DEUTSCHE TELEKOM AND PARTNERS DEMONSTRATE NON-REAL TIME RAN OPTIMIZATION IN A MULTI-VENDOR ENVIRONMENT

A Whitepaper by Deutsche Telekom AG, AirHop, Juniper Networks, VIAVI Solutions and VMware

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EXECUTIVE SUMMARY

This whitepaper provides a technical discussion on the integration complexity of one of the key components of the O-RAN architecture as defined by the O-RAN ALLIANCE: The Non-Real-Time RAN Intelligent Controller (Non-RT RIC).

The Non-RT RIC promises to bring intelligence and programmability to RAN by enabling third-party applications (rApps) to manage and optimize radio resources. However, a multi-vendor deployment of Non-RT RIC, rApps and a Service Management and Orchestration (SMO) also introduces interoperability and integration challenges that must be addressed to drive solution development.

In that context, Deutsche Telekom initiated a Proof of Concept (PoC) for non-real time RAN optimization in a multivendor environment to assess the technical integration complexity of the components delivered by the different parties, the level of customization required, and to gauge the maturity of products as well as to identify potential future standardization requirements.

Working together with AirHop, Juniper Networks, VIAVI Solutions and VMware, the partners completed a RAN closed-loop optimization PoC within Deutsche Telekom's lab environment based on Open Networking Automation Platform (ONAP) and O-RAN standards. Closed loop rApp algorithms were onboarded and deployed on partners' Non-RT RIC.

While the PoC demonstrated promising overall potential of the SMO, Non-RT RIC and rApp framework for disaggregated RAN optimization, it also confirmed the integration challenges associated with a multi-vendor framework. After describing the setup and test approach in the PoC, the whitepaper provides a detailed outline of the integration challenges, as well as customizations and future standardization requirements.

Based on these requirements, the whitepaper concludes with an outlook on key focus areas for ecosystem collaboration, including certification initiatives and operational concepts, to transition Non-RT RIC/rApp development from the lab towards production readiness and to reduce multi-vendor integration efforts.

1 TRANSFORMATION OF RAN

The ambition for open RAN is to evolve RAN technology and industry towards a disaggregated/modularized, more software-driven, virtualized model that will provide operators with more flexibility and agility to deploy and operate mobile networks.
The most important enabler for ecosystem diversification is further disaggregation of RAN architecture. A system disaggregation model requires well-defined and open interoperable interfaces which allow different sub-system vendors to integrate and interoperate with the various sub-system parts that make up a RAN system. The O-RAN ALLIANCE – a worldwide, carrier-led effort founded in 2018 – lays the standardization groundwork for re-shaping the RAN industry towards more open, virtualized, intelligent, and fully interoperable mobile networks.

The logical architecture for disaggregated RAN, which complements and extends the reference RAN architecture standardized by 3GPP, is depicted in the *Figure 1* below:

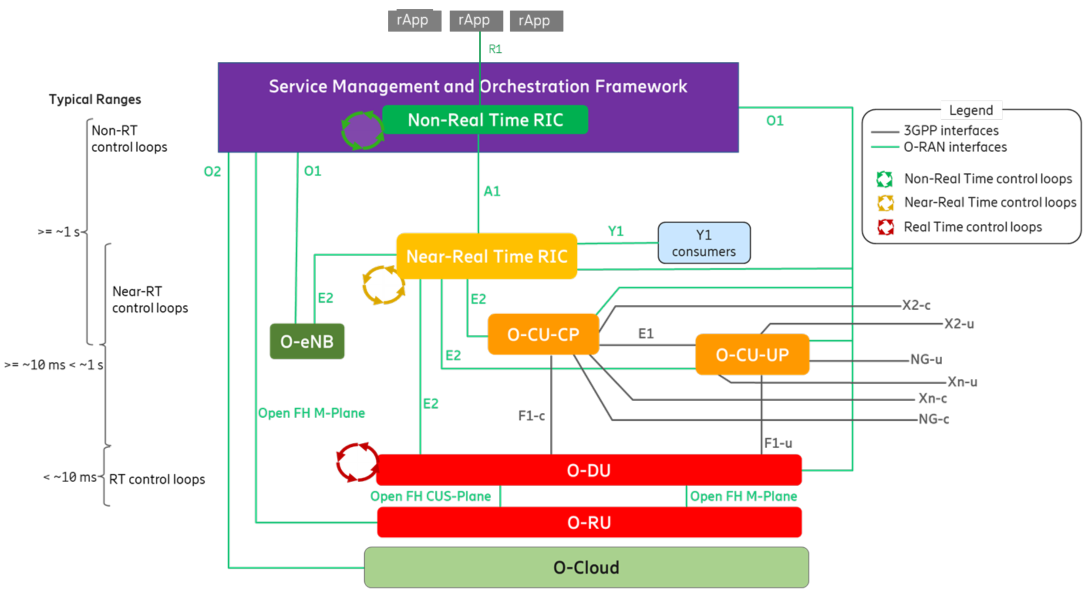

Figure 2: High level disaggregated RAN architecture (based on O-RAN Working Group 1 O-RAN Architecture Description)

O-RAN is transformative in three main technical areas around openness, virtualization, and intelligence:

1. Open interfaces to realize interoperability

Open fronthaul (OFH) is the key interface to implement and enable RAN disaggregation. The OFH interface decouples the Open Radio Unit (O-RU) from the Open Distributed Unit (O-DU) baseband functions. The O-RAN ALLIANCE also specifies profiles for 3GPP RAN interfaces to achieve interoperability (IOT) among different vendors (e.g., X2/Xn interface).

2. O-RAN cloudification and orchestration enabling virtualized RAN

Fast evolution and availability of highly efficient General-Purpose Processor (GPP) based Commercial Off-The-Shelf (COTS) hardware has already led operators to migrate functions in the core network and other domains to the cloud.

This trend is now moving to RAN. The O-Cloud approach is enabling RAN hardware and software disaggregation and allows operators to use COTS hardware with acceleration for baseband workload processing.

All RAN nodes and the underlying cloud computing layer (O-Cloud), which enables virtualized deployment of network functions (vRAN), are managed and orchestrated by the Service and Management Orchestration (SMO) framework via the OFH M-Plane, O1 and O2 interfaces, respectively.

3. Intelligence driving optimization and automation of RAN operations.

The RAN Intelligent Controller (RIC) is a key technology to provide intelligent radio resource management and optimization. RIC enables RAN programmability through xApps/rApps which will be critical for mobile operators to efficiently manage the complexity and costs of their expanding networks. RIC includes two layers.

- The Near-Real Time Radio Intelligent Controller (Near-RT RIC) with a control loop below 1 second. Near-RT RIC should bring enhancements in terms of intelligence and programmability via the E2 interface.
- The Non-Real-Time (Non-RT) RIC with a control loop over 1 second. The Non-RT RIC, which is hosted by the SMO, supports non-real-time radio resource management such as configuration management, network optimization, policy management and analytics by using AI/ML models.

