O-RAN: Defining the path for innovation in the RAN

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Executive summary

- The telecoms industry is seeing a big shift towards open RAN as communications service providers (CSPs) consider how best to future-proof and manage their increasingly complex networks for long-term innovation and revenue growth, with the goal of monetizing emerging technologies such as 5G, network slicing and edge computing.

O-RAN will give CSPs the flexibility, scalability and agility they need to grow, as they rethink what it means to be a CSP and seek to deliver on the promises of 5G by offering services beyond connectivity

There is no single straightforward route to O-RAN – CSPs should take steps **now** to define their unique path and ready their networks to support their innovation and growth ambitions

- O-RAN represents a shift from closed, proprietary architectures dominated by a few vendors towards a disaggregated, multi-vendor environment with open interfaces and programmable infrastructure.
- There are different steps towards a truly "open" RAN, each of which unlocks different benefits. VMware is committed to enabling and supporting this transition at each stage with proven solutions, relevant domain expertise and key ecosystem partnerships to help its customers navigate the RAN evolution.
- As CSPs begin to define their strategies, there are steps they can take now to ease the transition to a fully disaggregated RAN:
  1. Begin with small-scale deployments (for example with private cellular networks) to build expertise and experience
  2. Understand and explore how O-RAN can support longer-term growth strategies, not only in the RAN as a siloed part of the network, but as part of a broader network transformation across a multi-cloud environment (from the core to far edge)
  3. Engage with the wider O-RAN ecosystem and develop partnerships with those who can leverage O-RAN capabilities for private cellular networks, neutral host networks or those who can build innovative capabilities on the RIC

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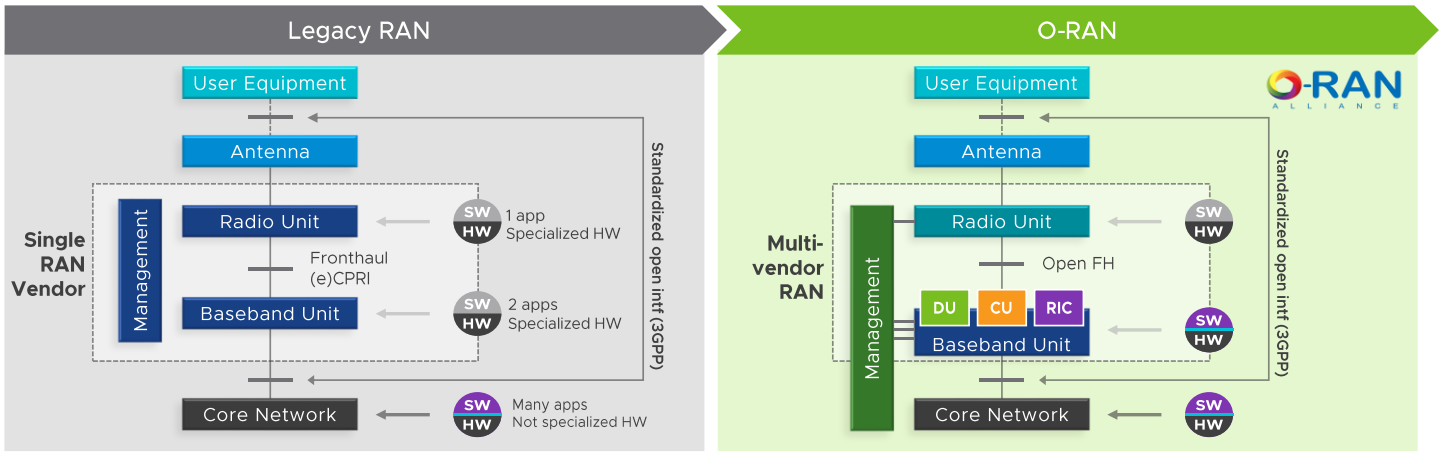
The big shift to O-RAN

The telecoms industry is seeing a big shift as CSPs rethink their core propositions and seek to deliver on the promises of 5G, moving beyond connectivity and exploring new opportunities for revenue growth. With this shift comes significant challenges: as the network becomes more complex, CSPs must consider how they can prepare for innovation, whilst driving cost and operational efficiency.

