# Advancing connectivity

A Guide to OpenRAN Success

# Introduction

# O-RAN - what it is and why it is important

An '**Open Radio Access Network**', also known as an 'Open-RAN' or 'O-RAN' is an architecture for building Radio Access Networks (RANs) in the 5G era.

RANs are the part of the mobile network that connects everything. As the name suggests, Open-RAN uses standardized, interoperable, open interfaces, combined with AI, and virtualization, to allow multiple networking technologies to be stitched together to build a mobile network. This is in contrast to the traditional approach, where each network needed to be built by one company to be sure that its constituent parts could interoperate.

O-RAN offers several advantages compared with traditional RAN architectures. These include:

- **Lower total cost of ownership (TCO):** Opening the market to more vendors through interoperable standards increases the amount of available solutions - driving competition among vendors and pushing down prices.
- **Greater agility, flexibility and scalability:** O-RAN's modular architecture allows it to more easily add or remove components to a network, in order to quickly respond to demands and scale accordingly.
- **More and faster innovation:** Opening the network allows more innovative vendors and developers to enter and enrich the ecosystem, by offering new and/or improved solutions.
- **Improved performance:** A new technology - RAN Intelligent Controller (RIC) - which we will cover in more detail later - allows networks to make use of new features, like advanced algorithms that can better optimize the network to specific uses.
- **Improved automation and observability at scale:** Open interfaces will standardize telemetry, driving better observability across multiple vendors. Applications can be built that leverage this data to enable massive automation across thousands of sites.

In this paper, you will learn about the state of the art today in O-RAN – how it is being created, its recent breakthroughs, its major challenges, and how, through collaboration and technical ingenuity, these challenges may be overcome to realize the transformative benefits of this technology.

# The journey to O-RAN

# The long journey to O-RAN needs people to work together

Rome wasn't built in a day, as the saying goes. Nor was it the work of one person. Like any major project, it took time and the bringing together of many skills. The same is true of O-RANs, which are fundamentally different from any previous mobile generation.

We will start by looking at the evolution to date and the journey ahead of us, then discuss what we need to do to get there.

## The telco network is evolving: RAN to vRAN to O-RAN

Telco networks have evolved from switches and boxes to being increasingly software defined (see Figure 1 below). But they now face a dauntingly steep climb as they migrate from virtualized RANs (vRANs) to O-RANs.

### *RAN to vRAN…*

The journey started with disaggregating radio software and hardware. This allowed network functions to be 'virtualized' – ie controlled by software – usually run in the cloud – which in turn meant networks could use a wider variety of hardware, so long as it could communicate with the software. This brought network flexibility, better performance, coverage and quality of service.

### *…vRAN to O-RAN*

However, despite the flexibility, networks still tended to be built upon proprietary interfaces from a single vendor, creating 'vendor lock in' for hardware and software, and a lack of competition.

Open RAN solves this, allowing operators to combine hardware and software from multiple vendors, choosing the best performing or best value solutions for their specific network needs. The O-RAN Alliance (a worldwide community of mobile operators, vendors, and research & academic institutions) has set definitions for open interfaces, making interoperable cloud-native RAN a reality.

But that is not the end of the story. Like all cloud-native workloads, networks require massive intelligent automation at scale to realize their full potential, whilst also minimizing TCO (Total Cost of Ownership). This step up requires a collaborative effort by vendors, operators, and systems integrators, because no single company has all the necessary technologies and expertise to do it alone.

