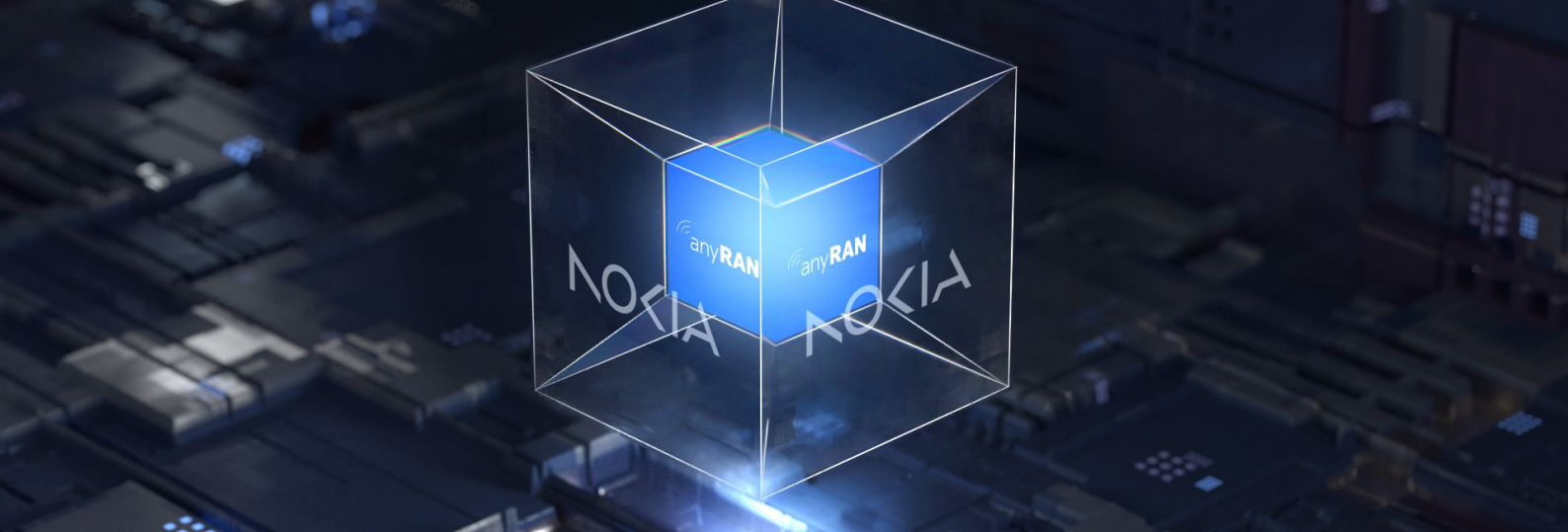


EXECUTIVE SUMMARY

Nokia Cloud RAN and Open RAN Solution Roadmap



NOKIA



Nokia anyRAN solution

Future Radio Access Networks (RAN) are expected to gradually evolve towards Cloud RAN based solutions, which will be mainly deployed alongside existing purpose-built RAN networks. The difference between Cloud RAN and purpose-built RAN is in the so-called baseband computing, consisting of the Distributed Unit (DU) and the Centralized Unit (CU), whereby the Radio Units (RU) are the same for Cloud RAN and purpose-built RAN.

In Cloud RAN, the vertical disaggregation of the baseband allows the abstraction of the CU and DU software from the underlying hardware and hence enables the use of commercial off-the-shelf (COTS) server hardware. Cloud-native CU and DU software and Containers-as-a-Service (CaaS) software together with COTS hardware are expected to bring typical cloud computing benefits.

Given there are few greenfield networks in the world that can be built from a clean slate based on Cloud RAN technology, the majority of Communication Service Providers (CSPs) will have to choose whether to adopt a hybrid network approach, in which Cloud RAN will co-exist with purpose-built RAN for many years. This hybrid mobile network will evolve over time with Cloud RAN being introduced for specific use cases and/or geographies.

Nokia anyRAN is the industry-leading approach to ensure a consistent, high level of performance, energy efficiency, resiliency, and security across hybrid networks of Cloud RAN and purpose-built RAN, while at the same time providing flexibility of choice and coexistence between cloud infrastructure and computing hardware options.

