Open RAN for Brownfield Operators
Challenges and Opportunities

GCC Open RAN Consortium Whitepaper

October 2022

Table of Contents

Table of Figures

1 Introduction

Zain Group, stc, e&, Mobily, du, Batelco and Omantel are joining forces to push forward the implementation of Open Radio Access Network (Open RAN) solutions in their brownfield networks. The move will see them share their industry knowledge and experience, setting a clear path to drive innovation for the ICT sector across the Middle East.

The Memorandum of Understanding (MoU) between the seven operators confirms commitment to deploy Open RAN across their footprint, providing an opportunity for traditional RAN vendors to adopt open interfaces, software, and hardware to build more agile and flexible mobile networks in the 4G and 5G era, support new entrants with innovative solutions and achieve cost efficiencies in RAN deployments.

Such partnership signals the entry into a new era of operators' collaboration in the Middle East to accelerate the development of Open Network technologies, which helps in diversifying strategic technology growth in the Gulf and gain an advantage with service catering to the local market requirements with faster time to market while focusing on introducing software capabilities that bring technologies like Artificial Intelligence (AI) to the forefront. The implementation of Open RAN solutions supports flexibility and provides more innovation in managing the network for more efficient operations.

Driving innovation and Open RAN deployment is the shared responsibility of every telco operator. With Open RAN, networks can be deployed and operated based on mix-and-match components from different suppliers. Operators will be able to draw on the reinvigorated supplier innovation to drive cost efficiencies and more flexibly deliver customized services in response to evolving customer demands.

Middle East operators have launched the first regional community lab, following the signing of the Open RAN MoU last year. The move will accelerate the testing and implementation of Open RAN solutions in their networks to support the early adoption and development of a robust regional ICT ecosystem.

The lab will provide shared facilities and access to Open RAN 5G SA Private Network use cases for members and vendors, and catalyst for Open RAN deployments.

The GCC operators elected to advance in a cooperative manner working and supporting the initiative together aligning on Open RAN trials, technology strategy, and leveraging on international partners' experience

The Main Objectives of the GCC Open RAN MoU are:

- ✓ Commitment to deploy Open RAN across GCC MNOs footprint.
- ✓ Inspire traditional RAN vendors to adopt open interfaces (i.e., O1 and Open FH).
- ✓ Support new entrants with innovative solutions enhancing the vendor ecosystem.
- ✓ Achieve efficiencies in the total cost of ownership (TCO) in RAN deployments.
- ✓ Achieve interoperable, competitive, and commercial-grade Open RAN products.
- ✓ Build a framework to exchange reports of Open RAN Technical outcomes, lessons learned and best practices.
- ✓ Study the feasibility of having Plug fest activity in GCC.
- ✓ Test and validation process for quick and easy access to products and solutions.
- ✓ O-RAN Alliance E2E architecture validation (RRU, CU/DU, RIC & SMO)

2 Open RAN Brownfield Challenges/Opportunities

The following figure summarizes the value chain as presented by the "Building An Open RAN Ecosystem for Europe" Whitepaper, on which we reflected on it the GCC Open RAN Consortium view on the Brownfield Challenges/Opportunities detailed elements which we elaborated on the sub-sections below.

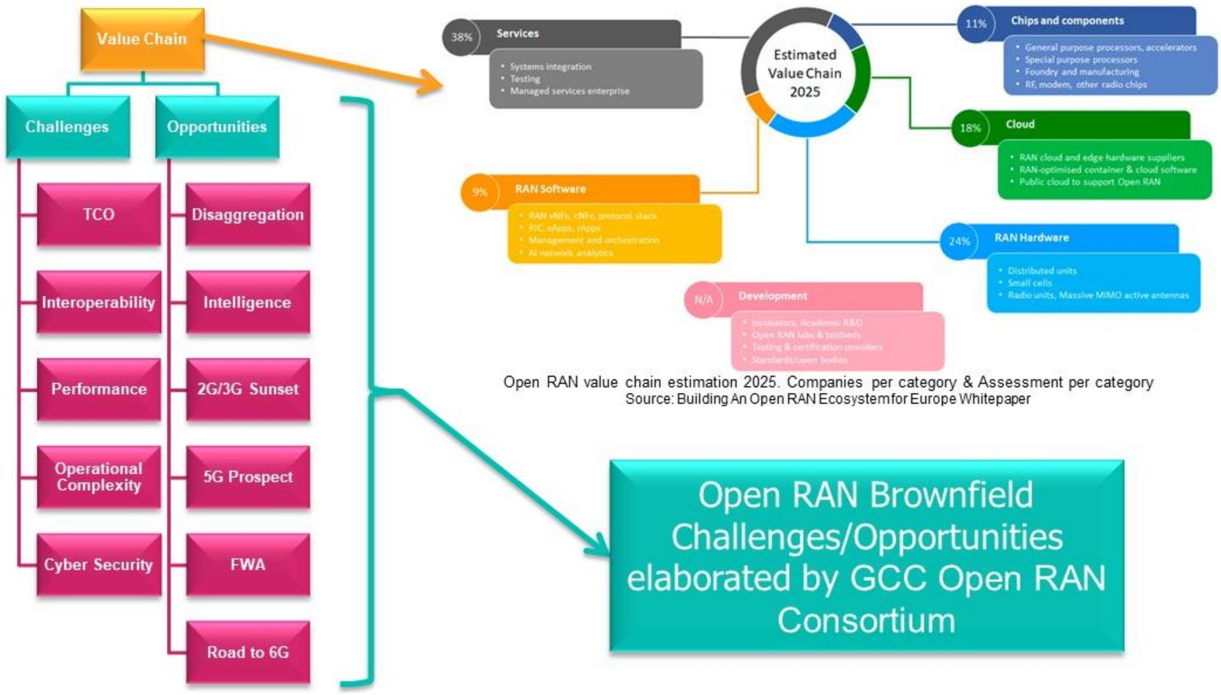

Figure 1: Open RAN Brownfield Challenges/Opportunities

2.1 Open RAN Brownfield Challenges

2.1.1 TCO

Operators face challenges with increased yearly CAPEX and the associated OPEX for expanding their networks. Every operator sources the telecom hardware and software from a limited number of incumbent vendors who offer proprietary equipment and software. Having such models means less leverage in achieving the most competitive prices which leads to a high Total Cost of Ownership (TCO).

Open RAN promises to substantially reduce the (TCO) as operators have the freedom to choose hardware and software from a wider vendor supply chain. Operators can choose the needed hardware and software that fits their requirements at the most competitive cost.

The promised cost savings in operations from open or virtualized RAN architectures are yet to be realized, as is often the case with the early adopters of innovative solutions. There is an implicit assumption that deploying open and virtualized RAN architectures will bring substantial cost savings. Open RAN brings cost benefits as multi-vendor interoperability allows operators to select products from any vendor, and to make the best choice from a cost perspective.

TCO significantly depends on the Open RAN topology the operator selects and, more precisely, on the resource and transport costs dictated by the chosen topology with a hyper-converged cloud platform, zero-touch automation, and lower processing latency crucial to make Open RAN economically viable. vDU/vCU pooling can provide substantial TCO reduction over years but it is not a realistic architecture for many operators today. The pooling of vDU and vCU resources in EDGE DC potentially offers the greatest efficiency benefits of all the modeled scenarios. However, this scenario is also very difficult to realize for many operators today because it requires expensive and available fiber in the fronthaul to meet the latency requirements. In addition, the limited availability of far-edge data centers to host vDU functions is another barrier. Overall, the costs associated with these challenges can be highly detrimental to the business case (Gorkem Y., Caroline C., Audrey B. & Gilles M., Analysys Mason, 2022).