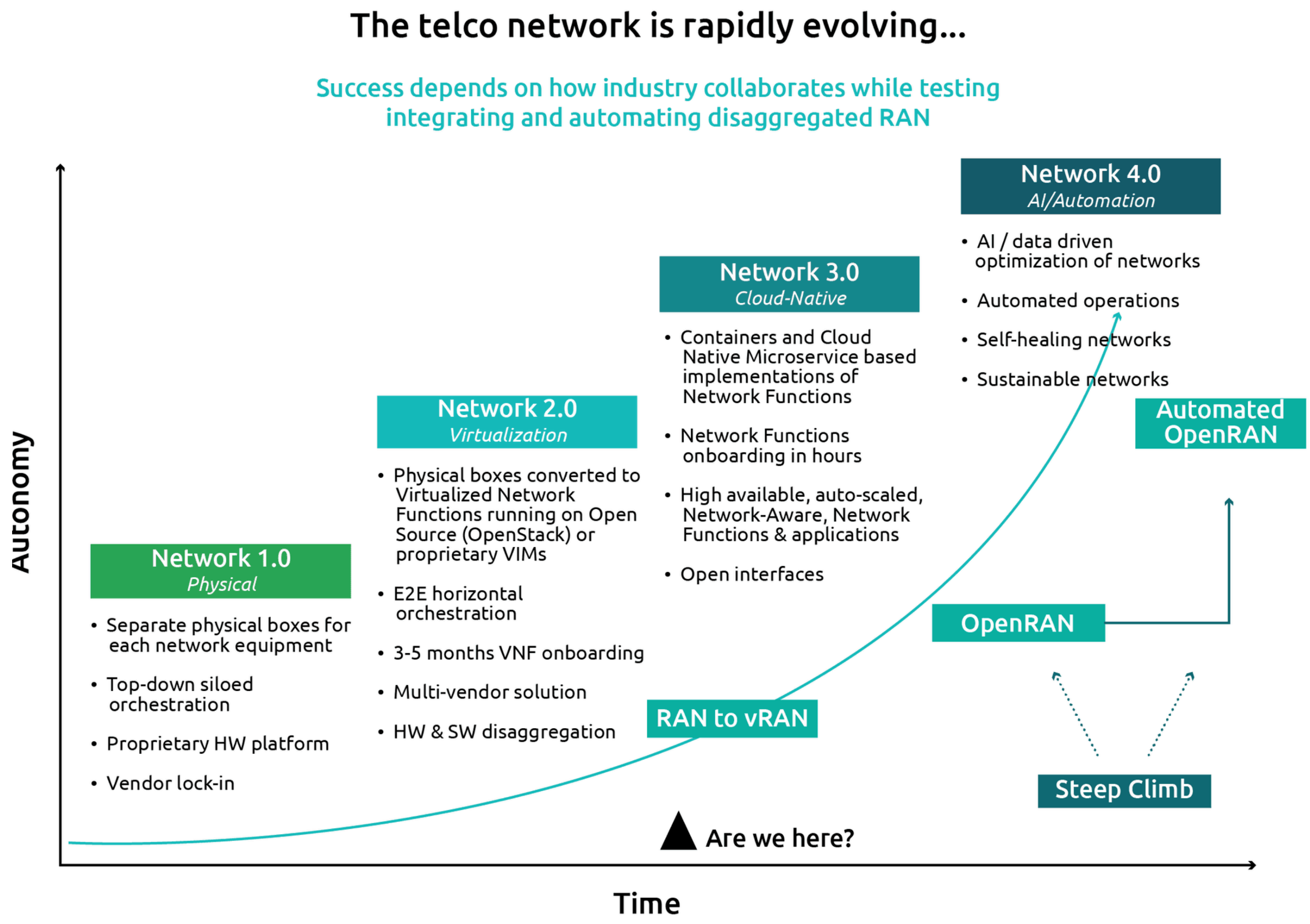



*Figure 1: telco network evolution*

## The many factors of making O-RAN work

So, what will it take to bring about O-RANs successfully? As an industry, we must work together to address six major focus areas in an integrated way:

1. **A cloud-centric architecture** for baseband software will enable the true benefits of a virtualized RAN in a cloud environment.

2. **Cloud-native edge compute** - edge compute is a type of network architecture that offers services at the edge of the network, increasing service quality and reducing latency. This cloud-native, real-time platform with carrier-grade resilience will provide reliable services for hosting virtualized or containerized RANs.

3. **Disaggregated O-RAN and cloud RAN -** RAN software operating separately - in the cloud - from the specialized hardware it used to run on, and instead running a variety of heterogeneous, interoperable hardware in an 'open' environment. Disaggregation will split the radio units from the baseband software. The software can be hosted on the network edge. Large scale automation, leveraging carrier-grade DevOps, will allow operators to manage radio networks at a reduced TCO.

4. **A data-driven autonomous network -** autonomy allows networks to respond to demands dynamically without human input - replacing manual tasks with intelligent machine learning that can learn to reconfigure the network better than a person can. This supports lower TCO, whilst allowing networks to be more agile and adaptable. Data collected from the open interfaces of the O-RAN/CloudRAN architecture can now be leveraged to develop machine learning models that will power autonomous RANs.

5. **A sustainable cloud-native network -** a system for operating the entire network and its services and functions in the cloud.

These focuses require broad industry collaboration to create the common standards, architecture and models that will be critical for test and automation.

## The challenges of interoperability

The main challenge to delivering all these different areas of focus is **interoperability** – ie the successful integration of many multi-vendor components.

