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Lawrence Miller

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# RAN Transformation

VMware Special Edition

**by Lawrence Miller**

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# RAN Transformation For Dummies®, VMware Special Edition

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# Introduction

The telecommunications industry is on the brink of significant growth spurred by the arrival of 5G and the demand for new services. A recent industry study by MarketsandMarkets (`https://marketsandmarkets.com`) projects that the 5G services market, comprising consumer and enterprise segments, will grow at a compound annual growth rate (CAGR) of 29.4 percent through 2026. The 5G services category will jump from $53 billion in revenue in 2020 to $249 billion by 2026. A separate study by Acumen Research and Consulting (`https://acumenresearchandconsulting.com`) reached similar conclusions, projecting a CAGR approaching 30 percent through 2027.

This vigorous growth potential arises from 5G's ultra-high speed and low latency, both of which greatly enhance the user experience. The increase in speed is so significant that it will be transformative for telecommunications, healthcare, retail, automotive, and industrial use cases. Communication service providers (CSPs) will have the opportunity to create new services in fields like telemedicine, municipal government, and beyond.

For many CSPs, this technology transformation requires an evolution of the traditional radio access network (RAN) infrastructure, which could constrain their ability to execute on 5G-based strategies. Operating costs, flexibility, and security are key considerations for the 5G revolution. At the same time, openness is needed to thrive in this vast competitive landscape.

Innovative new solutions are emerging that enable CSPs to modernize their RAN infrastructure in ways that facilitate profitable RAN monetization now and in the future. For example, a high-performing and highly automated virtualized RAN (vRAN) platform can serve as a common horizontal foundation for the deployment of 5G and traditional services, offering CSPs a path toward the vRAN and Open RAN future with deep automation, low latency, and the potential to function as a 5G multiservices hub.

# About This Book

*RAN Transformation For Dummies*, VMware Special Edition, consists of six chapters that explore the following:

- The challenges of the legacy RAN (Chapter 1)
- How to address the legacy RAN challenges with an agile RAN infrastructure (Chapter 2)
- How to unify the RAN and the network (Chapter 3)
- Future use cases for a modern RAN (Chapter 4)
- Important milestones on the RAN transformation journey (Chapter 5)
- What to look for when selecting a RAN transformation partner (Chapter 6)

Each chapter is written to stand on its own, so if you see a topic that piques your interest, feel free to jump ahead to that chapter. You can read this book in any order that suits you (though we don't recommend upside down or backward).

# Foolish Assumptions

It has been said that most assumptions have outlived their uselessness, but we assume a few things nonetheless.

Mainly, we assume that you're an executive or senior technical engineer and that you work for a CSP. As such, this book is written primarily for technical readers with at least a basic understanding of 5G and RAN technologies and challenges.

# Icons Used in This Book

Throughout this book, we occasionally use icons to call attention to important information. Here's what to expect:

REMEMBER

The Remember icon points out important information you should commit to your nonvolatile memory or your noggin — along with anniversaries and birthdays!

TECHNICAL STUFF

If you seek to attain the seventh level of NERD-vana, perk up! This icon explains the jargon beneath the jargon and is the stuff legends — well, legendary nerds — are made of.

TIP

Tips are appreciated, but never expected, and we sure hope you'll appreciate these useful nuggets of information.

## Beyond the Book

There's only so much we can cover in this short book, so if you find yourself at the end of this book wondering, "Where can I learn more?," go to `https://telco.vmware.com/solutions/ran` and `https://intel.com/5G`.

IN THIS CHAPTER

- Tracing the history of the radio access network
- Understanding the path toward radio access network disaggregation

# Chapter 1
# Understanding the Challenges of the Legacy Radio Access Network

To understand and address the potential challenges of the legacy radio access network (RAN) model, communication service providers (CSPs) must understand how the legacy RAN model came into being and where RAN architectures are heading. This chapter fills you in.

## Reviewing the History of the Radio Access Network

The RAN is a key component of a mobile telecommunications system. It connects mobile devices (such as smartphones) to the core network of the CSP via a base station (transceiver).

The traditional RAN traces its history back to the late 1970s and early 1980s and 1G (analog cellular) service, which supported only unencrypted voice traffic because the Internet was still in its infancy.

With the advent of 2G (digital cellular) in 1991, the RAN evolved to support digital signals that could be encrypted and, for the first time, Short Message Service (SMS) text messages.

The first 3G networks were introduced in 1998 and, with the release of the first smartphones in the early 21st century, the RAN became an increasingly data-driven network.

TIP

The 3rd Generation Partnership Project (3GPP) was formed in 1998 to develop the 3G specification based on the 2G Global System for Mobile Communications (GSM) standard. Today, the 3GPP continues to work on developing and maintaining 4G and 5G standards, among other things.

As Apple iPhones and Google Android devices began to proliferate, creating an insatiable demand for more and faster data, the first 4G networks were deployed in 2008, quickly followed by 4G Long-Term Evolution (LTE) in 2010. The moniker *Long-Term Evolution* was apropos because 4G required significant changes to existing CSP networks to support high-speed data (such as streaming video) and, most notably, the requirement for a packet-switched all–Internet Protocol (IP) core network, which didn't happen overnight.