The Proof-of-Concept on “Non-real time RAN optimization in a multi-vendor environment” described in this white paper is focusing on the Non-RT RIC, hosting applications/microservices (rApps) providing intelligence and programmability for RAN automation and optimization.

4. Programmability and automation are essential

O-RAN enables programmability through open interfaces and standardized protocols such as the R1 interface, providing greater flexibility and innovation in radio network deployments. It allows network operators to introduce new functionalities, optimize network performance, and experiment with new services by developing and deploying their own or third-party applications on the network.

Also, there is a complexity challenge in disaggregated solutions to ensure cost efficient integration for optimized performance. Automation is required to manage complexity across all lifecycle management (LCM) disciplines such as testing, deployment, and operation. The SMO will enable operators to orchestrate and automate elements from multiple different vendors in a disaggregated system.

2 DISAGGREGATED RAN AUTOMATION AND OPTIMIZATION

For over a decade, Centralized Self-Organizing Network (C-SON) technologies have been used to automate radio network management and to make planning, configuration, optimization and healing of RAN elements and cell-level parameters simpler and faster by reducing manual intervention. This can significantly reduce Operational and Capital Expenditures (OpEx/CapEx).

Nevertheless, C-SON remains a niche market characterized by proprietary offerings that have some essential drawbacks from an operators' perspective. C-SON applications and the underlying application platform are closely linked and are provided by the same supplier, including all algorithms driving radio network optimization, mainly as proprietary pre-built policies/objectives. Furthermore, the supplier specific C-SON technology requires complex, full proprietary and therefore costly integration with operators' OSS/RAN vendors' specific Network Management Systems (NMS).

The shift towards open interfaces, virtualization and software driven networking has triggered a transition in the C-SON approach to disaggregated RAN automation and optimization with open standard-based components supporting RAN programmability for advanced automation and intelligent control. The disaggregated RAN automation and optimization framework, that will mainly consist of a non-RT RIC, as part of the SMO framework, and the rApps as specialized microservices, will mitigate the drawbacks of C-SON and will enhance RAN automation and optimization based on the following capabilities:

- Intelligence (AI/ML),

  it provides Artificial Intelligence and Machine Learning (AI/ML) to efficiently learn continuously from experience/underlying patterns of data, while maintaining or even improving the Key Performance Indicator (KPIs). With Deep Learning, it further reduces human intervention up to zero-touch management.

- Flexibility (intents/policies),

  it ensures fulfillment of RAN intents based on policies provided to the Near-RT RIC via the A1 interface. A RAN intent is a declarative operation model representing for instance the SLA from the Business Support System (BSS) that the RAN is to fulfil for all users or for a subset of users.

- Granularity (single UE/group of UEs)

  it provides policies that enable the Near-RT RIC for instance to optimize RRM for a single UE or for a group of UEs.

- Performance (in a range up to single digit seconds)

  it enables central non-real-time closed-loop automation and optimization with control loops in a range up to single digit seconds instead of today's 15 minutes

- Openness (enabling 3rd parties to write network management applications) it introduces programmable applications (rApps) that can run optimization routines with data driven closed-loop control. Such applications can be developed by the network operators or by any 3rd party, leveraging from a vibrant market and an increasing number of innovative smaller companies.

The Non-RT RIC brings intelligence, agility, and programmability to disaggregated radio access networks and enables third-party applications (rApps) that can perform closed-loop automation and optimization of RAN elements and resources.

However, a multi-vendor integration of Non-RT RIC, rApps and SMO also introduces challenges that are assessed by this PoC.

3 PROOF-OF-CONCEPT OVERVIEW

Working together with AirHop, Juniper Networks, VIAVI Solutions and VMware, the partners completed a RAN closed-loop optimization Proof of Concept (PoC) within Deutsche Telekom's lab environment in a multi-vendor setup based on Open Networking Automation Platform (ONAP) and O-RAN standards. Closed loop rApp algorithms were onboarded and deployed on partners' non-real time RAN Intelligent Controllers (Non-RT RIC).

The major target of the PoC was to assess the technical integration complexity of the components delivered by each party and the level of customization required, to gauge the maturity of products and to identify potential future standardization requirements.

3.1. MULTI-VENDOR SETUP

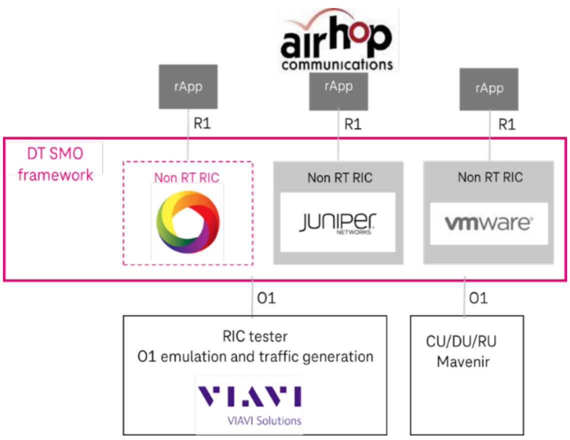

Figure 3: High level multi-vendor PoC lab setup

- Deutsche Telekom provided a self-developed SMO framework along with a Non-RT RIC solution based on the O-RAN SC Non-RT RIC
- Juniper Networks and VMware integrated their non-RT RIC products into DT's SMO framework
- AirHop integrated two rApps for PCI optimization and AI/ML-based Energy Savings with each Non-RT RIC
- VIAVI provided their RIC tester to emulate the O1 interface

Deutsche Telekom SMO and Non-RT RIC

A key part of Deutsche Telekom's open RAN approach is to introduce a vendor independent Service Management and Orchestration (SMO) framework. The SMO is at the heart of the complete lifecycle management of all RAN components in the deployment for managing the RAN disaggregation complexity. It provides the necessary control and flexibility to adapt RAN infrastructure according to current needs, such as easier RAN software vendor swaps, as well as the opportunity to differentiate by introducing innovation. In concrete terms, this means that software upgrades can be tailored to specific situations and rolled out much faster. In addition, new functionalities can be tested more quickly and ultimately made available to customers much sooner.

Deutsche Telekom's' SMO is based on selected components of the open-source ONAP, partly adapted and functionally enriched. The functional scope of the SMO framework is defined by the O-RAN ALLIANCE. Besides hosting the Non-RT RIC for RAN optimization, the SMO offers further key capabilities such as FCAPS management procedures, Service and Resource Inventory, Topology and Network Configuration, O-Cloud Management, Orchestration, and Workflow Management.

However, the O-RAN ALLIANCE has not so far defined a detailed internal SMO architecture and internal interfaces between the functional building blocks, including the interface(s) towards the Non-RT RIC. To bridge the gap, five big European network operators have created an O-RAN technical priority document under the Open RAN MoU, among other requirements reflecting MoU members' understanding of how an internal SMO structure might look like (see *Figure 3*). The internal SMO architecture and the interfaces between all functional building blocks will ultimately be defined by the respective Working Groups of the O-RAN ALLIANCE. The MoU members' current understanding of a SMO functional breakdown is reflected in Deutsche Telekom's' vendor independent SMO platform.

