WHITE PAPER

Nokia Open RAN Industry and Solution Update

Nokia's commitment to the Open RAN vision

Nokia anyRAN is a revolutionary approach that provides Communications Service Providers (CSPs) and Enterprises with industry-leading flexibility and the widest choice of strategic options for migrating between purpose-built RAN, Cloud RAN, and hybrid RAN solutions. All these solutions can also support Open RAN (O-RAN) using a common Nokia RAN software that provides feature and performance consistency across any selected deployment.

In this white paper, we primarily focus on all aspects of horizontal disaggregation, specifically O-RAN Open Fronthaul, in radio access networks. While we include aspects of vertical disaggregation, please also refer to our upcoming Cloud RAN Industry and Solution Update for more details.

Nokia has demonstrated a long-standing commitment to making the O-RAN vision a commercial reality, starting with having made more contributions than any other company to the O-RAN Alliance:

- As the pre-eminent, long-term tier-1 advocate of an O-RAN ecosystem, Nokia drove the adoption of the evolved Common Public Radio Interface (eCPRI) based 7-2x fronthaul interface between the Open Radio Unit (O-RU) and the Open Distributed Unit (O-DU) as a basis for connecting radio and baseband units of different suppliers.
- Nokia strongly supported the recent Uplink Performance Improvement (ULPI) specifications.
- Nokia continues to co-chair the O-RAN Alliance's technical Work Group 4 (WG4), which focuses on creating the specifications for Open Fronthaul interfaces.
- Similarly, Nokia co-chairs the WG3, which covers the near real-time RAN Intelligent Controller (RIC) and associated E2 interface, as well as the WG10, which covers the O-RAN specifications related to Operation and Maintenance.

Within the O-RAN Alliance specifications, the Open Fronthaul (O-FH) interface is usually considered the most attractive to CSPs, as it provides them with the flexibility to mix and match baseband and radio unit (RU) suppliers. A CSP might choose to do this for a variety of reasons, such as product availability for low volume/niche spectrum support, performance, form factor, price, or local supply.

Adopting O-RAN specified fronthaul interfaces can provide technology benefits whether the radio and baseband are from the same supplier or from different suppliers. However, the O-RAN vision is clearly to enable true multi-supplier deployments.

Nokia recognizes the importance of supplier diversity for CSPs and continues to successfully collaborate with multiple RU suppliers, including the publicly announced integrations with Fujitsu, Mavenir and Samji, as well as with two other companies. Some of these third-party O-RUs are already being commercially deployed and proven in combination with Nokia's purpose-built AirScale baseband in large-scale CSP networks, such as Deutsche Telekom in Germany and NTT DOCOMO in Japan.

Some industry suppliers claim O-RAN leadership on paper, including that they might provide O-RAN compliant interfaces between their own products at some point. This has yet to be proven by any actual multi-supplier O-RAN deployment in a live network. Similarly, this has not been backed by a clear commitment to software feature and performance parity between Cloud RAN and purpose-built RAN. It remains to be seen if or when this will be observable with these suppliers.

By contrast, Nokia has been driving multi-supplier O-RAN implementations in networks, in close cooperation with several CSPs. In addition, in December 2023, Nokia established an advanced O-RAN system in its Dallas Integration Center, whereby O-RUs from three different suppliers were all simultaneously connected to Nokia's O-DU. Nokia demonstrated peak speeds of 1.8 Gbps on this multi-supplier integrated system, by combining four FDD/TDD carriers together with Carrier Aggregation on commercial smartphones. This is real O-RAN in action.

O-RAN Alliance fronthaul evolution

As O-RAN fronthaul interface specifications are evolving, more functionality is being pushed from the baseband into the radio units, to handle advanced capabilities. For complex Massive MIMO (mMIMO) radios, in particular, this improves radio performance while reducing the required number of fronthaul fibers, thereby enabling overall site implementation savings.

Figure 1 illustrates the evolution of the eCPRI 7-2x fronthaul interface options and related enhancements.