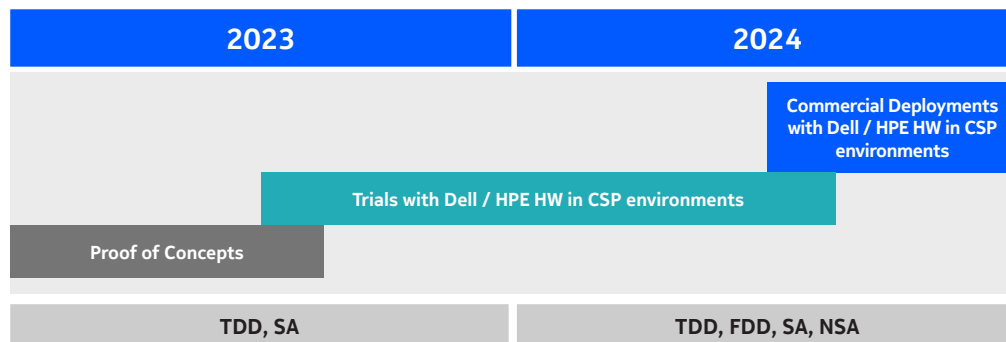
Following successful Nokia Cloud RAN trials in 2023, commercial deployments will start in 2024. Nokia will be delivering commercial Cloud RAN, including feature and performance parity with purpose-built RAN, from H2 2024 onwards.

Key Cloud RAN solution components

Nokia's Cloud RAN solution is built upon proven RAN software, which is running across millions of sites in commercial networks throughout the world.

The key components of Nokia's Cloud RAN solution are COTS server support, Cloud RAN SmartNIC for L1 acceleration, CaaS and network management. The following sections introduce each of these components in more detail.

Nokia Cloud RAN solution timeline



COTS server support and partnerships

Nokia is partnering closely with both Dell and HPE to develop server options for its Cloud RAN solution. The initial development focus was to integrate our Cloud RAN SmartNIC with each server supplier's hardware while ensuring its compatibility with each of the server suppliers' hardware management toolsets.

Nokia has already completed successful L3 calls with both Dell and HPE servers using Nokia's Cloud RAN SmartNIC solution. The first generation of Nokia's Cloud RAN SmartNIC is being used for R&D partner engagements and customer trials during 2023. Testing is ongoing in parallel with the Dell XR8620t server and the HPE DL110 Gen 11 server, both with the Intel-based 32-core Sapphire Rapids processor.

Nokia's next-generation Cloud RAN SmartNIC for L1 In-Line acceleration, which is available in 1H 2024, uses next-generation high-capacity System-on-Chip technology and is, therefore, the optimum platform for mass commercial deployment of Cloud RAN.

Depending on the specifics of the use case and deployment scenarios, additional server variants will be evaluated and added to the portfolio

L1 acceleration

Hardware acceleration technology is the critical element in Cloud RAN performance. The two primary options for implementing Cloud RAN acceleration are the so-called “Look-Aside” and “In-Line” architectures.

With a closer look, some so-called general-purpose CPUs promoted by some companies for Cloud RAN are actually not general-purpose CPUs. They are essentially “Cloud RAN – specific CPUs” with the overhead of hardware acceleration required by L1, integrated Look-Aside acceleration which is less efficient than inline acceleration.

After comprehensive evaluations of all available L1 acceleration options, Nokia concluded that there are clear advantages to using In-Line acceleration technology. These extend to enabling feature and performance parity with purpose-built RAN, higher capacity and connectivity, improved energy efficiency, lower comparable TCO, ease of integration into any server and cloud environment, and flexibility in choosing higher-layer processing computing architectures and associated server hardware providers without any supplier lock-in. It is important to note that leading server makers and hyperscalers came to the same conclusion.

Some tier-1 RAN suppliers have selected alternative approaches to L1 acceleration that rely on unnecessary L1/L2 software re-development and duplication across purpose-built RAN and Cloud RAN architectures. It will be a major challenge for them to achieve feature and performance parity between their purpose-built RAN and Cloud RAN offerings. This means that it will cause operational impossibilities for CSPs to run the two models in coexistence, for example in city-center and suburban geographies.

To realize its goal of delivering industry-leading Cloud RAN, Nokia therefore selected and has since developed a Cloud RAN SmartNIC for L1 In-Line acceleration. This solution guarantees:

- **Feature and performance parity:** Based on common System-on-Chip technology, co-created by Nokia and Marvell, for Cloud RAN and purpose-built RAN, enabling feature and performance parity in hybrid networks from day 1.
- **Scalability:** L1 capacity can be matched to the CPU (GPP) capacity by adding SmartNICs independently from the CPUs (GPPs) that are processing L2/L3. With multiple SmartNIC cards on a single COTS server, the Nokia Cloud RAN solution offers higher cell capacity per server for Distributed and Centralized Cloud RAN scenarios.