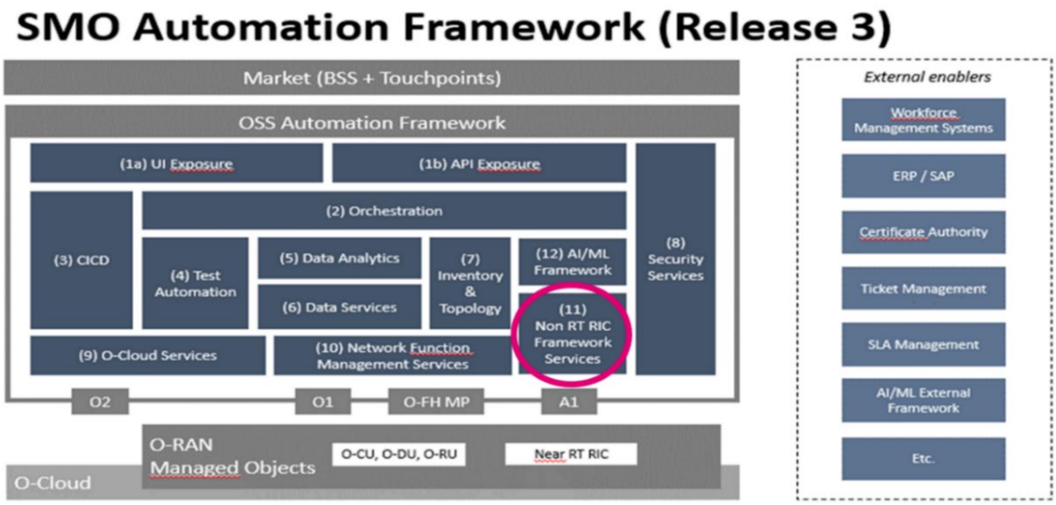

Figure 4: MoU members' understanding of a SMO structure / functional breakdown

For the PoC, Deutsche Telekom has integrated 3rd party Non-RT RIC products from Juniper Networks and VMware. Integration details and challenges are described later in this White Paper.

Additionally, Deutsche Telekom integrated a Non-RT RIC solution based on the O-RAN SC RIC. Current OSC RICs' R1 specifications are still incomplete and the OSC RIC still misses essential elements. The initial focus was to add functions to enable the PoC use case execution and to stepwise close the gaps and make the OSC fragments more mature. In detail (see *Figure 4*), a Configuration Management Service (CMS) was developed and deployed as part of the OSC RIC framework. The CMS is required to expose CM APIs towards the rApp over the R1 interface, enabling the rApp to query and modify the RAN configuration as determined by the rApp algorithm. From the security perspective, CMS is acting as an intermediary layer to avoid a direct rApp access to the RAN configuration and to expose data on R1 interface on need-to-know basis only. In addition, the OSC RIC Control Panel was improved to allow rApp helm package onboarding and deployment as well as rApp offboarding and deletion via the RIC Control Panel UI.

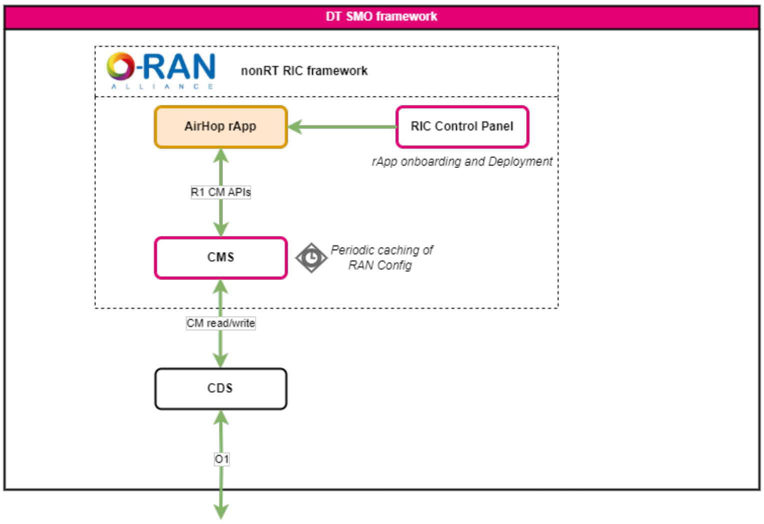

Figure 5: Enhanced OSC Non-RT RIC framework

The SMO performs its services in general through five key interfaces. Three out of the five are terminated by the SMO framework itself:

- O1 Interface between the SMO and the O-RAN Network Functions for FCAPS support.
- Open Fronthaul M-plane interface between SMO and O-RU for FCAPS support in hybrid model,
- O2 Interface between the SMO and the O-Cloud to provide platform resources and workload management.

For RAN optimization two further interfaces are logically terminated by the Non-RT RIC as an integral part of the SMO:

- A1 Interface between the Non-RT RIC and the Near-RT RIC,
- R1 Interface between the Non-RT RIC and the rApps.

For the PoC, only the O1 and R1 interface services were utilized as the use cases selected for the PoC were non-RT RAN centric with no requirement for O2/A1/O-FH M-plane. Here, the Deutsche Telekom SMO adheres to the O1/Netconf CM interface adopted as standard by the O-RAN community. The SMO is also flexible in terms of integrating proprietary interfaces such as the VIAVI simulator O1 REST interface. The SMO O1 PM interface supports both, event streaming (VES) from the RAN network functions and file-based PM format, where PM files are fetched from the RAN at periodic intervals, converted to VES format and published on a Kafka topic for consumption by other components such as the RIC framework/rApp.

As previously described, the Deutsche Telekom OSC non-RT RIC R1 interface is provisioned by the CMS service. An abstract interface was provided for the PoC, whereby the O1 model is not directly exposed to the rApp. On deployment, the rApp queries for the RAN cell topology and the RIC responds with cell topology information including the Cell Global Identifier (CGI). The CGI value is then used by the rApp as the key for querying RAN config data required by the algorithm.

Juniper Non-RT RIC

In this PoC, Juniper Non-RT RIC solution is used to showcase non-real time RAN optimization use cases in a multi-vendor O-RAN environment. Juniper Non-RT RIC has been integrated with Deutsche Telekom's SMO framework to enable non-real-time control of RAN elements and their resources through third-party rApps. Figure 5 illustrates the high-level overview of this PoC setup, showing some of the main elements and integration points utilized during use case execution. The rApp use cases from AirHop were onboarded and deployed onto Juniper Non-RT RIC platform.