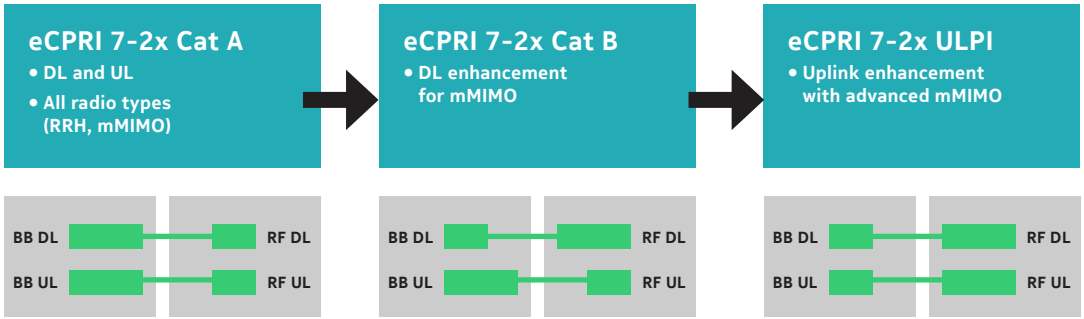


Figure 1. The eCPRI 7-2x fronthaul interface options

Typically, the initial step in a CSP's strategy is to start the O-RAN rollout in geographies and/or frequency bands where O-RUs provide a suitable deployment option, usually starting with non-Massive MIMO. In this type of deployment, the O-RAN fronthaul eCPRI 7-2x Cat-A option has been the ideal solution as it minimizes the complexity and cost in the radio unit, and the fronthaul interface data rate is low enough that only a single fiber is needed.

Massive MIMO can be introduced as the next step. There is a direct correlation between Massive MIMO performance with beamforming and the level of integration complexity required. The beamforming schemes that provide the best performance, such as Sounding Reference Signal (SRS) based beamforming, require a certain level of R&D integration and knowledge exchange between the O-DU and O-RU suppliers.

The O-RAN Alliance took steps to enhance downlink Massive MIMO performance by introducing the eCPRI 7-2x Cat-B option, which essentially moves downlink precoding functions from the baseband into the Massive MIMO RU. This also allows us to reduce the number of fronthaul fibers needed in high-capacity use cases. The uplink for eCPRI 7-2x Cat-B remained the same as with Cat-A.

Most recently, it was investigated and agreed between O-RAN Alliance members that additional changes regarding the positioning of selected uplink functions would help achieve higher Massive MIMO uplink performance, especially for advanced receivers and high-order MIMO. This uplink performance improvement is known as eCPRI 7-2x ULPI.

Simulations conducted by Nokia suggest that the resulting performance gains can be significant. This new uplink functional split will reduce the required number of fronthaul fibers by approximately 50 percent in the case of multi-branch receivers. These improvements were agreed upon during 2023 and have been added to the O-RAN fronthaul specifications in early 2024.

Commitment to O-RAN uplink performance improvements (ULPI)

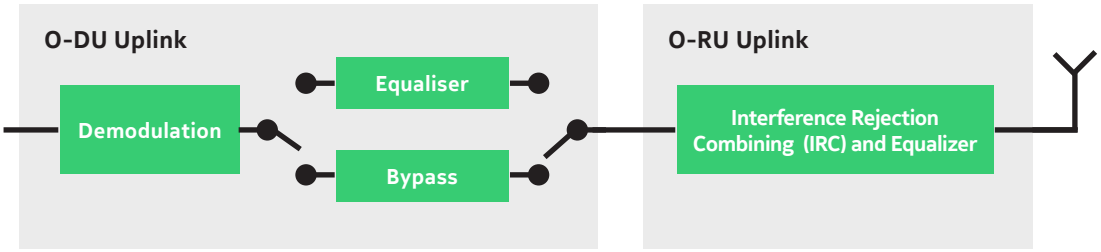
The O-RAN Alliance has defined two alternatives for uplink performance improvements:

- UL with equalization in the O-RU (the EQ option)
- UL without equalization in the O-RU (the NEQ option).

