Non-RT RIC in this case has three subtending Near-RT RICs. Then, the Non-RT RIC might split the SLA parameter of 600,000 kbps into three A1 policies: `maxDlThptPerSlice` = 120,000 kbps for Near-RT RIC #1; `maxDlThptPerSlice` = 180,000 kbps for Near-RT RIC #2, and `maxDlThptPerSlice` = 300,000 kbps for Near-RT RIC #3 for the respective slice. This example use case is shown in figure A.1.1-1.

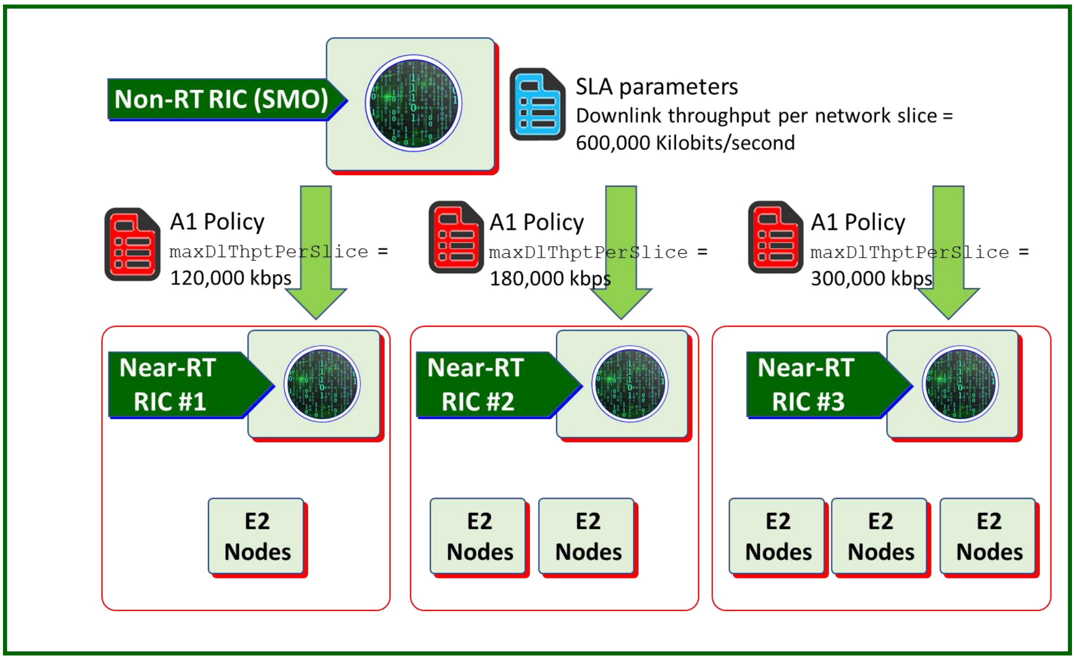

Figure A.1.1-1: A1 policy decomposition example

The consumer of the `maxDlThptPerSlice` and `maxUlThptPerSlice` parameters is the Near-RT RIC via A1 policy. Slice SLA assurance-related xApp(s), within the Near-RT RIC, can apply or utilize this parameter to provide control of throughput within the E2 nodes. The xApp(s) can utilize E2 interface to adjust throughput-related RAN parameters, such as adjusting PRB allocation levels The Near-RT RIC has influence over the operation of cells in a geographical area. The adjustment of the PRB allocation levels in MAC schedulers directly impact the throughput achieved by the slice. Therefore, this parameter at the RAN level influences the throughput. There might be other throughput-related parameters that could be employed, such as MCS, which is left for future study.

3GPP Release 17 will introduce the concept of a Network Slice Admission Control Function (NSACF), see reference [(TR23.700-40 S2-1908583)] and reference [(TS23.501 v17.1.1 clause 5.15.11)]. The purpose of the NSACF is to enforce some of the slice SLA parameters from a 5G core perspective. The NSACF handles slice-specific user admission control into the network based on NG.116 criterion. However, the NSACF has no knowledge of RAN and RAN resources; thus, it cannot control RAN resources. Therefore, there is no interaction between NSACF and the handling of these parameters by the Near-RT RIC. Thus, the usage of the SLA-related parameters by the Near-RT RIC xApp(s) are in the scope of gNBs and will complement the 5GC SLA enforcement but from the perspective of the RAN.