Against this backdrop, CSPs are looking to O-RAN as a way to re-structure how the radio access network (RAN) is organized and run, and future-proof for long-term innovation. The ultimate vision for O-RAN is to disaggregate the network and make it more open, fostering greater choice in a traditionally closed market. This will provide a strong foundation for CSPs to offer more innovative solutions to enterprise and consumer customers, as well as partners within their broader ecosystem. These are the big drivers for the shift to O-RAN, as CSPs hope to secure a return on their 5G investments and monetize the network by enabling new applications and services, especially at the edge.

At a basic level, O-RAN means virtualizing and disaggregating the baseband unit (BBU) functions, separating the control plane from the data plane and opening up fronthaul interfaces.

Figure 1: O-RAN represents a shift towards a multi-vendor ecosystem with open (non-proprietary) interfaces



Pre-integrated software and hardware from a **single vendor** with **proprietary interfaces** (if interfaces are exposed, it is limited)	**Decoupled software and hardware** with **open interfaces** enabling multi-vendor compatibility – smaller vendors can enter market
Market largely **dominated by 3 vendors** resulting in a limited drive for competition and innovation	**Multi-vendor environment** encourages competition and innovation with **best-of-breed solutions** from different vendors
Innovation stymied by **long release cycles** (can take 6-12 months), CSPs are dependent on vendors for changes and updates	**Strong relationship with software vendors** enhancing rapid innovation propelled by open ecosystem
Difficult to scale quickly to meet fluctuations in demand, limited programmability and flexibility to introduce new 5G services	More **programmable infrastructure** enables **dynamic responses** to fluctuating demand and prevents inefficient use of spare capacity

While the short-term opportunity is focused on virtualizing the RAN, CSPs face a number of challenges as they consider the transition to O-RAN:

- **There are multiple routes to O-RAN**. There is no single route to O-RAN. Each CSP will need to establish the best path based on individual business and technical needs, as well as external market factors.
- **The technology is still nascent**. Despite their limitations, legacy RAN deployments are more mature and proven. With the pressure to provide a consistent and reliable quality of service, there is significant appetite to find solutions which limit the risk to QoS impact.
- **It will require new operating models**. CSPs will need to consider new 'cloud-native' operating models and consider how best to acquire the skills and expertise required to transition to these.

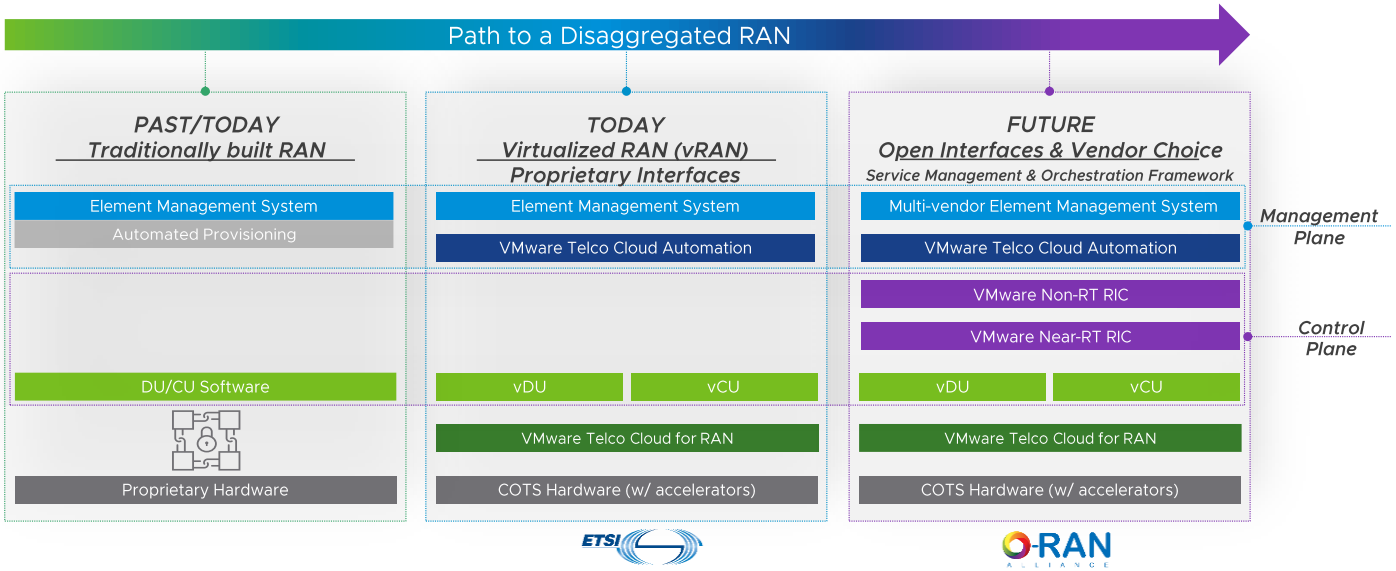
Taking these into consideration, CSPs are grappling with how best to enable and manage the seamless transition from legacy deployments to unlock the promise of greater innovation, scalability and performance.