In both ULPI options, Channel Estimation and Interference Rejection Combining (IRC) are moved from the baseband into the Massive MIMO radios. The difference between the two ULPI alternatives is that with the EQ option, the Equalization function is handled within the Massive MIMO radio, and the baseband equalizer is bypassed, while with the NEQ alternative, the Equalization is handled within the baseband.

Figure 2 illustrates the distribution of functions in the two ULPI options.

ULPI EQ



ULPI NEQ

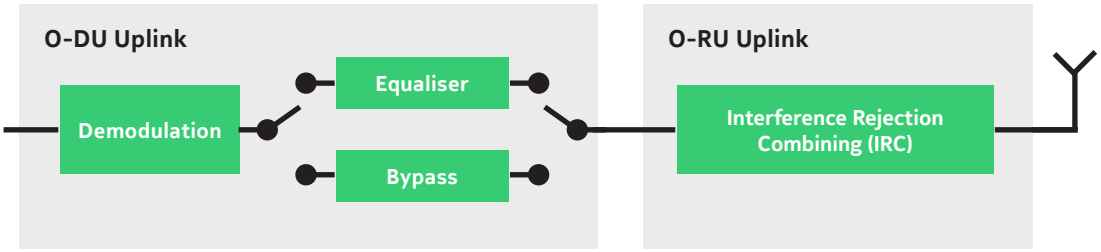


Figure 2. Comparison of the two O-RAN Fronthaul ULPI options

It is important to note that the O-RAN specifications require the Distributed Unit (O-DU) of the baseband to support both ULPI alternatives whilst the Massive MIMO radios can support either the EQ option or the NEQ option.

Nokia's AirScale baseband and Nokia Cloud RAN are designed to fully comply with these O-RAN requirements and have the capability to support ***both*** ULPI alternatives. This is an important contributor to the openness of the solution so that all supplier Massive MIMO radios, whether simple or more advanced, can be integrated with a given O-DU. When building their network evolution plans, operators should carefully select baseband suppliers who comply with ***both*** ULPI alternatives above.

Ensuring multi-supplier O-RAN fronthaul integration

The adoption of O-RAN fronthaul is not only dependent on eCPRI 7-2x and ULPI developments by the involved O-DU and O-RU suppliers. Fronthaul interoperability 'profiles' also need to be aligned between suppliers to ensure an O-RAN based system can truly match the performance, robustness, energy efficiency, security, and resiliency of a purpose-built RAN system.

Nokia's experience from live O-RAN deployments has demonstrated that this is not a one-off exercise. Rather, the key to success has been strong cooperation between the O-DU and O-RU suppliers, from extensive initial integration testing to continuous testing and support whenever new software capabilities are introduced into the network. In successful O-RAN deployment cases so far, a key success factor has been to clearly identify the primary solution integrator. Frequently, this has been the O-DU supplier who takes responsibility for planning and leading these activities.

The O-RAN Alliance Interoperability Test Specifications detail numerous interoperability profiles associated with Fronthaul Management, Synchronization, Control and User Planes. These profiles reflect various configurations in the RUs and fronthaul interfaces, such as TDD DL:UL configurations, Carrier Bandwidths, Physical Random Access Channel (PRACH) formats, Duplex type, MIMO streams, and more.

Figure 3 details how some selected Nokia customer projects differ from one another, including who takes the prime solution integrator role, which always comes with the accountability for delivering the overall RAN system and for the resulting end-to-end live network performance.