In a traditional closed RAN, one vendor is responsible for all of the hardware, which it designs to work together according to its own clear standards. But, what has been described as "subtle ambiguity' in certain O-RAN standards can lead to variations in implementation between vendors that can cause compatibility problems. In the early stages at least, it is likely that the usual tasks; service orchestration, network management, and maintaining an inventory of spares, will be more challenging with multiple vendors.

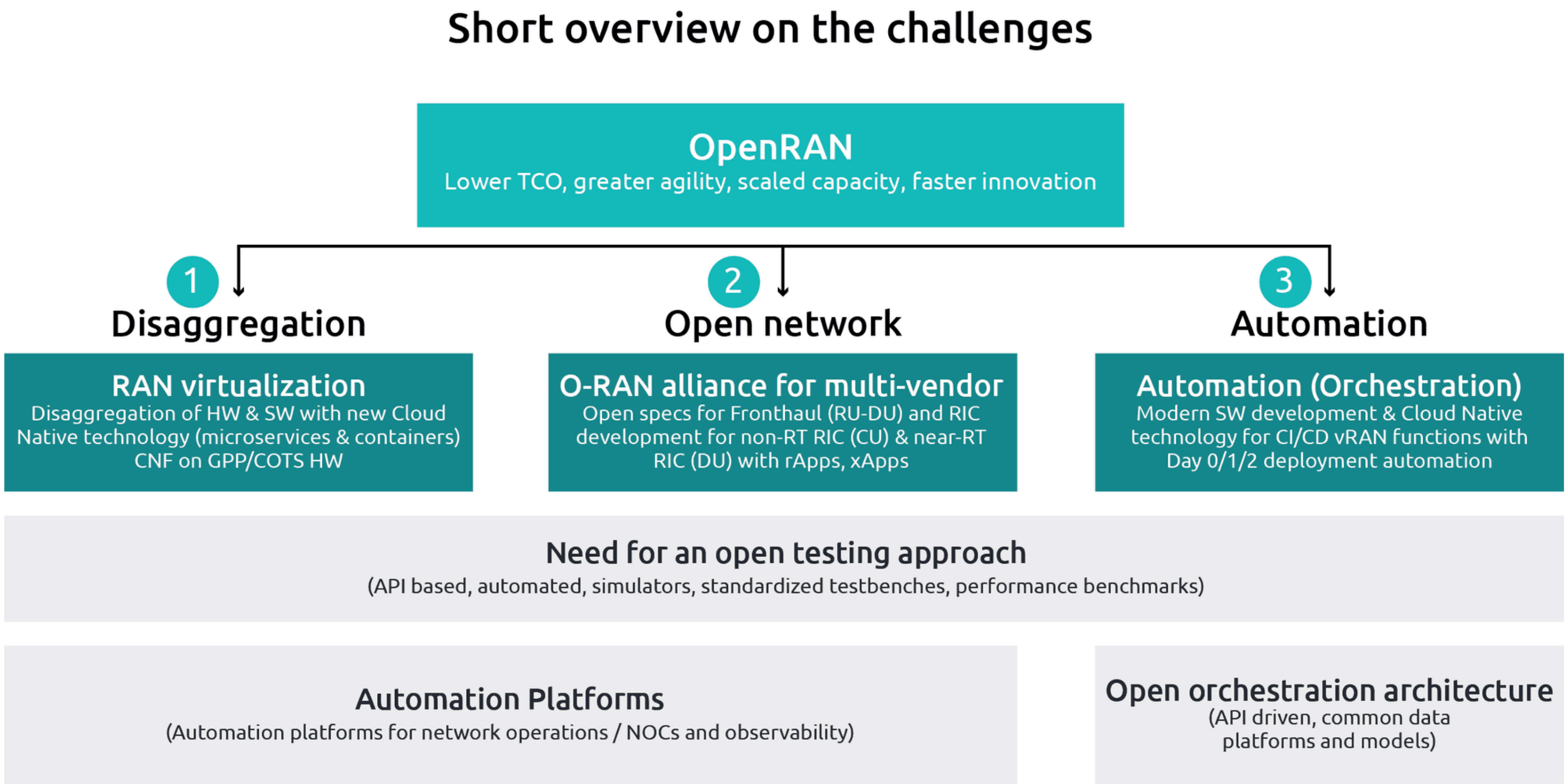



*Figure 2: a summary of OpenRAN's challenges*

## Three solutions to interoperability

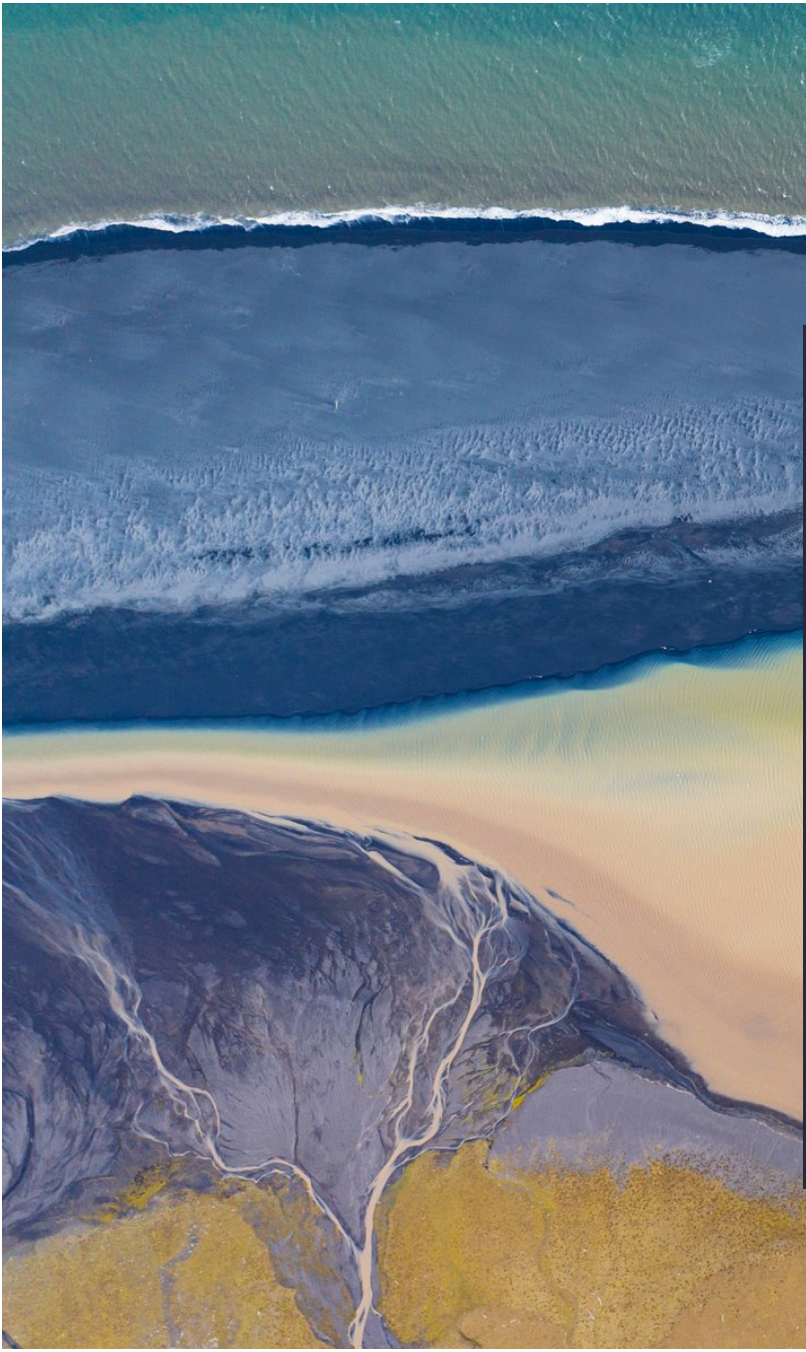
Currently, there are three major approaches that will help us succeed with O-RAN.

1. **An open approach to testing that spans all network domains.** This approach would be automated and API-based, with standardized test benches and performance benchmarks. Collaboration initiatives, like the i14y Lab, could also provide test tools such as robust 3GPP- and O-RAN-compliant simulators that can emulate Layer 1, user equipment or base stations.

2. **Standardized automation platforms for network operations.** These would automate both the network and the alerts that it generates. Besides providing the network operations center (NOC) staff with greater visibility, automation also would maximize their productivity and make the network more predictable, which aligns with one of O-RAN's major goals: a lower TCO than traditional networks can achieve.

   For example, automation can enable the use of digital twins for multiple RANs, where the NOC can access several configurations in real time, provide a simulated environment before deploying new configurations, reproduce faults and correlate events. Automation platforms require enormous amounts of data, so they can be trained to handle a wide variety of real-world scenarios. Industry collaboration labs (like i14y) can play an important role, by providing that data.

3. **An open orchestration architecture.** Driven by open APIs, this architecture would include common data platforms and models. The collected data also would be open, so developers can build use cases around it.



## Winning the NTIA 5G challenge

In 2022, the US National Telecommunications and Information Administration (NTIA) launched a 2-year '5G Challenge' program to foster a vibrant 5G O-RAN vendor community, hosted by the US Institute for Telecommunication Sciences (ITS).