The two major factors impacting TCO are CAPEX & OPEX:

CAPEX:

Hardware investment: Mostly the HW investment involves RRUs for all bands, Switches (as aggregator GW & clock) and Cloud setup to host CU/DU (COTS/ Accelerators/Switches/PTP Clock). CAPEX may have a significant impact on brownfield operators' initial rollouts due to the complete new multi-tier Data centers setup, especially bringing up large number of EDGE Datacenters. However, the CAPEX requirement may reduce in later years of expansions or rollout. The increase in COTS capacity, CU/DU capacity, and RRU/Antenna multi-bands approach would reduce significant CAPEX.

Transport layer upgrades investment: For the massive rollout of Open RAN, the transport network with dark fiber needs expansion or upgrade to match the FH requirements, which is a key factor impacting the CAPEX.

Software investment: One of the challenges of introducing RAN virtualization is an investment in the virtualization layer to host either VNF or CNF-based applications. For Open mix-and-match solution in case, NFV complete stack of Openstack, host OS, Hypervisors, etc apart from key components like CU, DU, EMS functional software is to be procured. And post rollout, most license procurement will be part of yearly CAPEX. TCO is also impacted by a hyper-converged platform that enables the deployment of cloud-native functions (vCU, vDU) and Kubernetes-based container orchestration (control plane) together in a single COTS server with compute, storage and networking resources (Gorkem Y., Caroline C., Audrey B. & Gilles M., Analysys Mason, 2022).

The licensing model: The licensing model for each SW component is a big challenge for initial procurement and maintenance upgrades. Overall, the Lifecycle management and Level 3 support are critical parts as well.

Automation Layer investment: As part of the O-RAN alliance architecture and to leverage Artificial intelligence & Machine Learning, an automation layer is introduced. Radio intelligent controller near real-time and non-real-time along with Service & management

Orchestrator or RAN Domain orchestrator automation components are introduced. Having zero-touch and E2E automation in the RAN network, there is a new vendor introduction and reduction in operational complexity leading to savings with an initial impact on CAPEX.

OPEX:

Operation and maintenance cost: Due to changes in the operational model, the operational costs may increase significantly for maintaining the virtualized environment and RF part which would have a significant impact on OPEX.

Integration cost: Testing with multi-vendor products is also challenging. Building an end-to-end solution with multi-vendor products involves appropriate testing which requires skillset and know-how.

SW/HW upgrade Cost: Virtualized products have shorter lifecycles requiring testing and migration at end of each cycle. If regular upgrades are to be implemented, an interoperability verification is required with other SWs deployed (for example: Host OS upgrade or K8s upgrade).

Energy Cost: Two separate opposite effects:

A) Introduction of General-Purpose HW and Switches building the Datacenter setup would increase the power requirements, apart from DC Airconditioning norms. However, the dedicated hardware consumes less power compared to general-purpose servers. Overall, the OPEX due to power consumption increases.

B) Cloud data centers can leverage centralized cooling, lighting, and electricity purchasing agreements, bringing down power costs compared to local compute and reducing the tower space rentals as well.

2.1.2 Interoperability

Interoperability is a key factor in either the success or failure of any system including Open RAN deployment. Disaggregating base station functionality into multiple components (RU, DU, and CU) based on the open RAN concept allows operators to select products with flexibility from multiple vendors customizing their networks to suit their own unique needs.

Having the main components (CU, DU, RU) disaggregated and the option to choose from any supplier means that interoperability validation and verification may need to be repeated with every introduction of new hardware. This can add challenges to operators to secure the right resources to perform this step. Also, verification and troubleshooting can lead to delays in the timelines before making services up and running.

2.1.3 Performance

It is expected that initial multi-vendor Open RAN networks may not yet have performance or security parity compared to conventional network deployments. The gap to a single vendor network will reduce over time as profiles and testing mature but is unlikely to reach parity instantly due to vendor readiness. Introduction of AI & ML in X/r-APPs hosted on RIC with SMO orchestration adds intelligence to the network enhancing the KPIs and customer experience. Network slicing and centralized policy-driven user data analytics would enhance the overall network KPI and performance despite unplanned events and changes in customer behavior.

By disaggregating RAN hardware and software, the benefit of purpose-built hardware and optimized software is lessened. However, to counteract this minor loss in performance, various hardware accelerators such as FPGA, and eASIC are being developed, each serving a variety of deployment scenarios depending on its characteristics.

2.1.4 Operational complexity (multi-vendor)

Virtualization and Disaggregation are attractive for the RAN implementation. However, some challenges are specific to the RAN, such as more stringent performance requirements and more distributed deployment scenarios. Always, multivendor ecosystem setup leads to several operation issues which MNO must be ready to imbibe in their operational model building. Mainly following concerns are to be addressed:

- Life cycle management of each Software component.
- Hosting CNFs Image registries and regular patch upgrades with historical records.
- Unit/block/interoperability, testing for each software upgrade.
- End to End global IP schema modeling with dual-stack
- Software components end of service/sale monitoring and replacement with testing.
- Firmware upgrades for Hardware components and corresponding SW requirements.
- Maintaining SLAs, issue tracking, and Level-3 support coordination.
- Inter vendor coordination for technical issues (patches/upgrades involvement).
- End-to-end application and service reliability.
- Agility for service development delivery.
- CI/CD-DevOps sync with network services demand.
- Interoperability and interfacing with existing network elements

Operational issues are also dependent on deployment scenarios in the network (Figure 2: Open RAN deployment scenarios), during implementation various deployment scenarios to be considered based on the business objectives and use cases

Since the packet processing of radio systems requires real-time processing on the order of µsec. Because such processing requirements are difficult to be realized only by CPUs, especially for the most demanding scenarios (e.g., 5G with 100MHz or more bandwidth and/or a large number of MIMO layers), hardware accelerators will be required to offload L1 processing (partially or fully). Currently, various hardware accelerators such as FPGA, GPU, and ASIC are serving a variety of deployment scenarios adding complexity.

One of the example scenarios of virtual RAN is to be able to run multiple 5G workloads efficiently on common COTS hardware. These workloads could be DU/CU, RIC, UPF, or even MEC applications, blending elements of the core and access networks flexibly to realize optimal performance but the handling of multi-domain network functions adds complexity.

Considering the flexibility and scalability of Open RAN CU & DU, they can be instantiated in different locations as per the capacity & use case requirement at each location. Leveraging the containerization of CU & DU, CNFs capacity scaling, redundancy, replacement/reboot, and reduced latency techniques, would enhance the overall reliability of the application. However, this would add complexity as well.

System Integrator (SI) plays an essential role in the Open RAN space. SI is vendor-neutral and should be capable of bringing together all different software and hardware component of Open RAN. Unlike the traditional RAN where the full turnkey basis makes it easy for MNOs to deploy the purpose-made HW/SW, the Open RAN needs SI that will be responsible for the intensive interoperability activity before launching the system.