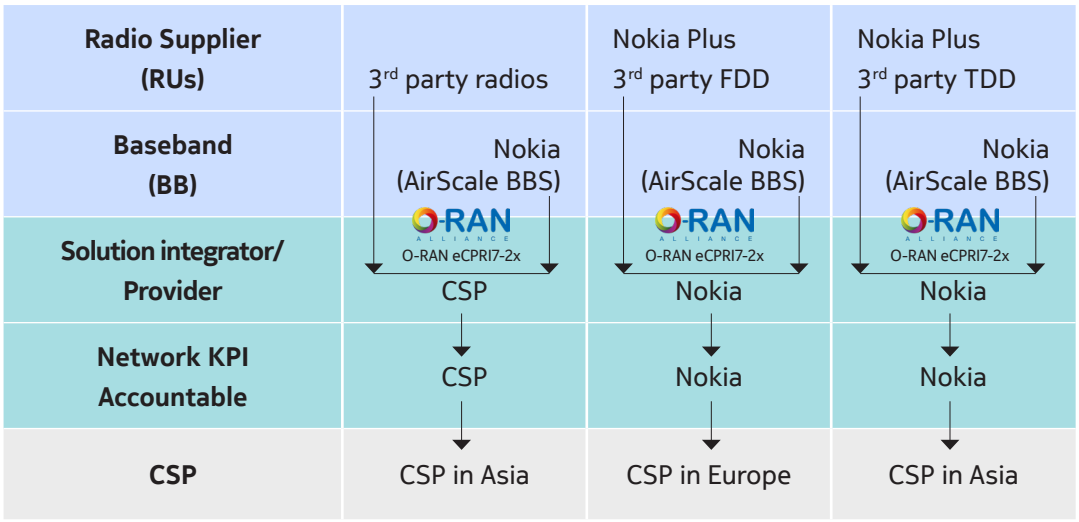


Figure 3. Radio and baseband supplier, solution integrator and CSP roles in Nokia projects

Nokia supports the O-RAN Alliance Open Testing and Integration Centers (OTIC) and has, in addition, invested in its own collaboration and testing centers located in Dallas, USA, and Ulm, Germany. These centers exist to support technology partnerships among O-RAN suppliers, specifically the introduction, verification, and launch of O-RAN and Cloud RAN compliant solutions.

Typical activities include the testing of Open Fronthaul and intelligent O-RAN applications or xApps. Examples of the tested applications include Cloud Gaming, energy-saving solutions, Cell Anomaly Detection, and Advanced Traffic Steering.

These activities are complemented by Nokia's active participation in many of the O-RAN Alliance 'Plug Fests', in which suppliers can benchmark and validate their O-RAN solutions for interoperability and performance.

Nokia's phased introduction of O-RAN and Cloud RAN capabilities

Given that O-RAN specifications have matured well in the past years, multiple CSPs are engaging with Nokia to understand the benefits and potential challenges of an O-RAN solution. Some are even considering the near-term introduction of O-RAN Fronthaul solutions combined with Cloud RAN (aka. virtualized RAN) to introduce both vertical and horizontal disaggregation in parallel – two significant architecture changes in a CSP network at the same time.

Nokia is prepared that different CSPs will deploy different flavors of O-RAN. Some CSPs will deploy Open Fronthaul without Cloud RAN whereas other CSPs will deploy Cloud RAN without Open Fronthaul. Most networks will eventually become hybrid RAN networks with the coexistence of Cloud RAN and purpose-built RAN using various O-RU options in different geographies and/or frequency layers.

The flexible Nokia anyRAN approach covers all these scenarios, enabling feature and performance parity and ensuring a superior mobile user experience across all types of RAN environments.

Nokia has started early on its phased approach to introducing O-RAN and Cloud RAN capabilities in its products and software, which has been key to maximizing the benefits of each step while maintaining network performance and securing the best experience for end customers.

The following figure illustrates a phased approach for a CSP with a 'brownfield network' that considers the deployment of both O-RAN and Cloud RAN in the coming years.

Figure 4. A phased approach to O-RAN and Cloud RAN, supported by Nokia roadmaps

Nokia has developed its RAN solution following the principle of 'built-in O-RAN capability'. Nokia's widely deployed purpose-built AirScale baseband already supports O-RAN interfaces and is in commercial use with other suppliers' O-RUs in customer networks, utilizing the eCPRI 7-2x Cat-A fronthaul interface.