In its first year, NTIA and ITS required the contestants to successfully integrate hardware and/or software solutions for one or more 5G network subsystems: Central Unit (CU), Distributed Unit (DU) and Radio Unit (RU). The Capgemini team competed in the Central Unit category, winning all three challenge stages.

In the 2023 5G Challenge, NTIA selected contestants with high-performing 5G subsystems that showcased multi-vendor interoperability across RUs and combined CUs and DUs (CU+DU). CableLabs hosted the challenge and provided two separate 5G test and emulation systems. The NTIA awarded Capgemini first place for Multi-Vendor E2E Integration. NTIA specifically applauded Capgemini for achieving a 100% pass rate on all feature and performance tests. At the closing ceremony, Capgemini was presented with two prizes: Multi-Vendor E2E Integration and Wrap-around testing for the Open RAN CU and DU.

# Automation

# O-RAN must automate - and fast

A key benefit of cloud native networks is the ability to automate the network, increasing efficiency and lowering the total cost of ownership. It is also a major challenge of O-RAN, as it requires many different technologies to work in harmony, like the conducting of an orchestra to deliver a piece of music that is more than the sum of its parts. Intelligent automation turns Open RAN from a resource-intensive challenge into a source of value. But much must be done for automation to reach its full potential.

## The benefits of O-RAN automation

First, why automate? Some of the benefits include:

- **The ability to deploy in multi-vendor RAN environments** consisting of complex multi-technology networks, where the automation platform can create the greatest operational impact.
- **Lower operational costs,** thanks to the automation of network deployment and network operation, leveraging new automation rApps and xApps (specialized software apps for network automation) deployed over O-RAN service management and orchestration (SMO).
- **The ease of harnessing proven operational models of legacy RAN applications,** by modernizing to cloud-native services on a nRT (near real time) and nRT RIC platform.
- **The ability to deploy RAN automation across multi-technology networks,** using design patterns in alignment with the O-RAN Alliance, also providing future-proof flexible automation across varying technology and vendors. The level of automation can also be adjusted in the network's constituent layers to varying degrees – for example, a high level of automation on RAN compute and connectivity infra, and a medium level in radio resource management.

Solving the riddle of efficient Open RAN automation is only the beginning. With reliable RAN, telcos can create new innovative services, like network slicing, to create customized networks for different applications and data needs, and open and closed loop service assurance.

## But, no one said Open RAN would be simple

Even a few years ago, the complexity of trying to link multiple software systems would have been unthinkable. Today, disaggregated RAN is not only possible – it provides a very real competitive edge. The problem is, Open RAN requires a level of intelligent automation that is difficult to build completely in-house.

Telcos know that they must move towards an automated and efficient network if they want to support agile service innovation and delivery on a competitive level. But at present, automation has only reached varying levels of maturity across the network span. For many telcos, RAN automation is still limited to discrete trials with small groups of vendors; it's mostly experimental, and its scalability remains unproven.

Radio networks are inherently complex. Add to that business requirements that mandate compatibility between new, next-gen networks and legacy technologies, and that complexity multiplies.

Operators find themselves facing two options: automation that's fairly easy to implement, but limited in scope, or automation that links entire networks, but must be custom built, which typically requires some help from outside software experts.

Add to that the steadily increasing number of sites, plus the need to keep software expenditures and OPEX in check, and that complexity becomes a serious obstacle.

5G generates a flood of data that – for all the reasons listed above – creates some very real challenges for operators. These data need to be classified and prioritized for effective network control and management to be possible.

The solution? Classic automation is not enough. Open RAN needs intelligent automation. This requires the RAN intelligent controller.

## Automation with the RAN intelligent controller (RIC)

The RIC is a software-defined component designed to optimize the Radio Access Network (RAN).

The RIC has an essential 5G network architecture element responsible for facilitating network intelligence, flexibility, and optimization. Separating control plane functions from the base station hardware and centralizing them in a software-defined and cloud-native environment greatly enhances the RAN’s capabilities.

The RIC addresses several challenges of deploying and operating 5G networks. These include:

## Network optimization:

5G networks introduce complex requirements, like high data rates, low latency, and massive device connectivity. RIC employs real-time network data collection, analytics, and optimization algorithms to optimize the network dynamically. It can intelligently allocate radio resources, manage interference, and adjust network parameters to ensure efficient resource utilization and optimal network performance.