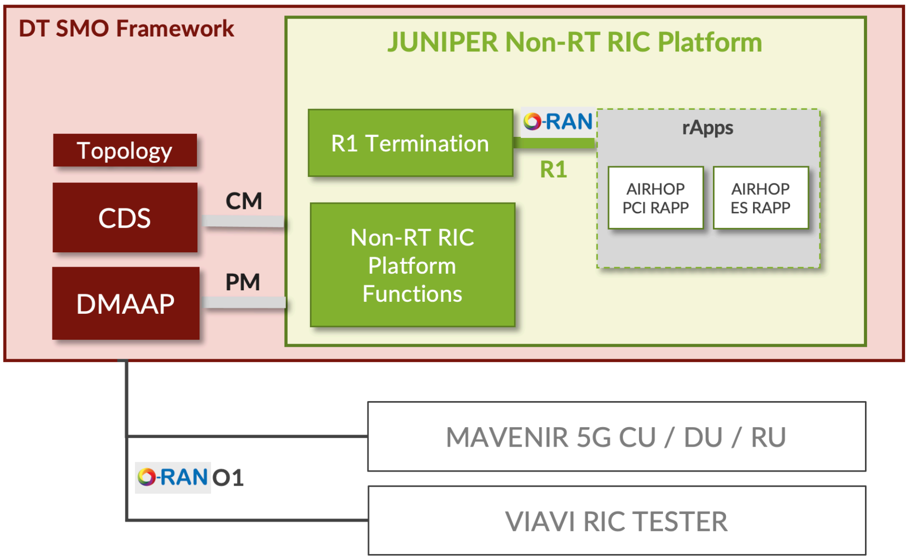

Figure 6: Juniper Non-RT RIC integration with DT SMO framework: A high-level overview of main elements and integration points

The following four goals were achieved using the Juniper Non-RT RIC Platform to realize the PoC:

- Discovery of RAN topology – to enable non-RT RIC platform functions and rApps discover the RAN topology
- Integration with DT SMO CDS API - to enable configuration management (CM) related operations
- Integration with DT SMO DMAAP over Kafka - to enable performance management (PM) related operations

- Exposure of topology, CM and PM related Non-RT RIC R1 services – to enable AirHop rApps perform CM and PM operations on DT SMO framework / E2 Nodes

RAN topology discovery includes information such as the RAN topology, node identifiers (e.g. gNB Id, CU-UP id, DU Id), cell local identifiers, latitude and longitude information along with other RAN parameters. The rApps are required to perform topology discovery to learn the available nodes and cells in the RAN to be able to carry out remaining CM operations like discovery of the available managed object instance (MOI) distinguished names (DN).

The configuration management operations have been enabled through integration with the CDS API of the DT SMO framework. CDS API provides generic CM read and write operations in which non-RT RIC can perform retrieval and modification of the E2 Node configuration over E2 node specific XML configuration data along with respective identifiers which is then translated into O1 NETCONF operations by the DT SMO framework. Through Juniper Non-RT RIC platform functions, rApps are allowed to carry out certain 3GPP and O-RAN aligned CM operation requests (e.g., getMOIAttributes, modifyMOIAttributes) over R1 interface with respective MOI DNs on the deployed radio access network nodes. Examples to these requests are retrieval of managed element and NR cell configuration, modification of cell PCI values and energy saving states.

For the PoC, the Juniper Non-RT RIC platform enabled collection of performance metrics (PMs) from Deutsche Telekom SMO orchestrated RAN nodes to allow rApps consume PMs needed to satisfy their PoC use cases. For this purpose, Non-RT RIC is integrated with DMAAP component of DT SMO framework over Kafka. Juniper Non-RT RIC platform functions receive VES events for streamed PMs as Kafka topics, processes and stores them within the platform to make it available for the rApps. Depending on the consumed PM related R1 service, the rApps then be able to retrieve desired performance metrics of RAN nodes in certain time intervals.

Juniper Non-RT RIC delivers an extensive set of REST based R1 APIs, aligned with O-RAN WG2 specifications, allowing application developers to choose and use any programming language of their choice. The APIs of the RIC solution are simple to use and enable the integration and onboarding of third-party rApps in few days. For the PoC, R1 services that are coupled with above mentioned integrated Deutsche Telekom SMO framework operations are developed and utilized by the rApps to enable their use case execution, such as RAN topology information discovery, retrieval, and modification of E2 node configuration, and performance data streaming.

As a result, Juniper Non-RT RIC platform functions provide an abstraction layer to rApps so that through same R1 services use case algorithms can be executed regardless of the existing SMO framework or RAN vendor product deployed which is crucial for enabling multi-vendor O-RAN environment. AirHop rApps were able to successfully obtain information and control Mavenir E2 Nodes and VIAVI RIC Tester (E2 Node Emulator) through Juniper Non-RT RIC R1 services.

VMware Non-RT RIC

In this PoC, VMware Centralized RIC has served as the Non-RT RIC platform to showcase non-real time RAN optimization use cases in a multi-vendor O-RAN environment. VMware Centralized RIC has been integrated with Deutsche Telekom's SMO framework to enable non-real-time control of RAN elements and their resources through third-party rApps. Figure 6 illustrates the high-level overview of this PoC setup, showing some of the main elements and integration points utilized during use case execution. The rApp use cases from AirHop are onboarded and deployed onto VMware Non-RT RIC platform.

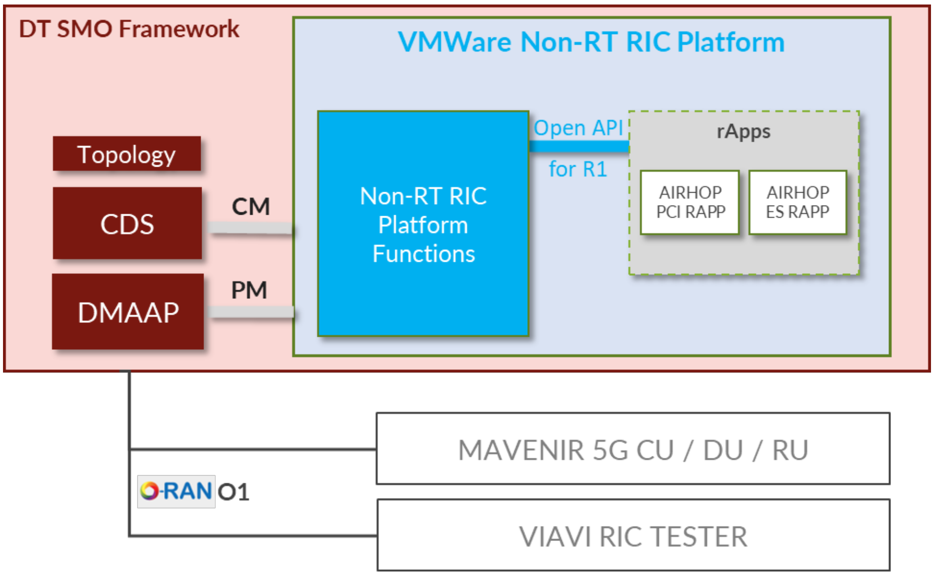

Figure 7: VMware cRIC integration with DT SMO framework: A high-level overview of main elements and integration points

Following goals were achieved using VMware cRIC:

- Integration with DT SMO CDS API - to enable configuration management (CM) related operations
- Integration with DT SMO DMAAP – to enable performance management (PM) related operations
- Exposure of R1 services – to enable rApps via REST based R1 APIs to obtain PM related measurements and to control and improve RAN performance via CM changes. OpenAPI specifications and a development kit are offered to assist the rApp development and integration.