Similar O-RU support will be available on Nokia's Cloud RAN baseband in 2025. Nokia not only supplies the most critical parts of the Cloud RAN solution but also delivers best-in-class capabilities when it comes to real-time complex systems integration. Nokia's Cloud RAN vision brings together several suppliers into a single RAN solution, for example, the blueprint solution includes Nokia Baseband Software + Dell/HP Compute Hardware + RedHat Container as a Service (CaaS) + Radio Units from multiple suppliers.

As a next step, Nokia will include the capability to connect Massive MIMO O-RU to Nokia's purpose-built and Cloud RAN baseband, utilizing eCPRI 7-2x ULPI and Cat-B downlink. For use cases that require remote radio heads, the Nokia AirScale Pandion radios have O-RAN eCPRI 7-2x Cat-A capability and software development is ongoing. For Massive MIMO use cases, the plans for Nokia AirScale Habrok radios include O-RAN eCPRI 7-2x ULPI uplink and Cat-B downlink support.

O-RAN Network Management and SMO considerations

The O-RAN Alliance has defined the Service Management and Orchestration (SMO) framework as an open platform to manage a multi-supplier, multi-technology RAN. The SMO framework aims to provide CSPs with intelligent service agility, automation, and operational efficiency as networks are becoming increasingly complex and requirements for on-demand services are surging.

The SMO framework should finally be able to support the RAN fault, configuration, accounting, and performance management (FCAPS) model through the O-RAN defined O1 interface between the management entities and the managed elements. It should also support Cloud RAN orchestration with virtualized Network Function Orchestration (NFO) and Federated O-Cloud Orchestration and Management (FOCOM) through the O-RAN defined O2 interface.

The Nokia MantaRay portfolio suite will be extended to support three main components of the SMO framework: 1) Network Management, 2) Non-real-time RIC and 3) Orchestration. This framework will support a range of functionalities, including a non-real-time (non-RT) RAN Intelligent Controller (RIC) with associated rApps, which enables innovative capabilities across the network.

MantaRay Network Management (NM) functionality and architecture are continuously evolving to support the management and optimization of today's networks while seamlessly enabling O-RAN capabilities. MantaRay NM will include SMO O1, O2 and A1 protocols over time. Besides support for the SMO and O1 interface, Nokia will continue to support the interface from RAN network functions towards the Nokia NM platform. This enables a low-cost introduction of O-RAN and provides support for any business logic and services that are not yet supported in an O-RAN SMO solution.

Multi-supplier operations become even more important as networks evolve. Nokia MantaRay SON, the Self-Organizing Networks solution, which is already deployed in more than 120 commercial CSP networks, combines true multi-supplier support with extensive capabilities. There will be steady migration from MantaRay SON with the porting of existing cSON modules to non-RT RIC rApps, which connect with the non-RT RIC within the SMO framework over the R1 interface. For orchestration capabilities, our SMO leverages Nokia Cloud and Network Services Orchestration. Figure 5 illustrates the SMO framework.