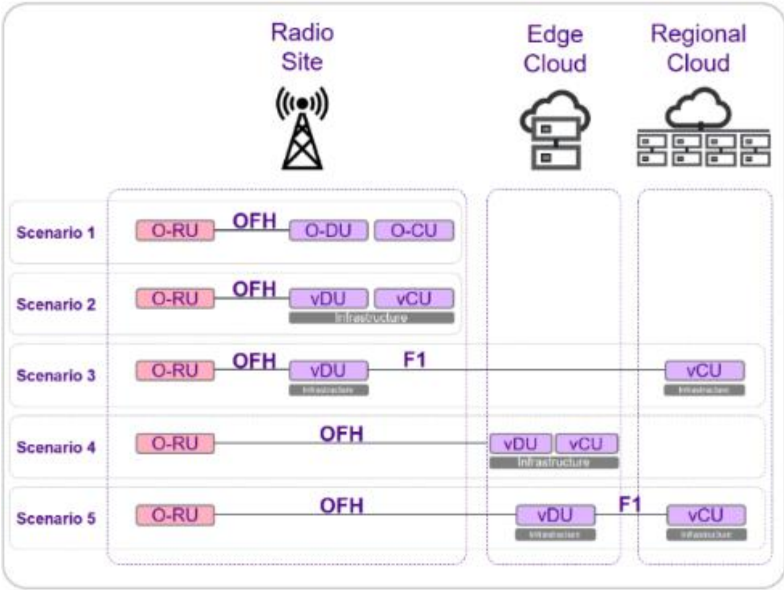

Figure 2: Open RAN deployment scenarios

As brownfield operators, there will be many updates on the internal and operations processes related to the procurements and the network operations. Further to this, skill uplifting and intensive training is essential to shift the paradigm and prepare the human resources for successful adoption.

2.1.5 Cyber Security

It is undeniable that the introduction of Open RAN poses new security challenges. The Openness and disaggregation are expected to enable and extend more threats on the network and user's data. Open RAN monitoring solutions must provide advanced features that can enable detection, trigger warnings and prevention, and take action against these threats. Operators should take advantage of the virtualized nature of the Open RAN to deploy tested security patches and software updates quickly and remotely.

The increasing complexity of mobile networks has raised questions about potential security vulnerabilities in the global supply chain, but Open standards would help users and network operators better understand, align, and demonstrate successful implementation of security requirements. Operators and suppliers can coordinate closely by sharing incident information about threats, vulnerabilities, exploits, and greater access to data about network performance, allowing greatly accelerated development and deployment of mitigations.

The introduction of open interfaces in the RAN allows the operator to distribute security analytics throughout the network and move RAN monitoring to the edge. Automation enables zero-touch management which eliminates the security risks inherent in human access to network functions (NF). With the open management interface for checking the security posture of a network function, the operator can quickly detect and fix degraded configurations – or anomalous network activity within the perimeter of a network – through closed-loop management.

Open and virtualized RAN disaggregates the network of 'threat surfaces' for any network. On the other hand, these shifts present mobile operators with a greater set of options to procure and configure best-in-class, secure, reliable, and resilient networks while adhering to national procurement restrictions and facilitating alignment with best-practice security principles. In addition to align with best-practice security principles, Open RAN components also need to comply with security requirements in the relevant standards and certifications (e.g. 3GPP SCAS, ETSI, and GSMA NESAS), and consider certification scheme for cloud to get assurance about the implementation of cloud services. Open RAN brings several enhancements leading to increased modularity combined with increased functional split, utilization of open source and commonly used protocols, interface to third parties, and use of the cloud.

2.2 Open RAN Brownfield Opportunities

Brownfield MNOs to opt for newer strategies that can simplify the adoption of an Open RAN and leverage the advantages of Openness and virtualization. For hands-on experiences with O-RAN deployment scenarios, as MNOs, we need to go for All-G trials in the Live network, in addition to a test lab(s) setup for accelerating the pre-validation of all hardware and software components. Software lifecycle includes several regular upgrades and patches for issues resolution or addition of new features, this would necessitate strengthening DevOps culture and enhancing Continuous Integration/Continuous Delivery (CI/CD) capabilities.

2.2.1 Disaggregation

The main differentiator of Open RAN is disaggregation. It means the implementation of the software has a little dependency on the hardware. The key driver is to move to cloud-based disaggregation Open RAN solution. Open RAN increasingly making telco vendors transform to IT cloud network, bringing benefits being carried to Telco cloud, simplifying deployment provisioning and automation.

Disaggregated BBU functions provide greater flexibility for use case-specific network deployment. The scenarios can vary based on the use cases and can be user-centric network with network slicing, accordingly the location of DU, CU- CP/UP can be maneuvered. In the future, due to open interfaces the function can be from different vendors as well adding another dimension to the flexibility. Adding one more key point, usually in traditional network user plane and control plane application resources were fixed but now due to user/control plane segregation a single control plane function can support multiple user plane functions which can be scaled as per requirement.

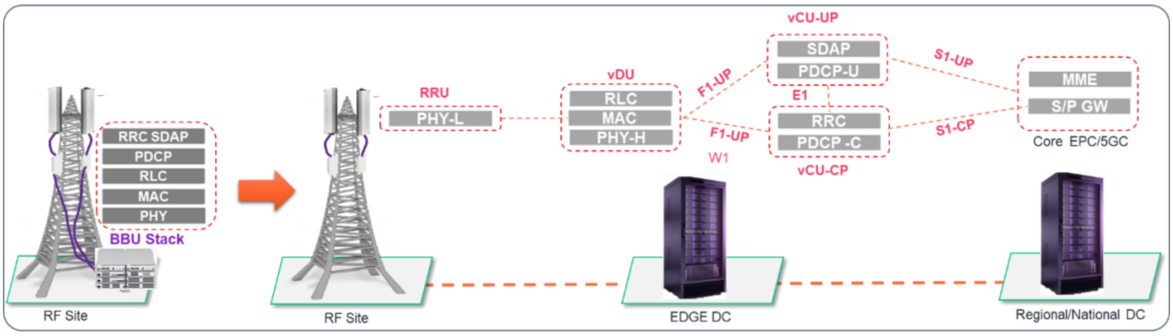

Figure 3: Disaggregation of BBU functions and open interfaces

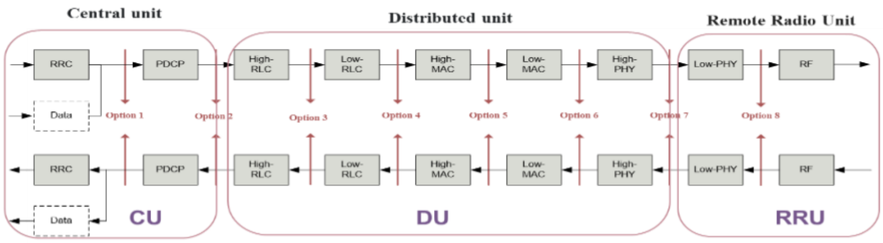

Figure 4: Disaggregation of BBU functions option 7-2X

2.2.2 Intelligence

Introduced in the O-RAN Alliance architecture, Service Management Orchestrator (SMO) and RAN Intelligent Controller (RIC) are the nodes which augments intelligence to the RAN domain. SMO is a common platform to orchestrate, automate both the legacy and Open RAN types. The RIC enables best-of-breed automation capabilities that fulfil mobile operator network requirements such as Artificial Intelligence/Machine Learning (AI/ML), analytics, and operator policies.