## Intelligent traffic steering:

Efficient traffic steering has long been a challenge in wireless networks, and 3GPP and other organizations have proposed numerous solutions. The key challenge is that typical traffic steering schemes use the radio conditions of a cell by treating all users of that cell in the same way. Hence, these schemes can only adjust cell priorities and handover thresholds. RIC can handle traffic steering by adopting UE-centric strategies and ensuring proactive optimization, by predicting network conditions and allowing mobile network operators (MNOs) to specify different objectives for traffic management, depending on the scenario. It can then flexibly configure optimization policies.

### Interoperability and open interfaces:

Traditionally, RAN solutions have been proprietary and vendor-specific, leading to limited interoperability and vendor lock-in. The RIC architecture promotes an open ecosystem through standardized interfaces, such as the E2 interface, O1 Interface, etc., which O-RAN specifications define. This enables multi-vendor interoperability, allowing operators to combine components from different vendors. The RIC, combined with SMO, acts as a control and management layer, abstracting the underlying hardware and facilitating seamless integration of diverse RAN elements.

### Flexibility and scalability:

As a software-defined component, the RIC adds flexibility and scalability to the RAN. It allows operators to create virtual network instances tailored to specific applications or user groups through dynamic network slicing. By managing resources centrally and orchestrating them dynamically, the RIC helps efficiently allocate network capacity based on demand, ensuring scalability and adaptability.

### Energy efficiency and saving operational costs:

Operators have to meet stringent energy efficiency goals by 2030. RIC xApps and rApps are developing innovative solutions that help reduce energy bills. Capgemini's energy-efficiency rApp/xApp is being deployed under trial in an operator-live network in Europe, and it has already shown **more than 10% savings in energy**. The xApp brings us closer to reaching the EU Green Deal goals and, in the process, also saves operational costs for operators who spend billions of dollars every year on energy bills.

### Network slicing management and edge orchestration:

Network slicing is a fundamental concept in 5G that enables the creation of virtual network instances with tailored characteristics. The RIC applications (xApp/rApp) act as key components in managing network slicing, by orchestrating the allocation of resources, enforcing service-level agreements, and dynamically adjusting network parameters. This enables operators to offer differentiated services, allocate resources on demand, and support diverse use cases, while ensuring isolation and quality of service.

### Enabling automation and self-healing:

As 5G networks become more complex, automation is essential for efficient operations. RIC utilizes advanced analytics, machine learning, and AI techniques to automate network optimization, resource management, and fault detection. It can detect network anomalies, proactively address issues, and even self-heal by dynamically reconfiguring the network to ensure continuous service availability and quality.

## The spark of intelligence: Capgemini's RIC

The heart of Capgemini's OpenRAN Operations Automation solution lies in a set of RAN applications driven by our NetAnticipate AI-Model platform. To address the issues of automation in real time – when millions of impulses are streaming through networks and each one must be routed correctly and immediately – something more than standard automation is required.

The innovative solution we've created uses the near Real-Time RIC (nRT-RIC) model. This is based on an extendible, abstracted architecture, that enables easy integration of multi-vendor xAPPs on nRT-RIC.

So, whatever vendors an operator is working with, the same powerful AI is able to handle the traffic. RAN-specific AI models that learn with no supervision can make O-RAN NonRealTime RIC implementation possible. The result is a complex network that essentially runs on autopilot.

# Greener connectivity

# Greener connectivity: why and how

Finally, a key part of any major project today must include addressing sustainability issues.

Energy consumption makes up a significant portion of the mobile network operator's OPEX, estimated at between 20% and 40% – a figure that is even higher in heavy diesel usage regions, like Southeast Asia and Africa.

In 2020, the annual global energy cost for running mobile networks was about $25 bn, a figure that is likely to be significantly higher now, due to subsequent global economic challenges, like the energy crisis and surging inflation.

RAN (Radio Access Network) accounts for the largest portion of this cost, almost 80% of the network's energy consumption, making it a prime target for energy-saving efforts. Successful interventions reduce costs as well as the CO2 footprint.

Several intelligent RAN energy-saving mechanisms, such as cell and carrier sleep modes, massive Multiple-Input Multiple-Output (MIMO) Rx/Tx reconfiguration, traffic steering, power control, etc., have been introduced over the years to reduce energy consumption in the RAN's active units.

However, adding AI/ML enables dynamic learning to intelligently control those mechanisms and improve energy saving further, while maintaining an optimal user experience. Initial trials have shown up to 12% additional savings over traditional techniques. However, for industrializing RAN energy saving for operators, the solution must be scalable, reliable, and replicable across a multi-vendor network environment.