The O-RAN transition: Paving the way to unlock enhanced capabilities

Embracing the technologies that will enhance the radio access network involves a series of steps – CSPs should evaluate their individual priorities that will determine how aggressively they pursue O-RAN. They should also be aware that as standards emerge and further develop, the overall way that they embark on these steps will affect their ability to achieve their long-term ambitions and the powerful combination of innovation, agility and performance.

The path to a disaggregated RAN involves a series of steps across two dimensions: the first is the virtualization of the RAN and the second is about decoupling the control and management planes from the data plane through open interfaces. CSPs should build their RAN strategy in steps with a view of how it will progress as they move towards an increasingly disaggregated, open, multi-vendor ecosystem.

Figure 2: Evolution of RAN infrastructure, the path to O-RAN



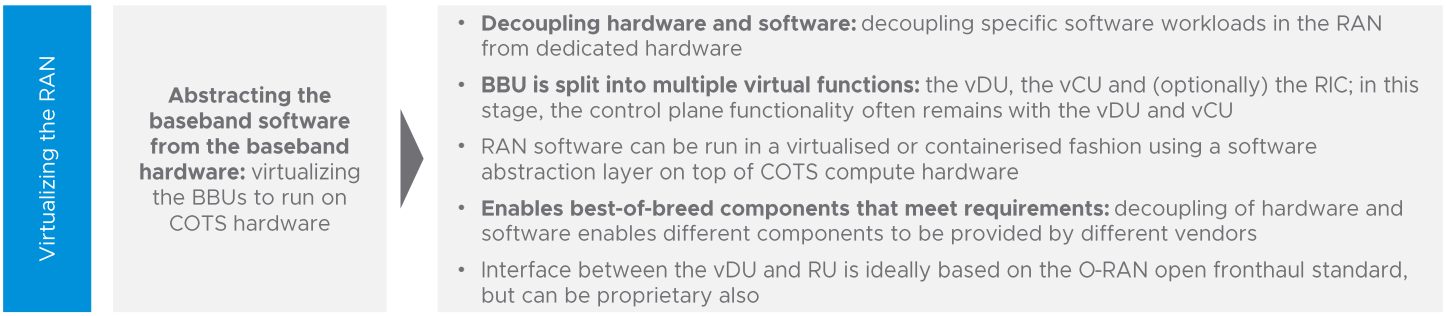
Virtualization of the RAN: Decoupling hardware and software

Virtualizing the RAN means decoupling the radio software from the underlying hardware by running it on a virtualization layer. More specifically, it involves virtualizing the BBUs so they can run as software on generic, IT industry standard hardware. The BBU is split into multiple virtual functions: the virtual Distributed Unit (vDU), the virtual Centralized Unit (vCU) and optionally the RAN Intelligent Controller (RIC). By logically splitting out these functions, CSPs have much more flexibility in terms of where they place their workloads and economies of scale through centralization. For example, vCUs can be centralized at designated sites, rather than each cellular site requiring its own CU (as part of the BBU). In certain configurations, the vDUs might even sit at aggregated local sites rather than out at the remote cellular towers.

With the software and hardware now independent of each other, services can now scale up and down as needed. In addition, the ability to shift from proprietary to commercial-off-the-shelf (COTS) hardware will allow CSPs to reduce their overall CapEx and OpEx. CSPs can also pool hardware for a hybrid infrastructure: simultaneously combine hardware from different vendors, different silicon architectures, and even blend-in cloud (e.g. hypervisor edge cloud infrastructure).