A.1.2 Guaranteed downlink and uplink throughput per slice

The *Guaranteed Downlink Throughput Quota and Guaranteed Uplink Throughput Quota* are attributes used in the definition and deployment of a network slice in NG.116. They are used in A1 policies as `guaDlThptPerSlice` and `guaUlThptPerSlice`. The guaranteed downlink/uplink throughput quota describes the guaranteed throughput or data rate supported by the network slice for the aggregate of all GBR QoS flows in downlink/uplink belonging to the set of all UEs using the network slice. This parameter is defined in GSMA GST NEST NG.116 Downlink/Uplink throughput per network slice [22], clause 3.4.5. See also 3GPP TS 28.541 [5], clause 6.3.4 which defines the `SliceProfile` which captures some of the parameters from GSMA depending on the slice type. The *Maximum Ul/Dl Throughput per Network Slice* parameters (clause 3.3.3.1.1) place an upper limit on the capacity of the slice while the *Guaranteed Ul/Dl Throughput Quota* parameters ensure a certain level of throughput. Thus, these two parameters complement each other: one giving a lower bound and the other giving an upper bound. For the upper bound (maximum Ul/Dl throughput per network slice) this ensures that the slice does not over-utilize available network resources while for the lower bound (guaranteed Dl/Ul throughput quota) meets a minimum throughput for the slice.

These attributes are sent by the Non-RT RIC to the Near-RT RIC(s) together with the scope identifier (S-NSSAI) and optional cell list or tracking area list. The Near-RT RICs split the A1 policy guidance from the Non-RT RIC. Thus, the subtending Near-RT RICs each provide guidance to the cells of the E2 nodes (O-DU, O-CU-UP, O-CU-CP) involved in the slice.

For example, suppose there is an SLA parameter, *Guaranteed Uplink Throughput Quota,* with a value of 1,000,000 kilobits per second (kbps). The Non-RT RIC in this case has three sub-tending Near-RT RICs. Then, the Non-RT RIC might split the SLA parameter of 1,000,000 kbps into three A1 policies: `guaUlThptPerSlice =` 170,000 kbps for Near-RT RIC #1; `guaUlThptPerSlice =` 230,000 kbps for Near-RT RIC #2, and `guaUlThptPerSlice =` 600,000 kbps for Near-RT RIC #3 for the respective slice.

The consumer of the `guaUlThptPerSlice` and `guaDlThptPerSlice` parameters is the Near-RT RIC via A1 policy. Slice SLA assurance-related xApp(s), within the Near-RT RIC, can apply or utilize this parameter to provide control of and throughput within the E2 nodes (O-CU-UP, O-CU-CP, O-DU). The xApp(s) can utilize E2 interface to adjust throughput-related RAN parameters, such as adjusting PRB allocation levels. The Near-RT RIC has influence over the operation of cells in a geographical area. The adjustment of the PRB allocation levels in MAC schedulers directly impacts the throughput achieved by the slice. Therefore, this parameter at the RAN level influences the throughput. There might be other throughput-related parameters that could be employed, such as MCS, which is left for future study.

Annex (informative): Revision history

Date	Revision	Description
2024.05.16	06.00.01	Initial version towards v07.00 Removed v06.00 revision history. Addition of CRs: - JNPR-2024.04.20-WG3-CR-0028-O-RAN-Use-Cases-Requirements-ODR-FFS-Concepts-v02 - JNPR-2024.04.22-WG3-CR-0029-O-RAN-Use-Cases-Requirements-ODR-Modal-Verbs_Shall_Shall_not_Should_Should_not_Must_Must_not-v01 - JNPR-2024.04.25-WG3-CR-0030-O-RAN-Use-Cases-Requirements-ODR-Modal-Verbs_Can_Cannot_May_Need_not-v01 - JNPR-2024.04.25-WG3-CR-0031-O-RAN-Use-Cases-Requirements-ODR-Clauses-v01
2024.06.25	06.00.02	Addition of CR: - CMCC.AO-2024.05.08-WG3-CR-0004-UCR-Adding measurements in NES use case-v02
2024.07.11	06.00.03	Addition of CRs: - JNPR-2024.05.31-WG3-CR-0032-O-RAN-Use-Cases-Requirements-ODR-Capital_Letters-Editorial_Changes-Fixes-v01 - DCM-2024.03.06-WG3-CR-0001-UCR-Addition of Uplink Power Control for QoS-v07
2024.07.11	06.00.04	Clean version for WG3 approval
2024.07.25	07.00	WG3 approval is completed. Final version ready for TSC approval and publication.

Annex (informative): History

Date	Revision	Description
2021.08.10	01.00	Version 1.0 (Details of v1.0 content can be found in v1.0 “Revision History”)
2022.08.02	02.00	Version 2.0 (Details of v2.0 content can be found in v2.0 “Revision History”)
2022.11.18	03.00	Version 3.0 (Details of v3.0 content can be found in v3.0 “Revision History”)
2023.07.30	04.00	Version 4.0 (Details of v4.0 content can be found in v4.0 “Revision History”)
2023.11.07	05.00	Version 5.0 (Details of v5.0 content can be found in v5.0 “Revision History”)
2024.03.30	06.00	Version 6.0 (Details of v6.0 content can be found in v6.0 “Revision History”)