Whereas 4G (and LTE) laid the foundation for high-speed data with the introduction of a packet-switched all-IP core network, 5G extends high-speed data to the edge (that is, the RAN) and beyond — to user equipment (UE) and Internet of Things (IoT) devices and sensors — effectively transforming the consumption model from human-to-human to human-to-machine and even machine-to-machine. 5G focuses on delivering speed (ultra-high-speed radio access), responsiveness (ultra-low latency), and scale (massive connectivity) to support billions of data-hungry mobile consumers and tens of billions of IoT-connected devices worldwide. The requirement to support massive machine-type communications (mMTC) in 5G is a driving force behind many innovations — including network slicing, carrier aggregation (CA), massive multiple-input/multiple-output (MIMO), and orthogonal frequency-division multiplexing (OFDM), among others — as well as a complete transformation of the legacy RAN.

TECHNICAL STUFF

Table 1-1 summarizes several key capabilities and features in 3G, 4G, and 5G New Radio (NR) networks.

**TABLE 1-1** Comparing 3G, 4G, and 5G NR Capabilities and Features

| | 3G | 4G | 5G NR (Release 15) |
|---|---|---|---|
| Downlink waveform | Code-division multiple access (CDMA) | OFDM | OFDM, single-carrier frequency-division multiple access (SCFDMA) |
| Uplink waveform | CDMA | SCFDMA | Orthogonal frequency-division multiple access (OFDMA), SCFDMA |
| Channel coding | Turbo | Turbo | Low-density parity check (LDPC) (data), polar (L1 controller) |
| Beamforming | No | Only data | Full support |
| Spectrum | 0.8–2.1 GHz | 0.4–6 GHz | 0.4–52.6 GHz |
| Bandwidth | 5 MHz | 1.4–20 MHz | Up to 100 MHz (200 or 400 MHz for more than 6 GHz) |
| Network slicing | No | No | Yes |
| Quality of service (QoS) | Bearer based | Bearer based | Flow based |
| Small packet support | No | No | Connectionless |
| In-built cloud support | No | No | Yes |

# Looking at the Evolution of RAN Capabilities

CSPs have reached an inflection point as they look to execute their 5G-based strategies. 5G isn't simply the next generation of mobile technology enabling "greater speeds and feeds." There is a perpetual cycle between society and technology; one advances, which facilitates advancements in the other, which then fosters change in the other, and so on. Today, we're living our lives differently with digital experiences increasingly defining our society. Technology enabled remote work at massive scale during

the COVID-19 pandemic, as well as innovative new applications such as smart farming, remote surgeries, and semiautonomous vehicles. Our mobile devices now communicate with smart thermostats, appliances, and security cameras in our homes. Enabling these kinds of digital experiences with legacy networks requires a transition to a more open and agile infrastructure.

Traditional RANs were enormously expensive to purchase, maintain, and operate. Virtualizing the RAN and beginning to break it down into manageable parts — that is, disaggregating it — not only reduces costs, eases maintenance, and streamlines operations, but also introduces key ingredients that are limited in traditional RAN environments: agility and innovation (see Figure 1-1).

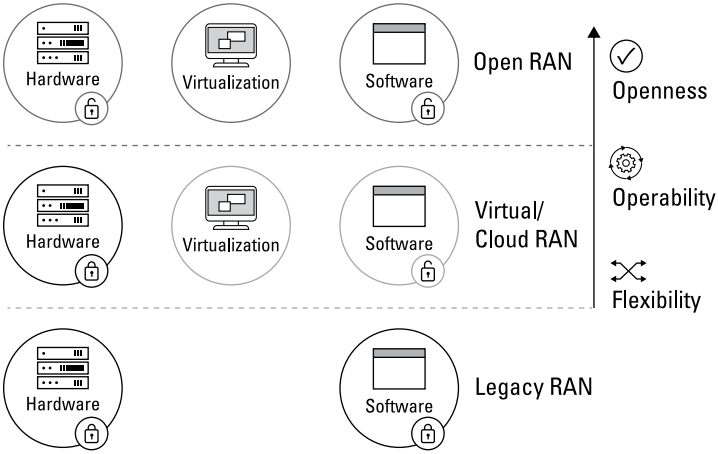


**FIGURE 1-1:** Virtual/cloud RAN and Open RAN enable openness, operability, and flexibility.

# Traditional RAN

In a traditional fixed-function RAN architecture, Layer 1 through 3 functions all run on a proprietary hardware/software system (the baseband unit [BBU]), which sits at or near the bottom of a cell tower (see Figure 1-2). Lack of programmability in the legacy RAN model limits the ability of CSPs to directly innovate and drive new, differentiated, and monetizable services. Instead, innovation happens at the pace of the network equipment provider (NEP) and can be slow. This fixed-function model hinders the ability of CSPs to integrate new ecosystem innovations.