- **Service Management Orchestrator:** oversees lifecycle management of multi-vendor network functions as well as O-Cloud with standardized interfaces O1, O2, A1 and O-RU M-Plane. It simplifies the complexity of networks, improve network performance, enhance customer experience, and minimize overall RAN operational costs. In addition to the support of advanced use cases.
- **The Non-Real Time Intelligent Controller (Non-RT RIC)** supports intelligent RAN optimization by providing policy-based guidance, ML model management, and enrichment information to the Near-RT RIC function. These are all tasks that require > 1s latency. The Non-RT RIC function resides in the Service Management and Orchestration (SMO) layer of the O-RAN OAM logical architecture. These control functionalities leverage analytics and data-driven approaches including advanced AI/ML tools (rApps) to improve resource management capabilities.
- **The Near-Real Time Intelligent Controller (Near-RT RIC)** enables near real-time control and optimization of O-RAN (O-CU and O-DU) nodes and resources. These tasks require latency of < 1s. The Near-RT RIC delivers a robust, secure, and scalable platform that allows for flexible onboarding of third-party control applications called xApps, which are used for multiple use cases such as mobility management, admission control, and interference management.

The Near-RT and Non-RT RIC functions leverage rApps and xApps to induce AI/ML-based decision-making. The underlying hardware platform for RIC functions must be optimized for AI/ML-based learning as well as efficiently run all the other usual workloads at the node. Using standard processors opens the possibility to implement schemes for reduced carbon footprint. These schemes can automatically tailor processor core allocation for different application workloads based on their specific activity levels at different times of the day.

The consortium is aiming at a potential array of use cases that can be implemented on O-RAN specified RIC platforms. Such as Traffic Steering and predictive load balancing, QoS & QoE Optimization, E2E slicing, Atmospheric Ducting Interference Mitigation and Energy Savings, in addition to Multi-User MIMO and channel estimation variety of use cases.

2.2.3 2G/3G Sunset

The majority of GCC operators are going through technology sunset of either 2G or 3G. Within such projects operators will eventually invest in upgrading relatively old equipment with modernized equipment to carry 4G/5G.

This can be an opportunity for operators to identify Single Geography clusters/sites as candidates for Open RAN migration, since a natural modernization is being conducted and investment will be allocated for such a major sunset project.

O-RAN standardization is limited to 4G and 5G but due to existing services, penetration and maturity still 2G/3G layer will remain at least for a couple of years. However, either 3G or 2G networks will be shut down in most of the GCC MNOs. Post sunset the frequency band would be utilized for the LTE network. There is a necessity to cohabit with a 2G/3G legacy until the sunset of all legacy technologies.

On the topic of MNOs' focus level for Open RAN support of legacy 2G/3G technologies there are multiple views, one balanced view is to sustain a layer of 2G or 3G and require such layer from Open RAN, with a major consensus to focus on 4G/5G as a future proof technology.

2.2.4 5G Prospect

Mobile operators have been criticizing the high infrastructure cost they endured for a long time, and it got a lot more serious with the rush to deploy 5G, which physically has a shorter range than previous-generation mobile networks, especially with higher frequency radio bands ranging from 24GHz to 40GHz. Therefore, 5G networks require many more base stations to provide general coverage. For sure that will even bring the TCO too high, this drives the mobile operators to be keen to support any initiative that could bring network architecture to a flexible, virtual, open, and automated with a lower capital expense.

The cost of infrastructure is a critical aspect in rolling out 5G networks, particularly when we consider the massive scale of this venture. Open RAN network standardized architecture allows operators to host the disaggregated BBU on cloud-native platform over commercial off-the-shelf (COTS) servers with open fronthaul interface towards any 3rd party radios. Moreover, the architecture includes intelligent controllers incorporated with AI/ML models. Such architecture offers virtual resources sharing, on-demand scaling, automation, self-provisioning/optimizing network functions, slicing, …etc., which with appropriate scale reduces the overall TCO.

The standalone 5G Core embraces a cloud-native, distributed infrastructure which uses microservices, running on a service-based, containerized architecture. This creates a faster, more reliable E2E network performance to customers' demand and reduces time to market for incremental network deployments (mobile sites) and new 5G services such as URLLC or mMTC, from the current requirement of several days to just a few hours.

Open RAN is an advantage to enterprises seeking private 5G and LTE. One of the main bottlenecks and even in some cases showstopper to wider adoption of private, licensed wireless networks is cost, and open RAN could change the calculation enough to let more organizations consider such networks.

2.2.5 Fixed Wireless Access (FWA)

Most countries are focusing on infrastructure improvements associated with digital transformation and the expansion of broadband connectivity for socio-economic benefits. The recent Covid pandemic proved the need for ubiquitous broadband. High adoption of connected devices, video streaming, and online gaming services are among the drivers of higher-quality broadband access. For all such services, FWA can be an optimum solution, it can be most useful in emerging countries where fixed broadband is not yet prevalent, the speed and capacity will make it a competitor in developed markets as well.

Some mobile operators see FWA as a hopeful game-changer in a fixed market for significant growth, while other fixed network incumbent operators tend to view it as supplemental in remote, rural areas. However, it gives operators a cost-effective, strategic option to remain competitive in new areas without having to build out a wireline network successfully capturing the demand for faster and reliable home broadband. Commercial 5G FWA deployments promise sustainable, high-speed internet access to otherwise poorly served or unconnected homes and businesses, with support for services such as smart homes, digital gaming, and enterprise broadband.

Opening FWA is not only about opening the RAN. Open RAN focuses on access disaggregation, which is not the only issue for FWA. Open FWA is closer to the recently launched OpenWiFi, which addresses the complexity of managing multi-vendor Wi-Fi networks. The difference is that in a Wi-Fi network all vendors use the same unlicensed bands, while FWA networks use a wider range of bands. In addition, Network Slicing and RIC QoS/QoE optimization use cases and features can help operators achieve appropriate SLAs when multi-services with different requirements are offered on the same RAN and same frequency band.

In all cases, openness liberates vendors and operators from technology, business models and enriching limitations that slow down technological innovation and market growth.

2.2.6 Road to 6G

The introduction of Open RAN came at a point where a majority of GCC operators were undertaking successful 5G rollouts with incumbent vendors. The opportunity for Open RAN in the region remains for use cases such as private networks, indoor and rural coverage. The opportunity for large scale Open RAN deployments will perhaps be even greater for 6G

To guarantee open RAN will be an ultimate part of 6G solutions would mean extending the 3GPP to partner with the O-RAN Alliance and TIP. This would offer an effective bridge between 3GPP and Open RAN to guarantee an essential 6G RAN architecture feature. Following the typical 3GPP Standards evolution cycle, the 6G Standard can be expected to emerge around the 2030 timeframe.

6G will integrate a set of previously disparate technologies, including deep learning and big data analytics. From a service management perspective, AI/ML will be needed to maintain operation cost-effectiveness of envisioned 6G services such as the interaction of human-digital physical worlds and the Internet of Senses. Besides, the proliferation of multiple virtualization technologies, including virtual appliances, microservices, containers, serverless functions, and their interoperability will increase the complexity of network operations. AI/ML mechanisms will be critical to automating decision-making processes. 6G Orchestration will target the continuum from end devices, to edge, to RAN and cloud/core.