- **Energy efficiency:** Superior power efficiency per cell, thus bringing savings with server energy consumption and site cooling, especially in high-capacity configurations.
- **Solution flexibility:** A simplified architecture with a clean L1-L2 interface also supported by the O-RAN Alliance. Cloud RAN SmartNICs use the PCIe interface offering ease of integration to all compute and cloud platforms, with the optionality of x86 or ARM processors for L2 and L3 processing. This provides optimal overall solution design and compute supplier flexibility. ARM-based computing might be key to evolving artificial intelligence in the mobile networks of the future.

Nokia is sure that the various deployment preferences and performance expectations of CSPs and enterprises will, therefore, be fulfilled by its Cloud RAN architecture.

CaaS layer and CaaS management

Nokia Cloud RAN solution is designed to work on any CaaS cloud infrastructure layer by leveraging open-source software whenever possible. Nokia's Cloud RAN reference implementations currently use Red Hat OpenShift Cloud Platform (OCP).

Nokia will finally support a variety of CaaS options, each of which will require some specific integration and testing. Nokia is already partnering with Amazon Web Services, Google, IBM and Microsoft to integrate Nokia Cloud RAN with their respective infrastructures. This allows CSPs and enterprises with specific requirements or preferences in cloud infrastructure to leverage the resulting CaaS layer synergies. Unlike some RAN suppliers using proprietary approaches with their own CaaS, Nokia will focus on working with third-party CaaS providers.

CaaS management is essential for the operational efficiency of Cloud RAN. The specific requirements of Cloud RAN differ from other workloads. Nokia optionally provides RAN-specific lifecycle and configuration management tools, which complement the general-purpose CaaS management solutions provided by the cloud infrastructure suppliers.

Nokia MantaRay solution portfolio simplifies hybrid network management, by handling overall network management, optimization and automation for both purpose-built RAN and Cloud RAN. This is a guarantee of simplified and efficient operations of Cloud RAN and purpose-built RAN, which will in practice coexist in networks for multiple years.

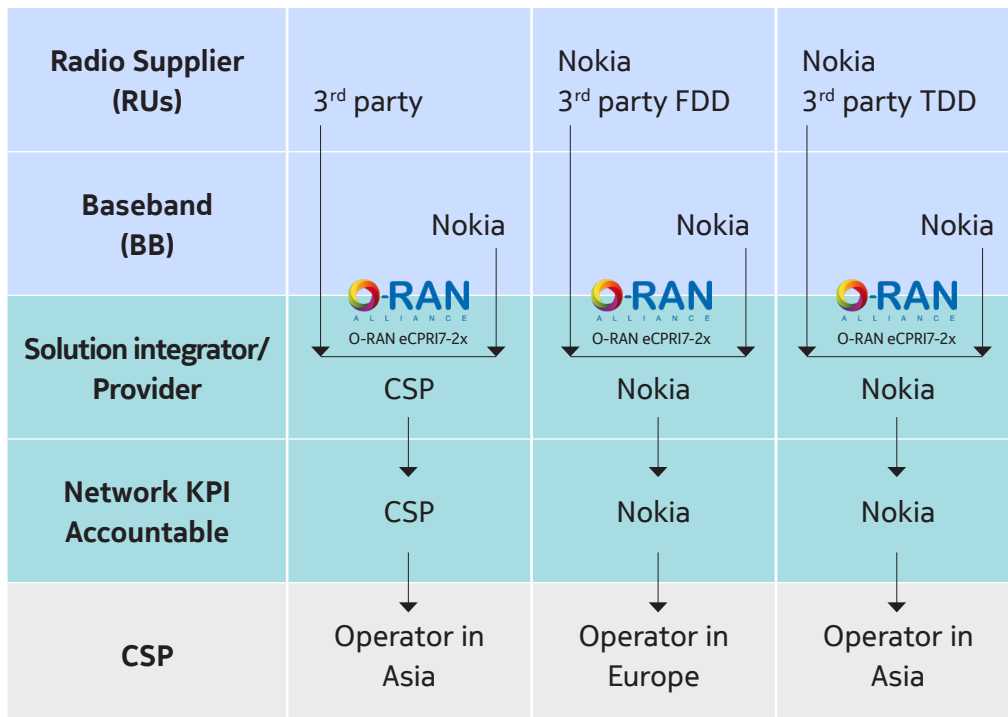
Open RAN, specifically Open Fronthaul

Whereas Cloud RAN introduces the vertical disaggregation of the RAN baseband software from purpose-built baseband processing hardware, Open RAN represents the other dimension of disaggregation, splitting a base station horizontally into three parts: the RU, DU and CU, where the DU and CU are the baseband functions.