## Challenges in building an industrialized RAN energy-saving solution

Industrialized RAN energy saving will not be easy to implement. The key hurdles are:

- **Technical complexity** – the mobile network consists of multiple technologies (2G, 3G, 4G, 5G). Energy efficiency must be implemented across these technologies and respective vendors.
- **Performance and quality of service (QoS) preservation** – operators must ensure that QoS is closely monitored, and that energy-saving measures do not impact user experience.

- **Compatibility and interoperability issues in a multi-vendor ecosystem** – networks are commonly built with equipment from different vendors. The RAN energy-saving solution must adapt to the respective data formats, KPIs, energy-saving mechanisms and APIs. This challenge can be mitigated by improving the standardization of network KPIs (usage, electricity consumption, QoS) and energy-saving mechanisms and APIs.

- **Cost considerations** – implementing energy saving solutions may involve upfront technology and infrastructure costs. Moreover, the energy-saving solution will have its own CO2 footprint. Operators should carefully assess the return on investment and develop strategies for cost-effective energy savings.

- **Measuring the savings** – to measure accurately, operators need to separate the contribution brought in by the new intelligent energy saving solution from the energy servings already built into vendor hardware and software.

## How to decrease energy use: the way forward for operators

To evaluate the potential benefits and gain confidence in their ability to overcome challenges, operators must engage in trials, starting with simulations based on real network data.

A simulation is risk-free, with no impact on the network, and can help evaluate returns. That can help make the case for field trials, and to deploy a better-tuned, industrial solution.

With Open RAN, it is possible to introduce near-real-time energy saving techniques in O-RAN Radio Units (O-RU), such as intelligent discontinuous transmission (DTx) - known as ‘micro-sleep’, intelligent discontinuous reception (DRx), intelligent radio resource control (RRC) inactive state, intelligent scheduling, and more.

These use cases provide deeper and more advanced energy-saving techniques that are not possible in traditional RAN.

Additionally, O-RAN can optimize the energy consumption of the cloud infrastructure in which it operates, through intelligent workload optimization and CPU tuning.

## Exciting opportunities on the horizon: future network energy saving technologies

The advent of 5G-Advanced and anticipated 6G technology will bring even bigger opportunities. New technologies are on the way, like IRS (Intelligent Reflecting Surface) and adaptive beamforming using sensing techniques also known as JCAS (Joint Communication and Sensing).

Together, these will make future networks more energy efficient and natively sustainable. Capgemini is actively engaged in research on these technologies with academic and industry partners, as part of our commitment to address climate change.

# Conclusion

# Better networks are possible when we work together

The opportunity in Open RAN is immense, and the move to a multi-vendor environment and software defined systems is opening up the market to a range of new innovative players. In fact, according to a report from MarketsandMarkets, the size of the global Open RAN market is anticipated to increase from **$1.1 bn** in 2022 to **$15.6 bn** by 2027.

However, cloud-native, open networks require broad industry collaboration to become a reality, and live up to their incredible potential. The good news is that many operators, vendors and other stakeholders have recognized that need and are now collaborating in initiatives like the aforementioned i14y Lab. But more is needed. With the momentum being seen by 5G and a plethora of new advances in technology and commercial opportunities just over the horizon, now is the time to start planning for O-RAN.