Decoupling the RAN software and hardware also diversifies the vendor ecosystem as it enables the baseband software and hardware to be provided by different vendor partners, allowing CSPs to select best-of-breed components. This separation of functions ensures greater competition among different vendor partners and can therefore foster greater innovation within the RAN.

Figure 3: Virtualizing the baseband units to run on industry standard hardware



Software-defining the RAN: Shift to open interfaces

This next dimension involves decoupling the control and data planes and replacing vendor-proprietary interfaces with open standards-based interfaces to enable the vCUs and vDUs to interoperate with control and management units from different vendors, thus enabling a fully disaggregated and programmable RAN. This is about deconstructing the RAN into modular elements with open interfaces that enable programmability and more advanced innovation at the RAN-level.

Critically, CSPs can run multiple versions of the same type of network functions at the same time without having to source the entire RAN stack from the same vendor. This is key for dynamic end-to-end network slicing and for introducing new operating arrangements for cost-effective end-to-end coverage in rural, in-building and dense urban settings.

Figure 4: Shift to open interfaces for multi-vendor compatibility and innovation

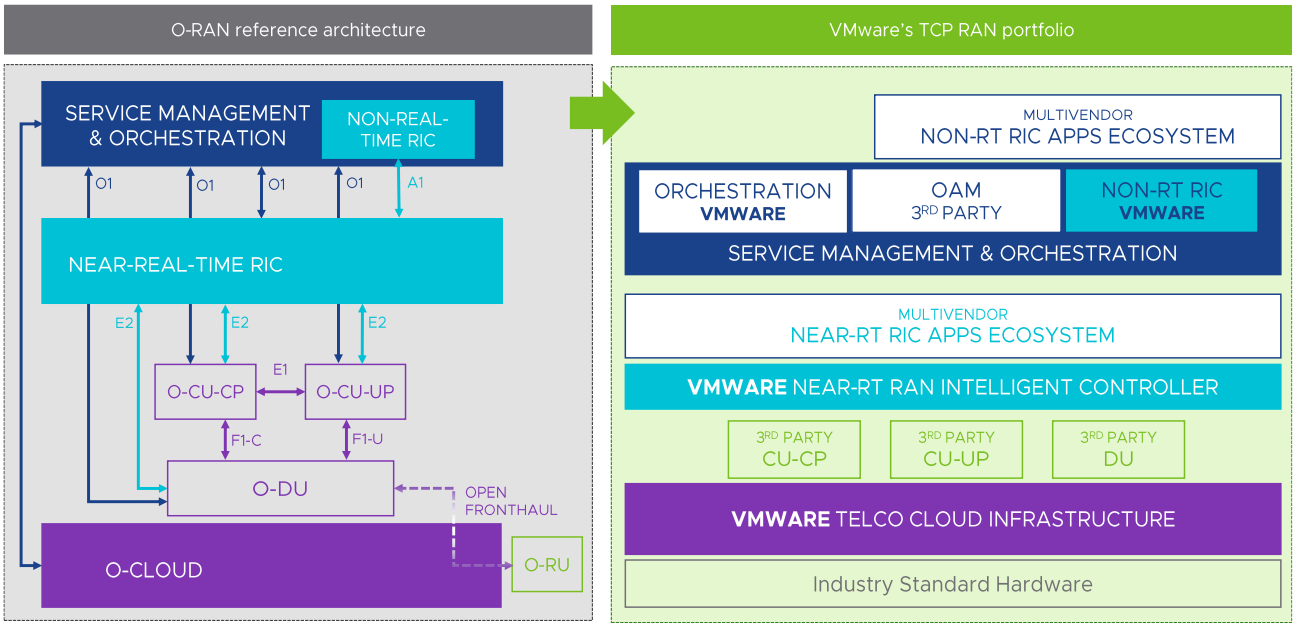
Decoupling the management function from the data plane to create a service management orchestration layer enables vendor neutrality in the lifecycle management of network functions in the RAN across all types of telco clouds (edge, regional, central and even public cloud), using open interfaces. This also allows CSPs to leverage greater automation to manage distributed deployments across the entire RAN topology, which can become a huge operational challenge otherwise. Having the management plane decoupled also ensures greater integrity of performance and customer experience testing, so that CSPs can accurately triage faults and identify root causes of any issues.