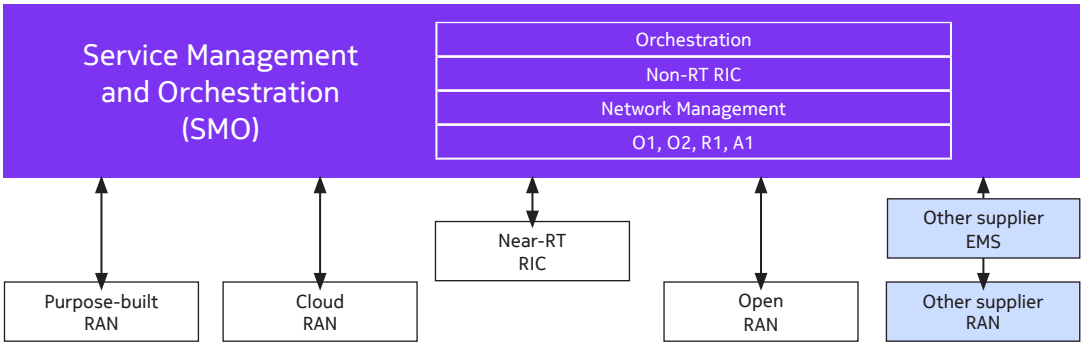


Figure 5. The Service Management and Orchestration framework

Conclusions

Nokia is leading the industry in making the O-RAN vision towards commercial horizontal and vertical disaggregation a reality. We are committed to continued investments in O-RAN Alliance WG stewardship, technical contributions, testing facilities, Plug Fest support, product implementations and successful integration with multiple O-RAN suppliers.

The Nokia anyRAN approach delivers maximum flexibility, maximum openness, and maximum performance while at the same time optimizing cost, including the reuse of existing infrastructure investments. It supports any purpose-built, Cloud RAN, hybrid, and O-RAN environment with common software, thereby delivering feature parity across a full commercial footprint.

The final target architecture for many CSPs will be Cloud RAN combined with Open Fronthaul, introducing both vertical and horizontal disaggregation. Nokia has been investing heavily to make this vision into a reality for CSPs and enterprises.

For example, Nokia started by introducing Open Fronthaul with its purpose-built baseband solution. This can in parallel connect to Nokia RU's (single supplier O-RAN) and third-party RU (multi-supplier O-RAN) using an O-RAN eCPRI 7-2x fronthaul. Upcoming steps during 2024-2025 include the introduction of commercial Cloud RAN and the addition of O-RAN Massive MIMO radio units. In every step, we ensure that an O-RAN based system can truly match the performance, robustness, energy efficiency, security, and resiliency of a purpose-built RAN system.

While other suppliers claim theoretical O-RAN leadership by suggesting that they might provide O-RAN compliant interfaces between their own products at some point, those suppliers have not engaged in multi-supplier O-RAN integration in a live network or made commitments to feature and performance parity.

Nokia supports a multi-supplier approach in both the vertical and horizontal layers. This approach will ensure that CSPs have the flexibility to select the most suitable and appropriate partner, promote competition, enhance innovation, and avoid supplier lock-in.

Nokia has been working closely with several CSPs in commercial multi-supplier O-RAN implementations with a clear O-RAN roadmap, including a clear commitment to a Cloud RAN based O-RAN solution. This plan is available upon request as part of detailed O-RAN planning discussions.

Visit the Nokia Open RAN webpage to learn more.

Glossary

BB	Baseband
CSP	Communications Service Provider
DL	Downlink
eCPRI	Evolved Common Public Radio Interface
EMS	Element Management System
EQ	Equalization is handled in the O-RU
FCAPS	Fault, Configuration and Performance Management
FDD	Frequency Division Duplex
FOCOM	Federated O-Cloud Orchestration
IRC	Interference Rejection Combining
MIMO	Multiple Input Multiple Output
mMIMO	Massive MIMO
NEQ	Equalization is not handled in the O-RU
NFO	Network Function Orchestration
NSMF	Network Slice Management Function
O-DU	Open Distributed Unit
O-FH	Open Fronthaul
O-RAN	Open Radio Access Network
O-RRH	Open Remote Radio Head
O-RU	Open Radio Unit
OTIC	Open Testing and Integration Center
PRACH	Physical Random Access Channel
RAN	Radio Access Network
RIC	RAN Intelligent Controller
RRH	Remote Radio Head
SMO	Service Management and Orchestration
SoC	System-on-Chip
SRS	Sounding Reference Signal
TDD	Time Division Duplex
UL	Uplink
ULPI	Uplink Performance Improvement
WG	Work Group

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At Nokia, we create technology that helps the world act together.

As a B2B technology innovation leader, we are pioneering the future where networks meet cloud to realize the full potential of digital in every industry.

Through networks that sense, think and act, we work with our customers and partners to create the digital services and applications of the future.