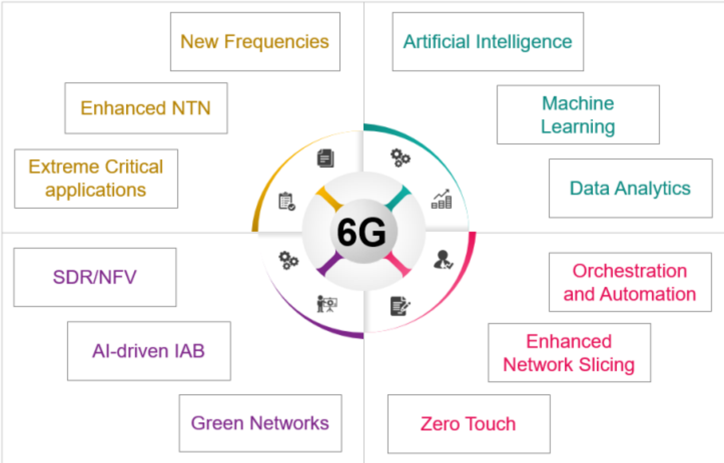

Figure 5: Expected Key Technologies in the 6G era

(Common similarities with O-RAN technical foundation)

O-RAN technical foundation has multiple similarities with most of the expected key technology enablers for the 6G. From the first release of the O-RAN specifications, the Alliance has demonstrated high attention to the use of AI/ML algorithms to optimize the quality of experience and save the power consumption. Moreover, the Service Management and Orchestrator will offer the automation capabilities to operate the network most efficiently and intelligently with the use of data analytics. The FCC experimental 6G spectrum falls in the 95 GHz to 3 THz range and such high band use increases site count to a huge number for network coverage. MNO can leverage the cloud-native and fully automated architecture of Open RAN to a spin-up large number of sites in efficient timeframe.

In 6G, we expect direct integration of different resources from networking to computation and sensing. In this way, the functionalities and services can be provided as microservices where needed. O-RAN Alliance has facilitated the exploration of new network concepts such as open Hardware/Software, open interfaces, and AI/ML-based automation which drives RAN futuristic and intelligent features.

Overall, 6G is expected to be a self-contained ecosystem with flexible management, control and automated human-like decision-making processes. It’s therefore fair to conclude that 6G will likely take full advantage of the O-RAN development and that the O-RAN specifications are likely to become parts of 6G fundamentals.

3 Trials Results Executive Summary

3.1 stc Trials results executive summary

stc has successfully done Live trials of Open RAN option 7-2X. Technically the trial focused on testing the end-to-end O-RAN cloud native solution deployment with live traffic validating the solution reliability, functionality, maturity, interoperability with multiple vendor components and standard open interfaces in several combinations. Also, trial results determine the existing transport network and Cloud set-up capabilities which could be the baseline for building deployment strategy. Overall, the results were optimistic and indicate that further evolution of HW & SW in terms of capacity, features, performance and automation is required to proceed with massive rollouts in brownfield operators.

As part of the live trial setup for O-RAN option 7-2x, a dedicated EDGE DC was installed hosting complete stack of hybrid platforms to host both VM & Container based virtual functions. And the high computational complexity DU Phy-H layer functions are hosted on accelerators installed on the COTS servers. Multiple 3rd party vendor O-RUs with different power and MIMO were involved in the trial. As brownfield MNO, succeeded in a key validation of CU authentication/ enrollment and control plane (S1-C) over IPSEC tunnel interfacing with multi-vendor existing Gateways. The crucial fronthaul interface over dark fiber met the latency and throughput requirements with optimal EDGE DC positioning. Also attained the Synchronization (S-plane) by isolated PTP master node and a PTP enabled switch as boundary clock. The key features like VOLTE, 2CC carrier aggregation, CSFB with incumbent vendors, etc. were tested, achieving overall fair results.

In parallel, testing is in progress for more deployment scenarios, different cloud native platforms, 3CC Carrier aggregation, zero-touch config, 5G use cases and RIC/SMO solutions, building a vendor ecosystem for commercial engagement.

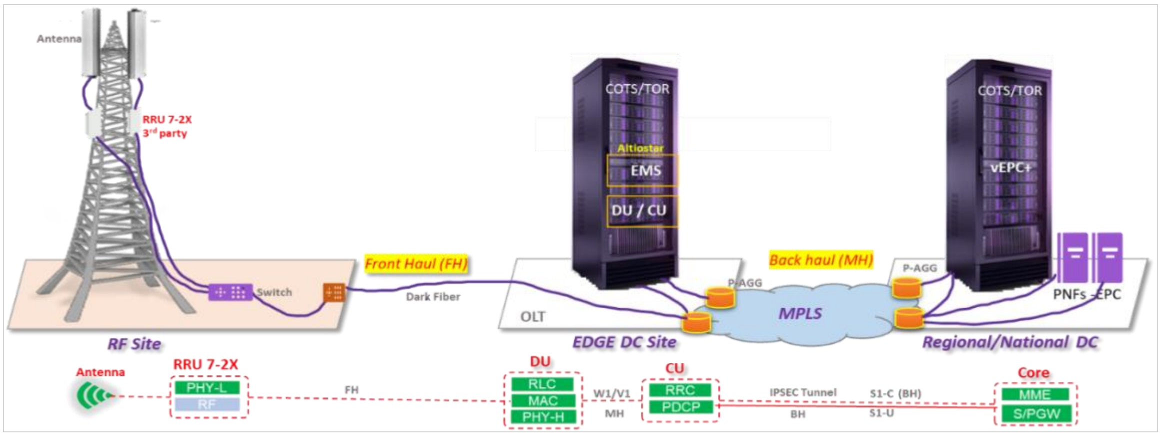

Figure 6: Open RAN trial set up high-level E2E topology

3.2 Etisalat Open RAN Trials

Etisalat has conducted several Open RAN trials. One of the PoCs involved two setups – a lab setup and field setup, consisting of 2 radio sites and 4 radio sites respectively – the deployment followed Open RAN standard and included disaggregated hardware and software, with DU/CU split. Drive tests for several network KPIs were conducted to investigate Open RAN performance. The objective of the PoC was to test the capabilities of a network running on Open RAN architecture.