Decoupling the near-real-time control plane is the last step in disaggregating the RAN and involves decoupling the intelligence of the RAN software so that this can be delivered on top of a controller platform. Introducing a controller platform, the near-real-time RIC, as an abstraction layer unlocks greater innovation within and across the CSP ecosystem. CSPs can provide APIs to partners to build applications on top of the RIC without the challenges of having to integrate with the underlying data plane. This enables rapid deployment of innovative RAN control-plane functions and x-apps to improve spectral efficiency and subscriber experience, and also enable the introduction of new monetization capabilities.

Managing the transition and enabling a vibrant, multi-vendor ecosystem

The journey to O-RAN is not intended as a sudden leap of faith into a new way of working. In reality, most deployments are brownfield and CSPs have to manage legacy systems and processes while having to continue ensuring performance, reliability and security in their networks. Therefore, the route to O-RAN should be seen as a series of deliberate steps to manage the transition. VMware helps CSPs globally with their individual RAN trajectories to ease their route to O-RAN through our proven solutions, expertise and partner ecosystem.

Figure 5: As part of its Telco Cloud portfolio, VMware has capabilities in each layer of the O-RAN architecture



VMware's telco cloud portfolio enables CSPs to deploy, operate and manage a disaggregated, multi-vendor O-RAN:

- **Enabling hardware abstraction for CapEx savings:** VMware's Telco Cloud Infrastructure (TCI) enables CSPs to virtualize or containerize their workloads, leverage industry standard hardware and run CU/DU network functions on pooled compute hardware, thus enabling a multi-vendor ecosystem and reducing overall RAN CapEx.
- **Driving operational agility across the network: VMware** Telco Cloud Automation (TCA) is VMware's distributed cloud orchestration system that enables the automated deployment and lifecycle management of network functions across all logical clouds (edge, regional, central and even public cloud) from a centralized location. This allows CSPs to manage thousands of distributed deployments in an automated manner, greatly reducing operational challenges and overall OpEx, especially as network complexity increases.
- **Achieving full visibility across your operations:** Given the complexity in network topology, CSPs can leverage VMware's Telco Cloud Operations (TCOps) automated assurance solution to help monitor the physical and virtual infrastructure across their networks in real-time. It provides intelligent, automated root-cause analysis to provide rapid insights for better identification, notification and resolution of faults in the network, enabling a more proactive approach to service assurance.
- **Managing increasing network complexity with AI/ML:** The non-real-time RIC provides control loops at latencies greater than 1 second and leverages AI and ML capabilities in the RAN EMS systems to provide closed-loop recommendations and remediations. As networks become increasingly complex with 5G, these capabilities will become key enablers for enhanced and efficient network management.
- **Accelerating innovation in RAN optimization and monetization**: Both the non-real-time and near-real-time RIC platforms enable greater innovation through the wider ecosystem. CSPs can leverage open APIs to build custom applications on top of the non-real-time RIC. VMware is also innovating on the near-real-time RIC that will enable partners to build x-apps and unlock innovative radio resource management capabilities to improve spectral efficiency, especially as we move to mid-band and massive MIMO.

- Securing long-term success with Day 2: Beyond the initial deployment of O-RAN, VMware provides Day 2 support with an automated CI/CD pipeline within the TCA layer. This framework will enable more advanced and agile DevOps for long-term success.

Figure 6: Our solutions help CSPs deploy a disaggregated, multi-vendor virtualized RAN

A vibrant, pre-integrated, multi-vendor ecosystem for O-RAN

One of the core aspects of O-RAN is enabling an ecosystem with open interfaces, and the ability for multiple vendors to be part of a CSP's RAN architecture, driving competition and innovation. Through its partner ecosystem, VMware provides CSPs the freedom of choice from both a hardware and RAN vendor (CNF) perspective and is committed to ensuring that solutions from its ecosystem partners function cohesively to reduce the burden of testing and certification falling on CSPs. VMware has an extensive pre-testing, certification and integration program with leading technology companies to operationalize and optimize performance across the different components.