VMware cRIC demonstrated the following capabilities:

- Provides RAN vendor-agnostic CM data interface to rApp so to achieve the "build-once, apply everywhere" objective.

- Converts the RAN vendor-agnostic CM data to vendor-specific CM data to facilitate the seamless integration with the SMO and the underlying RAN vendors.
- Processes change notifications sent on VES Kafka bus.
- Retrieves the RAN PM data and expose it based on rApp requests. The PM data can be delivered as bulk historical data as well as live stream. For ML/AI-based rApps, bulk historical data is desirable in training stage, while live stream data is desirable for inference stage.
- Collects the key information related to the network topology, abstracts it in a vendor-agnostic manner and provides it to the rApps. The rApps can quickly discover the network topology without complex operations.

AirHop rApps

AirHop's Auptim portfolio of rApps/xApps, offers a comprehensive array of AI/ML-powered non-real-time and near-real-time network intelligence, automation, and optimization solutions.

For the POC, two AirHop rApps are integrated with the Non-RT RIC: (1) **Physical Cell Identity Optimization (PCI)**, and (2) **AI/ML Energy Savings dynamic Multi-Carrier management (ESMC)**.

The two rApp use cases were selected based on algorithm maturity, 3rd party RIC integration experience and support by the VIAVI RIC tester. The PCI rApp was chosen to validate a cSON comparable use case and the ESMC rApp was chosen to validate a more innovative algorithm highlighting rApp/Non-RT RIC Artificial Intelligence and Machine Learning (AI/ML) capabilities for energy saving, which is an important driver for RAN programmability by network operators.

Upon registration with the Non-RT RIC, the rApp gains access to the network topology, containing essential information about the cells managed by the rApp. This information comprises the Cell Global Identifier (CGI), Uplink and Downlink Absolute Radio Frequency Channel Numbers (ARFCNs), neighbor relation information and other use case specific parameters. Following registration, the rApp proceeds to create digital twins of the cells in the network with each cell represented by a Cell Optimization Engine (COE). The primary responsibility of the COE is to optimize its associated cell, which entails close coordination with its neighbor COEs. The digital twin architecture is implemented using technology that provides fault-tolerance, resilience, and scalability across arbitrarily-sized cluster of compute nodes.

In addition, Auptim has its own Graphical User Interface (GUI) which provides detailed information about the cells under its management, as well as use-case specific information and configuration parameters to control the behavior of each use case. Thus, the operator has a complete view of the cells in addition to a full control on each use case behavior for any of the cells under rApp management.

Once registered, the PCI conflict detection and resolution rApp queries for configuration information (CMs). Any subsequent unsolicited changes to configuration are discovered through periodic polling of the various CMs. Upon detection of a PCI conflict, the rApp suggests a PCI change to the RIC, which in turn is communicated to the RAN. In addition to PCI resolution, the rApp generates reports on the PCI conflicts detected and resolved which is provided to the operator for further operational analysis.

In addition to CMs, the ESMC use case also requires periodic (5 min interval) retrieval of Performance Metrics (PMs) which is facilitated by the streaming service from the Non-RT RIC.

Due to the lack of a unified standard R1 interface, AirHop developed an R1 interface adaptor for its rApps to enable portability across different R1 interface specifications from different RICs. In all cases, the Non-RT RIC SDKs provide OpenAPI specifications for their various R1 services. With these specifications, AirHop auto-generated R1 clients for each RIC, which significantly simplifies the integration.

Physical cell identifier optimization

The **Physical Cell Identifier (PCI)** is a locally defined identifier for base stations with a restricted range of values which must be re-used throughout the network.

The AirHop **PCI optimization rApp algorithm** detects PCI confusion and collision scenarios based on RAN CM data and resolves accordingly by modifying the cell PCI.

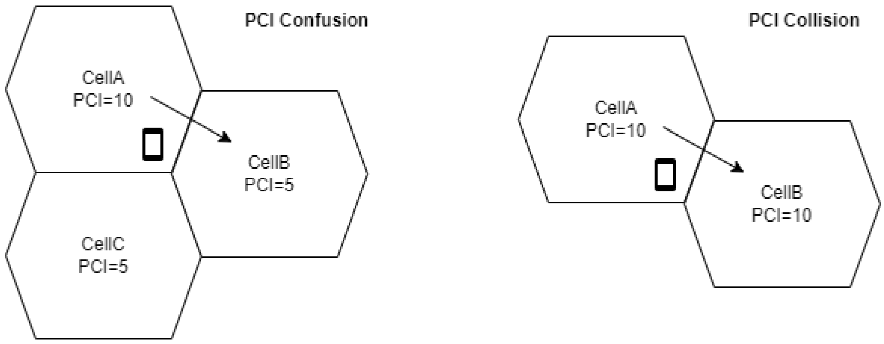

Figure 8: Physical Cell Identifier (PCI) confusion and collision cases

PCI Confusion

Occurs when two different neighbour cells on the same frequency have the same PCI value. A UE cannot distinguish between two cells if the cells have the same PCI and the same frequency. This may result in handover failures when the PCI which is included in the measurement report does not uniquely identify the cell.

PCI Collision

Occurs when a neighbour cell with an identical PCI is on the same frequency. If a UE needs to perform a handover to a cell with the same PCI as the source cell, the UE moves towards the cell with the same PCI and frequency. In most cases, this will result in a dropped call as the UE cannot distinguish the target cell from the source cell.

Energy savings dynamic multi-carrier management (ESMC)

The AirHop ESMC rApp addresses the Carrier and cell switch off/on use case as described in section 3.21.3.1 in O-RAN.WG1.Use-Cases-Detailed-Specification. The primary goal of this solution is to minimize the energy consumption of the network while maintaining the end-user Quality of Service. For this POC, a network with 103-sector sites was considered, where each sector has a coverage and a capacity frequency layer amounting to a total of 60 cells.

The solution comprises of a continuous action-space deep reinforcement learning AI/ML model which learns the traffic patterns of the network, generates and continuously adapts the following two thresholds on a per cell basis:

- Off: turn the capacity carrier to energy saving mode if the load on the sector drops below this threshold
- On: turn the capacity carrier to active mode if the load on the sector exceeds this threshold

The cell-specific thresholds dynamically adapt to the traffic patterns and are re-calculated every 5 minutes, based on which the algorithm takes decisions to switch off/on capacity cells in case of low/high traffic periods to save energy.

VIAVI RIC Tester

The VIAVI TeraVM RIC tester is a comprehensive test & measurement tool for validation of O-RAN RIC, xApps and rApps using a containerized easy to use platform.