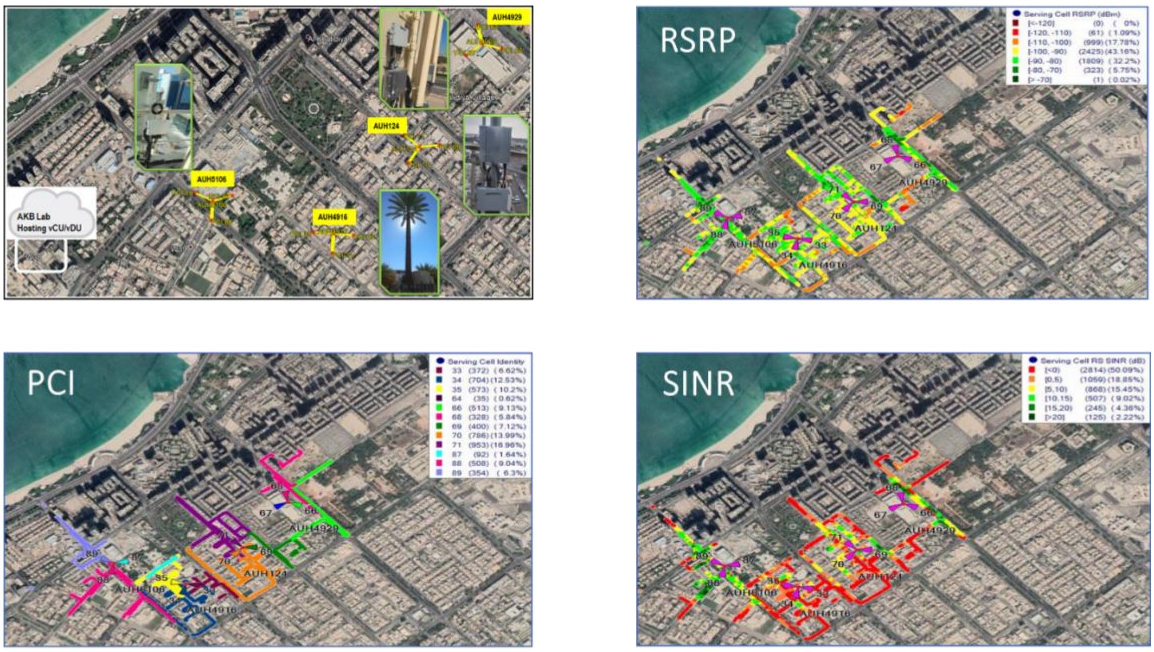

Figure 7: Snapshot of trial drive test results

The objectives were met successfully and indicated that Open RAN-based deployments are feasible for the relevant deployment scenarios and environment.

4 First GCC Lab

4.1 5G SA Private Network with ORAN Lab

Du's representing the GCC ORAN alliance established a partnership with Intel, Radisys, and Foxconn drives a revolution toward operators' cost-effective private 5G wireless deployment, and observes an industry collaboration for Edge Infrastructure and applications deployment over 5G.

The partnership started by establishing an open innovation lab demonstrating O-RAN Compliant Private 5G solutions for Enterprises and IoT segments. The end-to-end solution is empowered by:

- Intel COTS with Intel® Xeon scalable processor and Intel® vRAN Dedicated accelerator ACC100, Intel® Ethernet cards, and Intel® QAT - Quick Assist technologies.
- Radisys 5G RAN Cloud-native SW stack (DU & CU) using Intel® FlexRAN L1 and enabling O-RAN E2 interface for the communication with near-RT RIC
- Near-RT RIC from the ONF SD-RAN project and xApps
- 5G Core and management from the ONF Aether project
- Foxconn 5G O-RRU for indoor and outdoor setup.
- Dell is providing the edge servers for this trial.

Intel® Smart Edge Open provides CNCF certified Cloud Native framework for Private 5G deployment with edge AI services, and Intel OpenVINO provides AI inference optimizations for Edge Services.

4.2 High-level Architecture

The high-level architecture of the lab is depicted in Figure 8

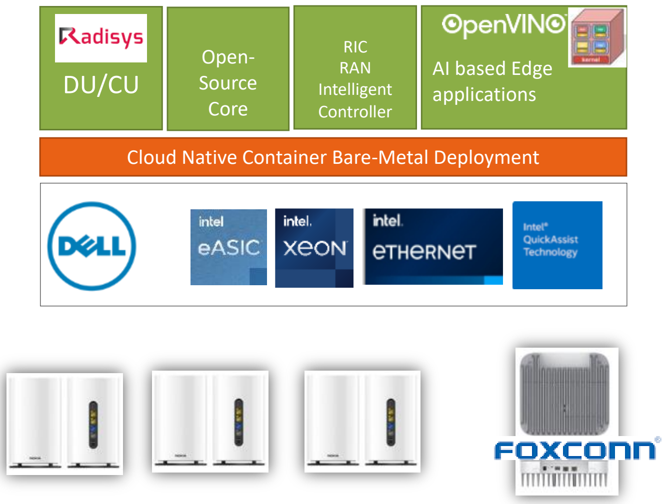

Figure 8: GCC 5G SA Private Network Lab - Main Components

The detailed architecture of the Lab is illustrated in Figure 9. **Three Edge Nodes with DU/CU Co-location and On-Premises Distributed Control (High-capacity use cases spanning indoor & outdoor)**

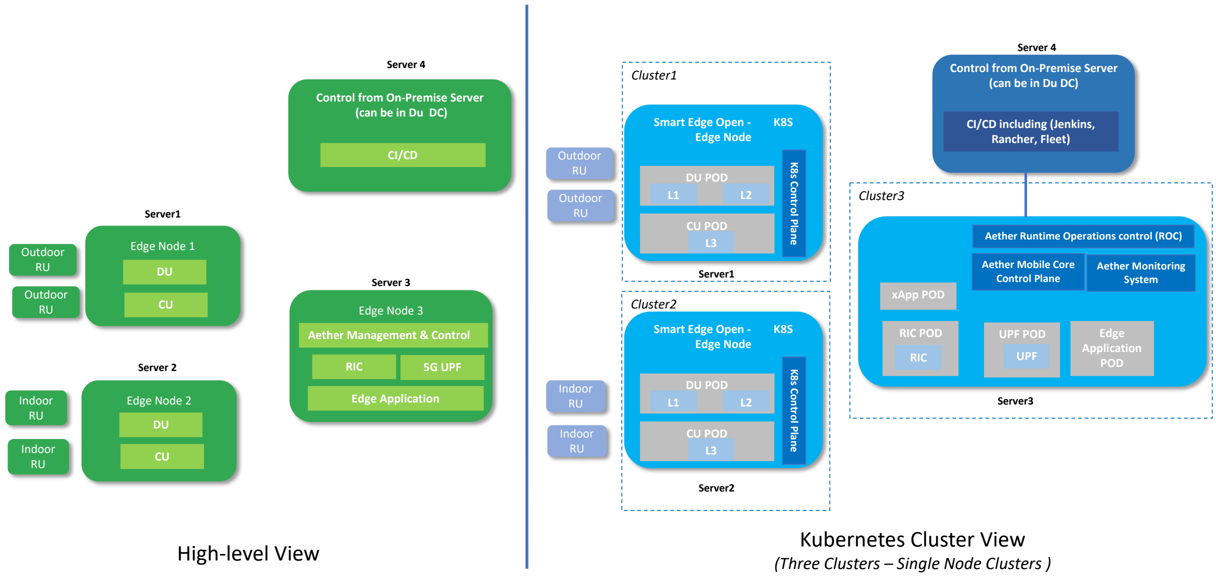

Figure 9: GCC 5G SA Private Network Lab Architecture

4.3 Partners and Objectives

The following partners will be part of the open 5G SA private network with ORAN Lab.

Figure 10: Open Private 5G Lab Partners

The objective of this lab will be as follows:

- Revolution towards Operator cost-effective private 5G network deployment in including ORAN, opensource near-RT RIC, and opensource 5G SA core network.
- Edge AI services with private 5G deployment
- Industry collaboration for Edge infrastructure and applications deployment over 5G SA
- Establish an Open RAN ecosystem from different partners in the GCC region
- The lab will be hosted at du (UAE) and will be open to all GCC operators.

5 Executive Summary and Conclusion

The GCC Open RAN Consortium confirms the importance to deploy Open RAN across their footprint, providing an opportunity for traditional as well as new entrants RAN vendors to adopt open interfaces, software, and hardware to build more agile and flexible mobile networks in the 5G and 4G era. It brings the opportunity to new entrants to create value in RAN business through innovation, influencing the telco equipment business to become more competitive to support current requirements of telco and more importantly the future requirements (like 6G), and offering choices to mobile operators to achieve innovative solutions and cost efficiencies in RAN deployments.