- Leading hardware platforms:
    - VMware works with leading hardware providers such as Intel, NVIDIA and Qualcomm to give CSPs freedom of choice and the assurance that regardless of vendor choice, VMware's cloud layer can virtualize and operate any infrastructure with carrier-grade scale and performance.
    - Intel and VMware are working closely together to provide an integrated, interoperable software platform for an open and virtualized RAN, leveraging Intel's FlexRAN software reference architecture and VMware's cloud infrastructure, RAN Intelligent Controller and Telco Cloud Automation platform. The partnership seeks to alleviate the burden of integration for CSPs and enable a seamless transition to O-RAN. The focus is to provide pluggable modules to FlexRAN-based solutions for enhanced capabilities in the RAN, including real-time radio resource management and network slicing, and to enable greater interoperability for radio units with the platform.
- Innovative RAN network function providers (VNFs/CNFs):
    - CSPs can also choose from a list of leading RAN vendors they would like to work with, from the likes of Altiostar to Mavenir, to realize their visions of having a multi-vendor, best-of-breed ecosystem. These partner VNFs and CNFs have been pre-tested and certified to ensure that they are optimized to run on top of VMware's virtualized platform.
    - Similarly, VMware plans to create an ecosystem of xApp and rApp partners whose applications will be tested and certified on VMware RIC platforms.

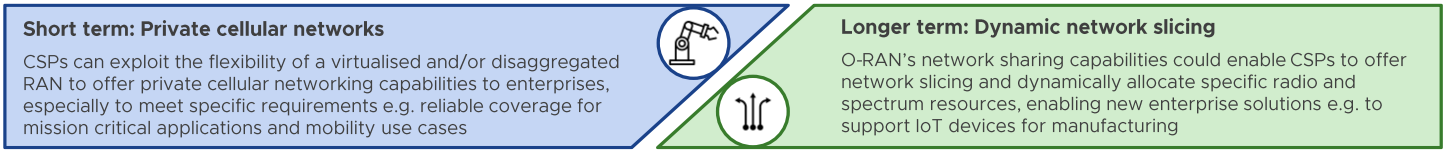
3 steps CSPs can take today to secure the success of their long term O-RAN strategies

1. Begin initial deployments in O-RAN to build the expertise and capabilities required for macro deployment
Small-scale deployments of elements of O-RAN (including distributing, centralizing and virtualizing baseband functions, before full disaggregation) can allow CSPs to build expertise and access new (short term) revenue opportunities before scaling in the macro network.

During this process, CSP RAN teams should move from focusing on cost-centric strategies, to more revenue-centric operating models that will better support product and service innovation with 5G and edge computing. As the roll-out of 5G standalone core expands, the flexibility of O-RAN and ability to dynamically share resources will be compelling for those seeking these opportunities.

For example, private cellular networks could enable CSPs to build the necessary skills to manage these deployments as just one of many network end points and gauge the benefits of making their networks more programmable for enterprise customers.

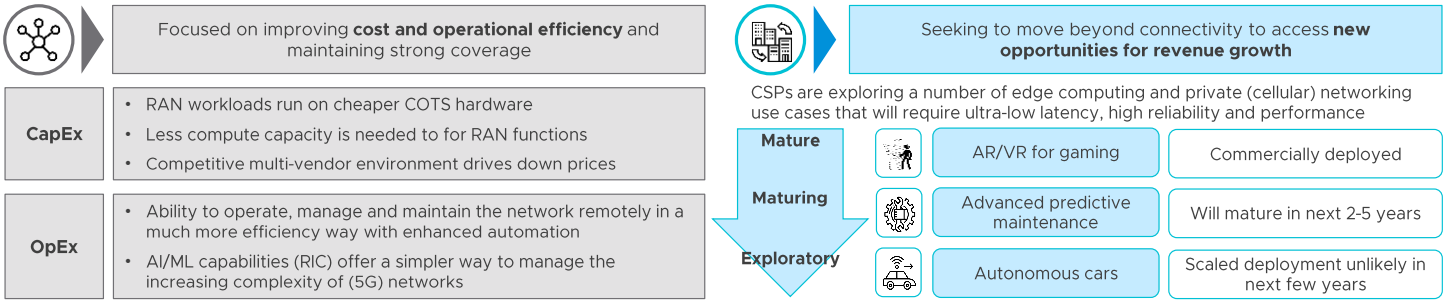
Figure 7: Private cellular networks are a key short term revenue opportunity for CSPs in O-RAN



2. Building from this revenue-centricity, understand how O-RAN can support your innovation and growth ambitions
CSPs can unlock cost benefits and achieve more efficient network operations through vRAN and O-RAN. But some CSPs may also be looking to access new opportunities for revenue growth and to expand their B2B(2X) portfolio, especially with 5G and other emerging technologies such as edge computing that require more programmable, agile networks.