The RIC tester has three main functions:

1. Interface Compliance Testing: Test E2/O1/A1 procedure implementation matches standard. Test RIC performance under large load scenarios
2. x/rApp Training: Run traffic scenarios including anomalies to train AI/ML models with real subscriber movement/throughputs
3. App Validation: Ensure that RIC output based on xApp/rApp decisions result in RAN improvements. Ensure that App conflicts are avoided.

In this PoC, the RIC Tester emulated O-RU and O-DU components providing reports, KPIs and measurements over the O1 interface to the Non-RT RICs for ingestion by the rApps.

Cloud deployment

The 3rd party RIC vendors were allocated in separate Kubernetes/OpenStack clusters (Kubernetes version 1.22) to deploy their RIC platforms. Likewise, the Deutsche Telekom SMO/OSC RIC is deployed as well in a separate cluster.

3.2. TEST APPROACH

Initial tests (Stage 1) were performed in a real end-to-end lab setup using a small O-RAN network to validate end-to-end configuration and performance management (CM & PM) integration in a real network environment.

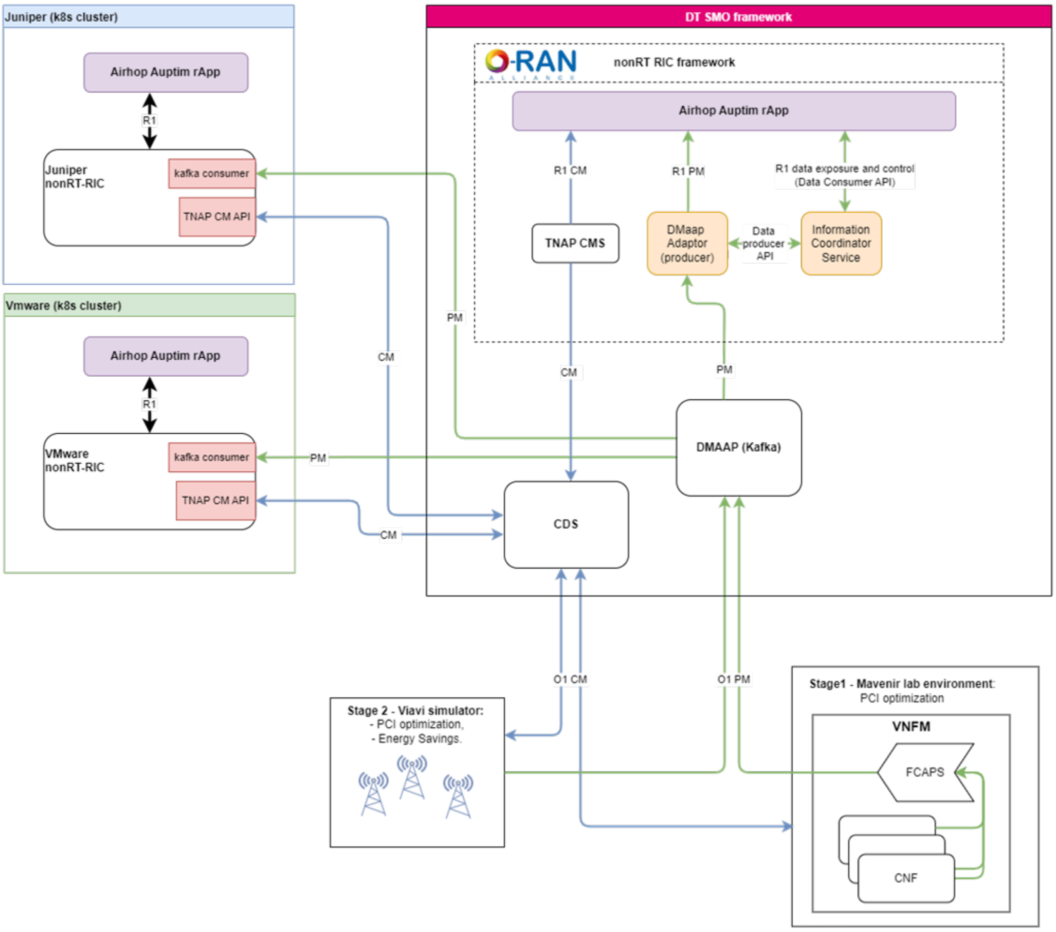

Figure 9: Test configuration

Most tests (Stage 2) were executed on a more complex network setup using an O1 network emulator (RIC tester) to validate rApp logic and stress test the RIC components to benchmark the various solutions.

For both stages, the O1 CM interface and PM events were exposed from the SMO to the 3rd party RICs via CDS CM APIs and DMAAP/Kafka respectively.

4 MAJOR LEARNINGS AND ACHIEVEMENTS

4.1. THE INTEGRATION CHALLENGE

NON-RT RIC <-> SMO FRAMEWORK INTEGRATION

From a high-level perspective, the SMO & Non-RT RIC framework looks promising in the context of RAN network optimization disaggregation (multiple 3rd party solutions).

On more detailed evaluation, we observed that the production RAN automation framework based on SMO and Non-RT RIC concept requires tight integration between those two.

As there is still no standard interface defined between SMO and Non-RT RIC (see chapter 4.2), this presents significant integration and maintenance challenges when both components are coming from different vendors.

One challenge is the implementation variability of specific functionality which can be provided either by the SMO or the Non-RT RIC framework (see yellow marked part in Figure 9). This potentially leads to duplication of this functionality in cases where SMO and Non-RT RIC are delivered by different parties.

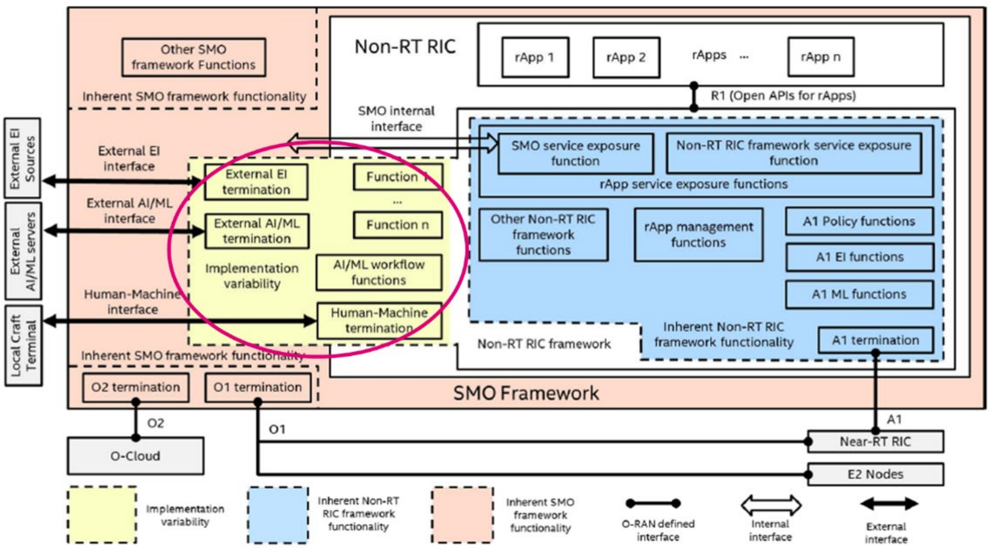

Figure 10: O-RAN WG2 Non-RT RIC architecture functional view diagram

Another challenge is that Non-RT RIC/rApp vendors provide their own dashboards and UIs. There is no clear picture of how these can be centrally integrated within the SMO framework. This may lead to a disjointed, cumbersome way of working for an operations engineer, requiring multiple applications from various sources (rApp/Non-RT RIC/SMO) to maintain and validate system performance.