In this whitepaper we elaborated on the detailed elements we identified forming the Open RAN deployment Challenges and Opportunities for Brownfield Mobile Network Operators.

We highlighted the current efforts done by the consortium members ranging from field trials, lab establishments, vendor interactions and organizations engagements to verify and explore the ecosystem and readiness, in addition to navigating through the variable Open RAN use cases.

We plan to continue our field and lab trials and establish/connecting further labs to accelerate the interworking and the Open RAN use cases developments and verification. In addition to working on setting and publishing our technical requirements which will address the challenges and opportunities discussed on this whitepaper.

It is a new era of operators’ alliance in the Middle East to accelerate the development of Open RAN to support diversifying strategic technology growth in the Gulf and gain an advantage with service catering to the local market requirements with faster time to market while focusing on introducing software capabilities that bring technologies like Artificial Intelligence (AI) and Machine Learning (ML) to the forefront. The implementation of Open RAN solutions supports flexibility and provides more innovation in managing the network for more efficient use cases and operations.

Appendix A *Open RAN Overview*

i. General

Historically RAN has undergone a series of developments in the network architecture. Starting from traditional RAN, centralized RAN (C-RAN), virtualized RAN (vRAN) and until the dawn of Open RAN. The first three were vendor lock-in, while Open RAN architecture provides openness and lays the foundation for 6G and future RAN.

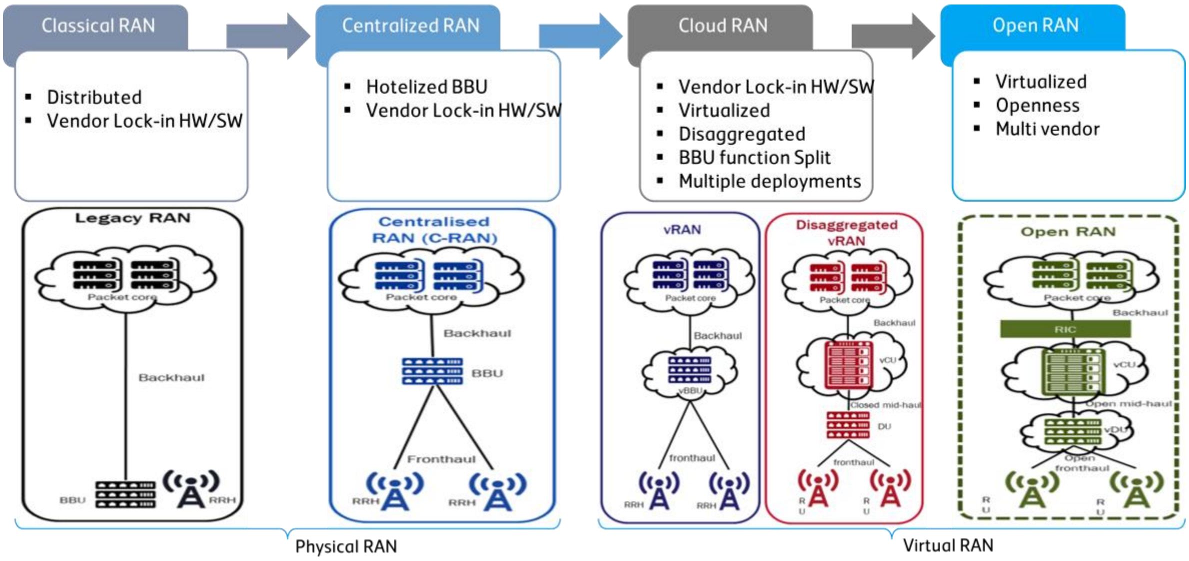

Figure 11: RAN Advancements in the Network Architecture

Source: [Analysys Mason]

Open RAN is an ongoing paradigm shift in mobile network architecture that allows MNOs to be built their network with multi-vendor ecosystem. MNOs are accustomed to traditional RAN over the decades hosted in their networks, where the RAN SW is installed on purpose-built hardware with proprietary interfaces towards the RRUs from the same vendor or supplier. Such setup leads to vendor locking reducing the flexibility of the multi-vendor ecosystem.

With Open RAN the industry is working towards standards and technical specifications that define open interfaces within the radio system, including hardware and software, so that networks can be deployed and operated based on mix-and-match components from different suppliers. Operators will be able to draw on the reinvigorated supplier innovation to drive cost efficiencies and more agile delivery of customized services in response to evolving customer demands. Each operator in the end will make its network design and cloud base configuration choices to align with its different business strategies.

There is a growing trend in the telecom industry towards open and virtualized technologies and infrastructures. A key use case is the adoption of Open RAN technologies and solutions, which is increasing gradually with the deployment of cloud native infrastructure, built on a foundation of IT hardware and infrastructure, standardized interfaces, and virtualized network elements. The 3GPP and O-RAN Alliance are working to standardize Open RAN technology including the architectures, functional split and open interfaces with the purpose to further supporting the adoption worldwide. They also define a set of functional splits between the distributed and central units of the RAN functions, which provide options for selection by operators depending on the deployment requirements and conditions.

The GCC operators believe that Open RAN development is rapidly accelerating towards a point of maturity with major performance enhancements and capabilities, in particular for LTE and 5G technologies and beyond. The transformation of radio access networks by Open RAN is driven by several technical aspects including:

1. Open interfaces supporting multi-vendor interworking RAN equipment
2. Disaggregation of RAN software from hardware through cloud-based virtualization of the RAN functions
3. Automation and optimization of RAN operations through intelligent controllers
4. Using COTS hardware and opensource cloud software to manage the underlaying infrastructure layer.

ii. Open Interfaces

Open RAN is characterized by open interfaces, which will allow for interworking between Telecom equipment and software in a multi-vendor environment. The O-RAN Alliance has specified several open interfaces to make possible a multi-vendor infrastructure deployment with interworking elements, such as the open fronthaul interface (the most critical to be supported) which will enable operators to select the most optimal radio units for their specific scenarios without vendor lock-in. The same is true for the CU/DU software – operators can select the most optimal (in terms of power, resource consumption, sizing, etc.) combination of SW/HW for their purposes, which will further drive competition and improve associated investments.

Open Interfaces allow operators to select hardware from variety of suppliers to mix and match during deployment. This gives operators wide options to choose among available options, specifications and eventually achieve optimized costs and timelines. O-RAN alliance defines the architecture that allows openness and fully supports and complements standards promoted by 3GPP and other standards organizations in the industry.

As per the O-RAN alliance defined Open interfaces, the Front haul plays an important role in interfacing with 3rd party RRUs. Other Open interfaces are E2 between near RT RIC and the CU followed by the A1 interface between the Non-RT RIC and near RT RIC. And the O1 & O2 interfaces from SMO towards E2 Nodes & the CLOUD platform play a key role in the E2E automation of RAN. Apart from the standard defined Open interfaces, standard APIs are in discussion (example tmforum) for interfacing the existing network elements.