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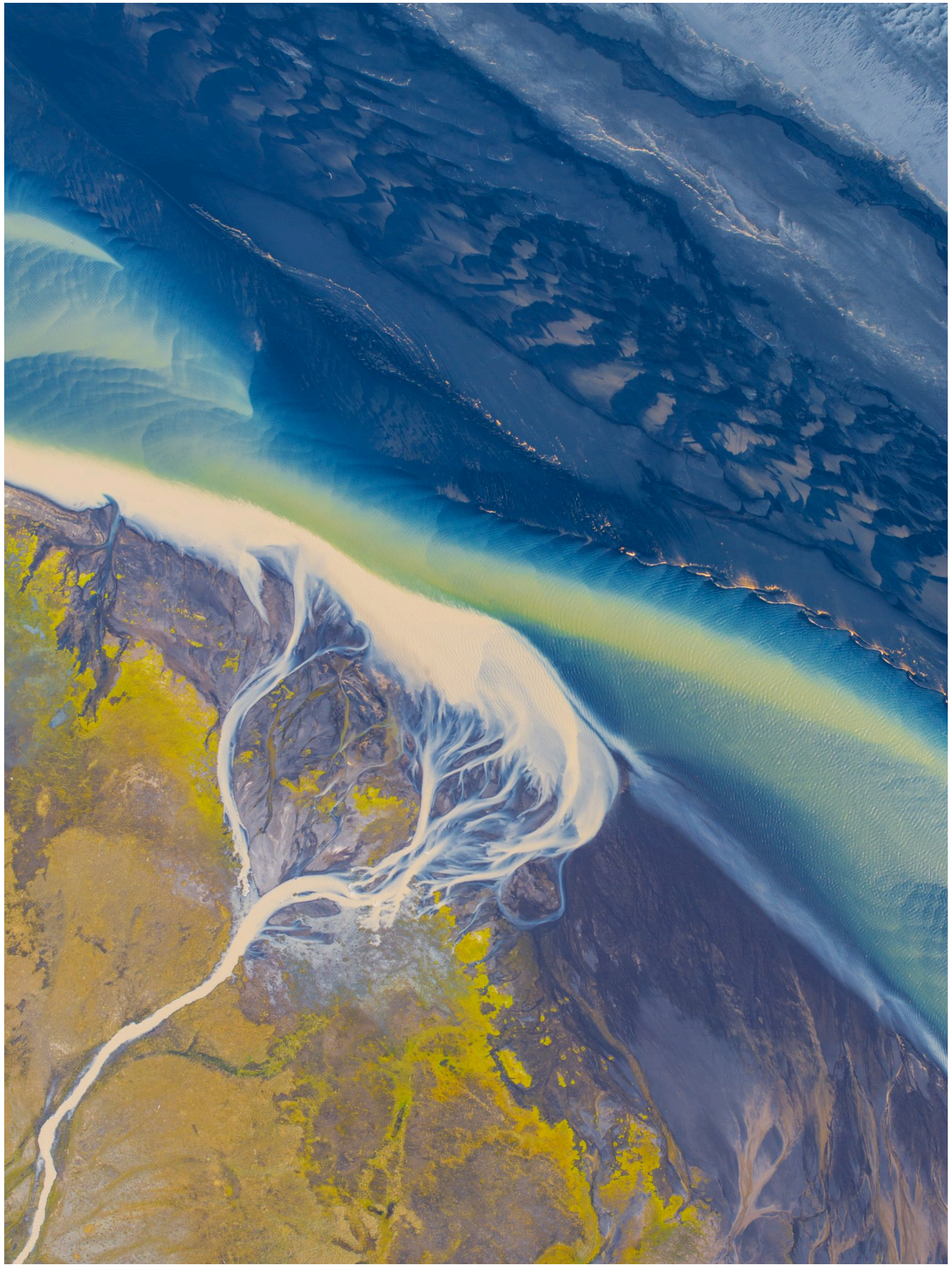
Collaboration is the key to unlocking the immense potential of Open RAN and creating better networks for the future."

# How Capgemini can help

# How Capgemini can help

A pioneer in open networks, Capgemini spearheads the design, development, and integration of virtualized and disaggregated radio networks. Our engineers accelerate O-RAN product development through customizable, standards-based, pre-built software frameworks for centralized and distributed units of the radio network.

We combine deep expertise - from silicon, protocol development, cloud platforms, orchestration, and data-driven intelligent RAN platforms – to accelerate O-RAN market readiness for network equipment providers. We help telcos design, test, validate, deploy, and manage O-RAN, while our global 5G labs provide testing, validation, and interoperability of multi-vendor solutions.



## Selected examples of our O-RAN work and achievements

We work with 50+ network equipment providers, test/measurement companies, semiconductor companies, telcos, and leading innovators. We're active in industry organizations and standardization bodies, including the O-RAN Alliance, Telecom Infra Project, and GSMA.

Some examples of this work are below.

### 2021

- Capgemini was chosen as a strategic vendor by a leading Telecommunications company in Europe and Africa to help them deliver the first commercial deployment of an O-RAN in Europe.

- Capgemini and various partners ran a trial with the Cohere RIC xApp, demonstrating how to boost 5G capacity where multiple customers were using the same site.

### 2022

- Capgemini participated in the O-RAN Global Plugfest Fall 2022 in Europe, successfully demonstrating a variety of advanced O-RAN features, like end-to-end multi-vendor integration and xApps/rApps functional verification.

### 2023

- Capgemini joined TM Forum's moonshot catalyst project 'Green and Efficient Radio Access Networks', a collaboration with leading CSPs and NEPs to address telecoms energy challenges.

- At the O-RAN ALLIANCE Spring PlugFest 2023, we demonstrated that the Capgemini traffic steering xApp, running on the Capgemini RIC, significantly improved the UE throughput; and the automatic and efficient detection of PCI confusion and collisions using AirHop's PCI optimization rApp (in collaboration with AirHop Communications).

## Do you want to learn more?

Connect on LinkedIn with Capgemini Engineering