Furthermore, it is observed that functionalities such as CM actions framework, PM correlation engine, rollback, and conflict mitigation are still being analysed by vendors. There is still no common view across vendors about where functionality should reside, i.e. within Non-RT RIC or SMO or Non-RT RIC/SMO.

rAPPS <-> NON-RT RIC INTEGRATION (R1 INTERFACE)

Previous vendor collaborations and therefore pre-integration experience, as demonstrated during plug fests or in partner labs, does not necessarily mean a ready-to-go integration of rApps and Non-RT RIC of different parties. We observed, as it obviously currently stands, that every new rApp/use case will require development effort (interface extension).

To reach a desired level of plug and play, the R1 interface needs further standardization. rApp and Non-RT RIC suppliers must ensure respective compliance. Otherwise, there is a risk that the ecosystem will evolve towards custom rApps per Non-RT RIC supplier.

Further on, we observed two different approaches by the 3rd party Non-RT RIC suppliers on the R1 interface. An R1 model agnostic version – seen as more lightweight – is attractive in terms of interface simplicity by using the Cell Global Identity (CGI) as key for querying or modifying RAN parameters. It gives possibility to use Non-RT RIC framework for traditional RAN network optimization. An R1 model driven version – which can be rated as more heavyweight – is more aligned with O-RAN and 3GPP standards but assumes full standard compliance of the underlying RAN. Based on the level of compliance, the rApp is burdened with making corresponding changes to the R1 interface definitions to be able to properly interact with the RAN. Over the course of the PoC, the process of uncovering the lack of compliance and making the corresponding modifications, proved to be time-consuming and cumbersome.

All parties agreed, that both R1 interface approaches have their benefits and it's likely that both are required in a production environment. A similar approach can be found in existing C-SON deployments, where the algorithm can operate on generic and vendor specific model. Different use cases may require different model usage.

One aspect that remains evident but noticeably deficient is the absence of a cohesive R1 interface specification that is consistent among the RIC vendors, independent of the supported RAN and their respective compliance to the O-RAN and 3GPP specifications.

SMO FRAMEWORK <-> RAN INTEGRATION (O1 INTERFACE)

The main challenge during Stage 1 testing (refer to chapter 3.2) were the unreliable or non-existent O1 CM change notifications from the RAN network functions which prevented the SMO/Non-RT RIC from determining if CM changes were successfully executed or not. As a workaround, a periodic polling mechanism was developed in the rApp/Non-RT RIC to fetch the current RAN config at periodic intervals.

The main learning from Stage 1 is that O-RAN vendors still lack maturity in basic CM notification functionality. There is a requirement to persist the active RAN configuration in the SMO framework through CM notification logic.

During Stage 2 testing, using an O1 network emulator (RIC tester), several issues were observed and had to be jointly resolved during the PoC. RIC testers' O1 model is by intention a subset of the 3GPP model required for the use cases supported by the RIC tester and therefore limits the set of CM parameters available. The supported model had to be aligned with 3GPP/O-RAN specifications, provide model validation and provision of a Netconf interface. In addition, a limited set of PM metrics are supported and stored inside the RIC tester. A database adapter service was developed in the SMO to fetch PM metrics at periodic intervals, convert to VES format and publish on a Kafka topic for consumption by the rApp/Non-RT RIC.

The generation of training data for the ESMC rApp use case had to be done manually. As accelerated mode simulation was supported by the RIC tester, this enabled the running of long duration simulations in non-real time, however, challenges remained concerning generating temporal changes of traffic levels in accelerated mode.

Based on the PoC experience, it is required to establish a regular information exchange and roadmap discussion with suppliers of RIC test equipment. This exchange should be supported with a tangible and reliable rApp introduction plan to ensure that required test equipment features are available in time. On-demand support is essential in the case of emerging new use cases/rApps.

4.2. STANDARDIZATION REQUIREMENTS

1. SMO/Non-RT RIC functional decoupling, including internal APIs, is needed to facilitate integration of those two components from two different parties (refer to chapter 4.1). O-RAN ALLIANCE is currently running a study item on “Decoupled SMO Architecture” with the goal to identify the internal SMO functions/services and related APIs; the outcome of the study time is expected to guide normative work on architecture and interface specifications that should be supported by the O-RAN community.

2. The RAN cell is a composition of logical and physical (antenna lat/lon, azimuth, heights, mech tilt) configuration. O-RAN/3GPP standard specifies logical configuration whereas the physical one is not covered. However, RAN optimization algorithms (like rApps) require both, cell configuration together with its topology/physical information. There should be a unified/standardized format how this type of data is stored and exposed to rApps. As a small step in that direction, Deutsche Telekom updated the ONAP AAI model by adding a cell object.

3. The R1 interface should more precisely define (API specification) how cell/node configuration will be exchanged between Non-RT RIC and rApp to get closer to rApp plug&play vision. O-RAN WG2 identified the related R1 service - Configuration management (CM) service – but Stage-3 work on Type definitions is yet to be delivered.

4. RAN E2E optimization User eXperience (UX) – we may have SMO, RIC and rApps from different vendors. Each of them most probably will deliver their own GUI. This may create a serious problem in e2e RAN optimization UX as users need to interact with multiple vendor GUIs. Standardization/guidelines/API specification is needed to avoid those UX problems. rApps should by default provide a possibility to control their behavior via API only. Moreover, the way an rApp expose its parameters/status should be unified/standardized to

allow Non-RT RIC vendors to deliver a generic framework for how to control the rApp behavior.

5. An rApp/optimization algorithm rollout in RAN production networks requires a set of steps to verify whether it works properly and doesn't have a negative impact on the RAN network. To do that, the following concepts are needed:
    a. CM action/change framework – to record every rApp requested configuration change (MOI, payload, timestamps etc.) in a dedicated object, to:
        i. correlate it with PM metrics and properly assess rApp impact on RAN network,
        ii. Build CM conflict mitigation engine on SMO level,
        iii. Have a quick rollback possibility in case of significant KPI degradation
        iv. Have possibility to operate in open loop mode.
    b. Open loop – partially correlated with CM actions/changes. Before algorithm will operate in close loop, it needs to be tested in open loop (user need to accept every configuration change requested by the rApp).