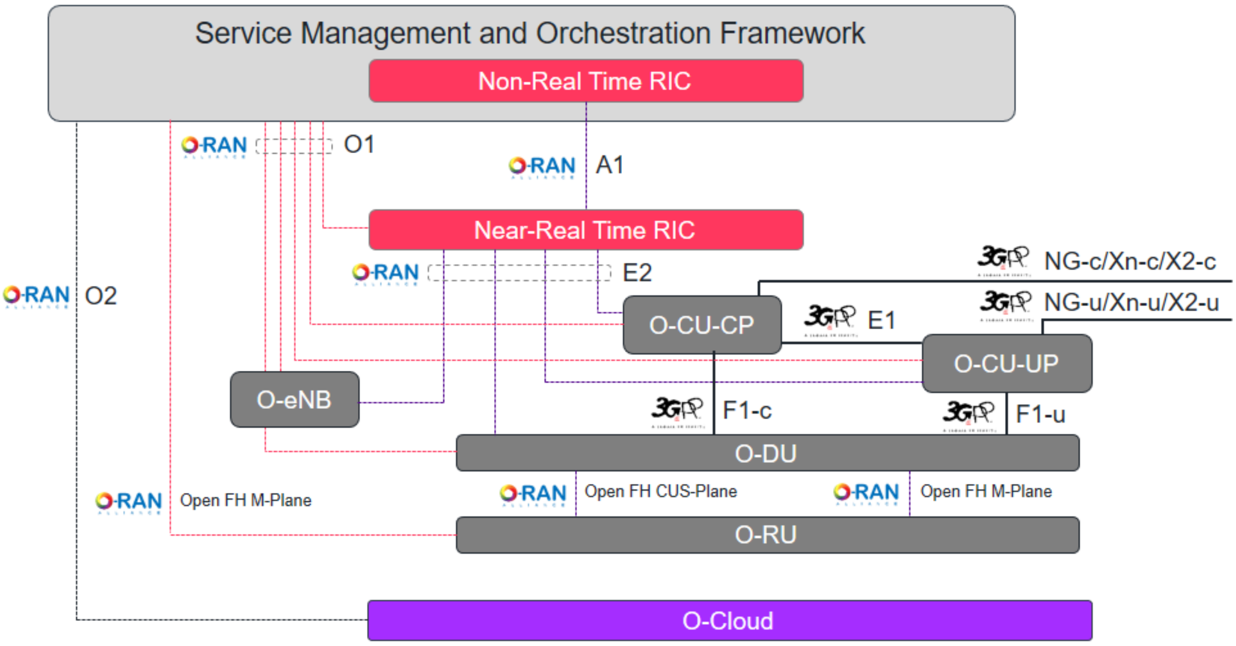

Figure 12: RAN interfaces –O-RAN alliance architecture.

iii. Virtualization

Open RAN is distinguished by virtualized RAN elements running on commercial off-the-shelf hardware, when compared with the dedicated network functions on purpose-built hardware. By separating the hardware from the software, many benefits can be realized, such as pure software updates to improve functionality, or using leading hardware infrastructure in the market immediately after release. This further results in less time-to-market for new solutions which rely on larger communities of open source and general-purpose developers.

Virtualization is defined as the decoupling of software from the hardware platform. Open Interfaces is about opening traditionally proprietary interfaces to allow multi-vendor deployment of hardware and software components. The convergence of these two technology trends creates new options for network deployment, enabling network innovation and optimization. The shift to mobile network virtualization first took with the service-based Architecture of the 5G SA core followed by RAN.

Virtualization involves the use of common hardware with specialized RAN functionality implemented in software (Virtualized RAN). This allows the baseband unit (BBU) to be implemented in software running on general-purpose hardware at a centralized Location (Centralized RAN), while the remote radio head (RRH) remains on the cell tower.

Benefits of Open and Virtualized RAN

- ✓ A diversified equipment ecosystem: It is important to bring new vendors into the ecosystem. Some of the existing vendors indicated an interest in providing open and virtualized RAN equipment, once it becomes possible to match the cost and performance of current integrated systems. Existing vendors may also benefit from open and virtualized RAN deployments as systems integrators or as providers of hardware and software. Open and virtualized RAN will help to optimize the investment needed to achieve connectivity targets.

- ✓ Faster innovation and reduced vendor lock-in: Open and virtualized networks use generic processor platforms, and the benefit comes from innovative software solutions and operations.
- ✓ Open interfaces expand the pool of suppliers from which operators can source hardware components, both RRH and BBU as well as the software components that allow for new feature introduction quicker.
- ✓ Support for customized networks: Key feature of 5G is its capacity to create customized/private 5G networks to deliver a distinctive connectivity requirement.

iv. Intelligence

Intelligence and automation in RAN are two critical parts to have end to end fully virtual and automated network. As part of the O-RAN alliance specification, Radio intelligent controllers Real-time and non-Real time with X-App and r-Apps which incorporate the Artificial intelligence and Machine Learning models in conjunction with Service and management orchestration. Network slicing leverages the automation at RAN and transport layer to spin up E2E slices. The SMO/RIC integrated with northbound nodes like E2E SO & Global orchestrator would make the network fully intelligent & automated. Moreover, complete network nodes as CNFs hosted on Cloud-native platforms support the automation.

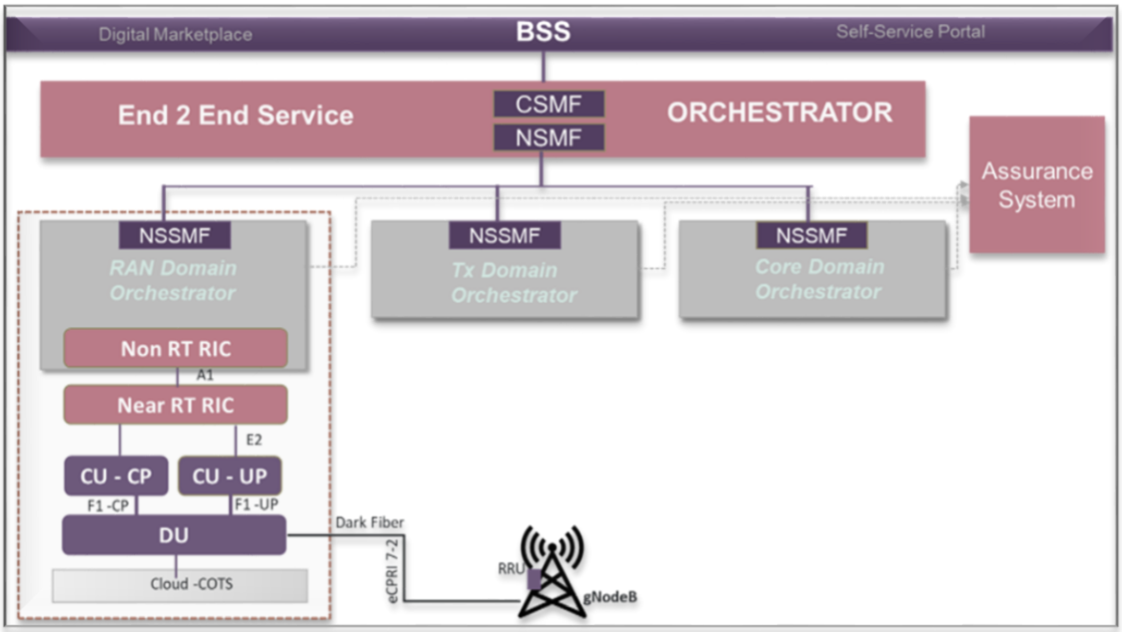

Figure 13: Open RAN Intelligence and Automation Components