The most typical Open RAN deployment scenarios are today focused on Open Fronthaul (the interface between RU and DU) for specific geographies or use cases.

Nokia has continuously demonstrated our commitment to making Open RAN a commercial reality, by making more contributions than any other company to the O-RAN alliance, and specifically through the execution of commercial contracts with several CSPs that include Open Fronthaul with third-party radio suppliers.

The below graphic details how some selected Nokia customer projects differ from one another, including who takes the accountability for delivering the RAN system and for end-to-end network performance.



As in the case of Nokia Cloud RAN, we are developing the required Open Fronthaul (7.2x) features on top of our high-performance RAN software. This ensures that these new architectures can be deployed and co-exist with the existing purpose-built RAN networks without compromises in performance, security, resiliency and energy efficiency.

Nokia baseband solutions (initially purpose-built RAN and later Cloud RAN) are combined with both Nokia radios and third-party radios (for example, 4T4R RRHs, TDD or FDD) using Open RAN compliant eCPRI 7.2x interfaces. Support for third-party TDD radios is available in 2023 and for third-party FDD radios in 1H 2024.

In summary, Nokia has fulfilled essential pre-requisites and is fully committed to cooperating with CSPs and enterprises to fulfill their Open RAN objectives:

- Nokia AirScale Baseband is proven to be fully Open RAN capable and available today.
- As a baseband supplier, Nokia generally proposes to be the Open Fronthaul System Integrator (where required by CSPs or enterprises) to work with mutually agreed radio suppliers.
- Nokia has already integrated third-party TDD RRH from three suppliers with its Baseband, and the solution is available today. Nokia AirScale Baseband is qualified for commercial Open RAN deployments for both TDD RRH (FR1) and mmWave (FR2).
- Nokia is currently integrating third-party FDD RRH with its Baseband; pre-commercial later this year and Commercial in 1H 2024.
- Once these initial integrations are complete, it will be possible to support commercial Open RAN deployments with third-party FR1 TDD RRH or FDD RRH across any frequency bands.
- If any part of the millions of radios already present in commercial networks evolves to O-RAN compliant interfaces (as was recently claimed by another leading tier-1 RAN supplier), then integrating those radios with Nokia Baseband will also be possible. Nokia will engage with CSPs to better understand the use cases to support this.
- Nokia is working on integrating and testing Open Fronthaul with its Cloud RAN solutions with the plan to be ready for commercial deployments during 2025.

Conclusions

Nokia has improved its RAN competitiveness, grown its market share and improved its customer satisfaction scores constantly since 2020. According to Dell'Oro, Nokia has grown its 5G share by 6 percent points in the last 1.5 years. This is a direct result of Nokia's increased RAN R&D investment in its Mobile Networks Business Group resulting in improved competitiveness of its product technology.

Nokia is making strong, sincere, and detailed Cloud RAN and Open RAN commitments with demonstrated evidence of true progress in industrial implementation with CSPs and enterprises.

Nokia will continue to develop Cloud RAN and Open Fronthaul on top of our high-performance RAN software. This ensures that these new architectures can be deployed and co-exist with the existing purpose-built RAN networks without compromises in performance, security, resiliency and energy efficiency.

Nokia challenges other leading tier-1 RAN suppliers to be truly open and consistent by sharing clear details of their execution plans for Cloud RAN and Open RAN, rather than making conflicting commitments to various CSPs, and vague leadership claims in the press and social media.

Nokia OYJ
Karakaari 7
02610 Espoo
Finland

Tel. +358 (0) 10 44 88 000

CID: 213602

nokia.com

NOKIA

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.

Nokia is a registered trademark of Nokia Corporation. Other product and company names mentioned herein may be trademarks or trade names of their respective owners.

© 2023 Nokia