4.3. VENDOR COLLABORATION

Industry plugfests, such as those organized by O-RAN ALLIANCE together with OTIC labs, are key to accelerate ecosystem development by offering an environment where ecosystem players can identify and solve initial integration and interoperability issues as well as showcasing new features and functionalities. PoCs such as this one in the operator environment remain an important and complementary step to achieve full e2e multi-vendor integration and validation towards final production readiness.

The pro-active collaboration of all parties was one key success factor for the multi-vendor PoC implementation and execution, implying a tight alignment among all parties during the entire PoC, steered by regular and on-demand bi- or multi-lateral exchange.

Another important factor to drive disaggregated RAN automation and optimization is the expertise provided by the involved parties and to leverage their individual strengths, exemplary on former C-SON based RAN optimization, on excellent knowledge of O-RAN standards and technologies, and on skills to adapt to open-standard based multi-party cooperation.

4.4. VENDOR TAKEAWAYS

While there were challenges related to putting together an extensive multi-vendor O-RAN setup for the first time that consists of many different vendors/producers (Deutsche Telekom SMO, VMware Non-RT RIC, Juniper Non-RT RIC, two AirHop rApps, a 3rd party RAN vendor, and VIAVI RIC tester), the successful integration hinged on significant progress in key areas of collaboration:

- Starting with a clear well defined and agreed SoW as a foundation for a detailed delivery and execution schedule that accounts for several rounds of fixes and refinements.
- Regular cadence of communication among all parties to keep the project running smoothly with clear actions and owners defined and tracked.
- Feedback from operator to vendor proved instrumental to align the Non-RT RIC roadmap with operator priorities.
- Importance of operator direct involvement, support, and expert knowledge in the domain significantly improved PoC effectiveness.

Progress in standardization and industry support for standard interfaces will ensure overall integration and PoC progress can be significantly faster and smoother.

As the current stage of standardization results in partly different interpretation across the involved parties, PoCs like this one help to align vendors, to agree on concessions, and to promote changes and extensions to the relevant standardization bodies for example, to the SMO and R1 interface– as detailed on 4.2 STANDARDIZATION REQUIREMENTS.

The engagement in operator trials plays a crucial role in refining industry standards and transitioning technologies from the lab to production environments. As to further improve standardization, operator and vendor stakeholders should contribute the learnings they acquired through PoCs such as this one.

5 KEY FOCUS AREAS AS OUTLOOK

The primary focus of Deutsche Telekom in open RAN development is to drive innovation to support the best customer experience. The RIC is key to programmability and automation in RAN. Taking the learnings from this successful trial, Deutsche Telekom will continue the work with its ecosystem partners to accelerate Non-RT RIC/rApp development towards production readiness and to reduce multi-vendor integration efforts.

The vision of Plug&Play on the R1 interface is not yet achieved. Related standards must be further improved. Pre-integration of rApps and Non-RT RIC products including certification must be strengthened by initiatives such as the i14y Open lab.

The internal SMO architecture and the interfaces between all SMO building blocks must be defined by the respective Working Groups of the O-RAN ALLIANCE. Open RAN MoU members' understanding of how an internal SMO structure might look like can foster and accelerate related standardization.

Essential RAN operation concepts such as cell site clusters are yet to be implemented in the Non-RT RIC/SMO framework. Network operators typically divide their RAN into site clusters with a single cluster containing several sites providing coverage in a particular geographical area - urban, suburban, rural. Different CM/rApp settings may be applied to clusters depending on cluster traffic/terrain profile. The cell cluster concept should be considered as a centralized SMO function where cluster configurations can be exposed to various CM agents such as SMO CM UI and Non-RT-RIC/rApp. This is important for the Non-RT RIC/rApp as different rApp instances (with different optimization settings) per cluster may be required to optimize the network.

Furthermore, open RAN and traditional RAN (S-RAN) will coexist soon in commercial networks. A similar coexistence needs to happen for RAN automation/optimization tools. As C-SON solutions have well established frameworks and outcomes for network optimization operators will continue to use them. There is an opportunity to also use the O-RAN Non-RT RIC/rApp concept for traditional RAN. Network operators need to investigate how future optimization of hybrid (O-RAN and S-RAN) RAN networks should look like.

6 GLOSSARY

▪ 3GPP	3rd Generation Partnership Project
▪ AI/ML	Artificial Intelligence / Machine Learning
▪ BSS	Business Support Systems
▪ CU	Central Unit
▪ DU	Distributed Unit
▪ EMS	Element Management System
▪ ESMC	Energy Savings dynamic Multi-Carrier management
▪ FCAPS	Fault, Configuration, Accounting, Performance, and Security
▪ FM	Fault Management
▪ gNodeB	next Generation Node B
▪ LCM	Lifecycle management
▪ LTE	3GPP Long-Term Evolution technology
▪ MoU	Memorandum of Understanding Five big European network operators have created an O-RAN technical priority document under the Open RAN MoU
▪ Near-RT RIC	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
▪ Non-RT RIC	Non-Real-Time RAN Intelligent Controller. A logical function within SMO 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.
▪ O1	O1 interface: interface between SMO and O-RAN managed elements, for operation and management, by which FCAPS management, Software management, File management and other similar functions shall be achieved.
▪ O2	O2 interface
▪ OAM	Operations, Administration and Maintenance
▪ O-CU	O-RAN Central Unit
▪ O-CU-CP	O-RAN Central Unit control plane
▪ O-DU	Open Distributed Unit
▪ ONAP	Open Networking Automation Platform
▪ O-RAN	Open Radio Access Network based on O-RAN ALLIANCE specifications
▪ O-RU	Open Radio Unit
▪ OS	Operating System
▪ OSS	Operation Support System
▪ PaaS	Platform as a Service
▪ PCI	Physical Cell Identifier
▪ PM	Performance Management
▪ PNF	Physical Network Function
▪ R1	R1 interface: Interface between rApps and Non-RT RIC framework via which R1 Services can be produced and consumed.
▪ R1 services	A collection of services including, but not limited to, service registration and discovery services, authentication and

authorization services, AI/ML workflow services, RAN OAM-related services as well as A1and O2 related services.

- **r**App — Application/Microservice used by a Non-RT RIC for central non-real-time closed-loop automation and optimization of RAN elements & resources, with control loops in the order of 1 second or more
- RAN — Radio Access Network
- RIC — RAN Intelligent Controller
- RRM — Radio Resource Management
- RT — Real Time
- RU — Radio Unit
- SMO — Service Management and Orchestration
- SON — Self-Organizing Network
- SoW — Scope of Work
- SRAN — Single RAN
- TCO — Total Cost of Ownership
- UE — User Equipment
- UP — User Plane
- UPF — User Plane Function
- vRAN — virtualized Radio Access Networks
- xApp — Application/Microservice used by a Near-RT RIC for near-real-time closed-loop control and optimization of RAN elements & resources, with control loops between 10 milliseconds and 1 second