To achieve this, CSPs must future-proof their networks and ensure that their roadmap for innovation and expansion will not be hindered by their network infrastructure – the O-RAN roadmap should be closely aligned with other initiatives.

Figure 8: CSPs should ensure their RAN strategies are aligned with other internal and external ambitions



3. Develop partnerships and engage with the wider ecosystem
As standards continue to develop, CSPs will need clarity on how they can exploit these opportunities and ready themselves now for their long-term RAN strategies. Engaging (in conversation) with the wider ecosystem will put them in good stead for this, e.g.:

- Application developers (e.g. for RIC apps: xApps and rApps, and enterprise applications that can leverage private cellular)
- Emerging (wholesale) neutral host providers (e.g. of in-building, small-cell or rural RAN services)
- Working groups for CSPs and developers e.g. O-RAN Alliance:
    - VMware is a member of O-RAN Alliance – a CSP-led working group made up of >200 companies
    - The aim of O-RAN Alliance is to provide standards for big commercial trials and deployments of O-RAN
    - O-RAN Alliance is partnered with TIP, the Facebook-backed Telecoms Infrastructure Project, developing and promoting standards for open architecture, focusing on use cases that will make RAN equipment more flexible, agile and efficient

Each CSP will have unique challenges and ambitions that will shape their approach to O-RAN and their timeline for doing so, but regardless of these individual nuances, *all* CSPs will benefit in the long-term from defining their approach today.

Glossary

Term/acronym	Definition
vRAN	Virtualized radio access network
O-RAN	Disaggregated RAN with open FH interfaces between RU and BBU
BBU	Baseband unit – with O-RAN this is split into the RIC, DU and CU functions
DU and CU	Distributed unit (DU) and centralized unit (CU) – data plane functions that can be on-boarded as software
RIC	RAN Intelligent Controller: open platform to control RAN functions/host 3rd party apps, to control and optimize O-RAN resources **Non-real-time (RT) RIC:** Control loop functions at latencies > 1 second, can be deployed in the network core **Near-real-time RIC:** Control loop functions that require latency < 1 second, deployed with CU close to cell sites
(R)RU	(Remote) Radio unit
CP	Control Plane = RIC
UP	User Plane = CU and DU
x-apps	Independent specialist software enabling 3rd party O-RAN functions in the near-RT RIC
r-apps	Independent specialist software enabling 3rd party O-RAN functions in the non-RT RIC
Option 7.2x	Defined by the O-RAN Alliance, this is a specification to functionally split the O-RAN DU and RU to enable an open fronthaul interface
FCAPS Mgmt.	Fault, Configuration, Accounting, Performance and Security Management

O-RAN reference architecture interfaces

Term/acronym	Definition
A1	Interface between non-RT RIC and CU (containing near-RT RIC) – allows network management applications to receive and act on reliable data from CU and DU
E1	Interface between the CU-CP and CU-UP (CP/UP split within the CU)
E2	Interface between near-RT RIC and CU/DU – feeds data (e.g. RAN measurements) to near-RT RIC to support radio resource management and allows near-RT RIC to initiate configuration commands directly to CU/DU
O1	Management interface between SMO and O-RAN managed elements to support virtual network functions (VNFs)
O2	Management interface between SMO and O-Cloud infrastructure
F1 (F1-C and F1-U)	Interface between DU and CU – F1-C is the control plane interface, F1-D is the user plane interface
O-CU-CP / O-CU-UP	Open central unit, control plane / Open central unit, user plane
O-DU / O-RU	Open distributed unit / Open radio unit
O-RAN FH	Open fronthaul interface – the O-RAN Alliance is working towards open fronthaul interfaces (between the BBU's DU function and the RRU) that will enable multi-vendor interfaces

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