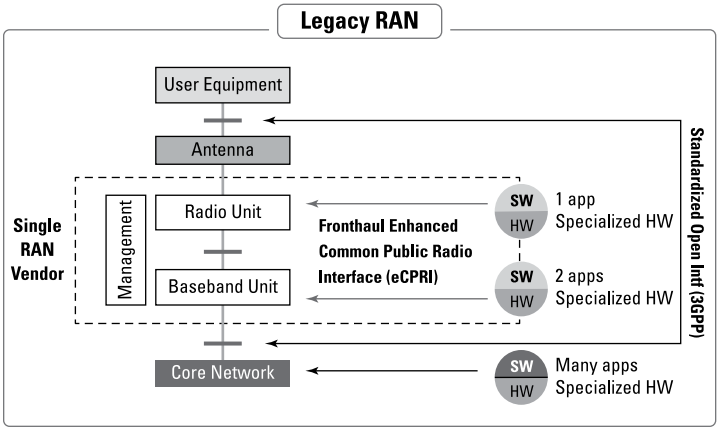


**FIGURE 1-2:** Legacy RAN architecture.

REMEMBER

There are significant constraints in traditional RAN architectures that inhibit a CSP's ability to directly execute a 5G-based technology evolution strategy, including the following:

- **Pre-integrated software and hardware stacks** from single vendors have closed interfaces (if interfaces are exposed, they're limited).
- **Siloed resources** run independently of the rest of the network and resources can't be shared across functions. It's a dedicated stack for a dedicated function.
- **Software upgrades typically require a full upgrade** of all software and bring-up/tear-down of the cell site. Evolving to cloud-native platforms and architectures streamlines upgrades/updates to individual components as new capabilities become available.
- **The market has traditionally been dominated by a small number of vendors,** limiting ecosystem competition, interoperability, and innovation.
- **Innovation is stymied by long release cycles** (which can take several months to over a year), and CSPs are dependent on vendors for changes and updates.
- **Scale and agility to meet fluctuating demand can be impeded due to an all-or-nothing implementation** resulting in resources being highly overprovisioned to guarantee performance during peak periods, but otherwise sitting stagnant much of the time.

- **Programmability and flexibility are limited by a single provider, which limits the CSP** to only that partner's newly offered 5G services.
- **Traditional RAN architectures, which deploy equipment largely at physical cell sites, do not offer an opportunity to pool and share resources across cell sites** during periods of inactivity and peak loading. As a consequence, this leads to large-scale energy inefficiency that hasn't been well managed in typical data center models.

## Virtualized RAN

CSPs are increasingly embracing virtualization technology to lower costs, increase agility, and drive new service innovation. Today, for the most part, CSP core networks are virtualized and software defined. Other than a few early moving CSPs, however, RAN workloads are still monolithic. The journey to migrate to a virtualized, cloud-based architecture known as virtualized RAN is underway.

Virtualizing the RAN means disaggregating 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, commercial-off-the-shelf (COTS) hardware. The BBU is split into multiple virtual functions:

- The virtual distributed unit (vDU)
- The virtual centralized unit (vCU)

By logically splitting out these functions and creating a pool of sharable resources, CSPs have much more flexibility in terms of where they place their workloads and better economies of scale through centralization. For example, vCUs can be centralized at designated sites, instead of 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 scale up and down as needed. In addition, the ability to shift from proprietary to COTS hardware allows CSPs to reduce their overall capital expenditures (CapEx) and operating expenditures (OpEx).

REMEMBER

The vRAN enables CSPs to use resources in the RAN, as well as public cloud resources, edge resources, and even core resources. Based on their applications' needs, CSPs will be able to access resources across the network with the vRAN. Say goodbye to silos!

Disaggregating the RAN software and hardware opens the RAN to a broader open vendor ecosystem. This first step separates the vDU/vCU capabilities from the hardware, enabling more vendor options. For example, this disaggregation provides flexibility by allowing aggregation of the CU while the DU is at the cell site.

TIP

The vRAN has many advantages, including the following:

- **Increased resource efficiencies and reduced CapEx:** The vRAN requires fewer hardware resources than the traditional RAN, and the hardware it does need generally costs less than purpose-built equipment, which potentially reduces CapEx. Competition among vendors as CSPs scale their networks over time will further reduce the cost of COTS hardware and software.
- **Reduced OpEx:** Streamlined operations across the network and increased visibility will reduce operational costs, drive new business opportunities, and improve customer experiences.
- **Greater operational efficiencies:** It delivers operational efficiencies along with elastic scale that can adapt to shifts in network demand. Innovative and consistent operational practices can be applied across the entire 5G network.

The vRAN is an important step on the path to an Open RAN architecture, but virtualized RAN functions are still proprietary and there is no interoperability between different RAN vendors' solutions. This is why the next step on the RAN journey — Open RAN — is so important.

## Open RAN

The shift from proprietary systems in the traditional RAN to an open, standards-based architecture leveraging COTS hardware and software is fully realized by an Open RAN. An Open RAN involves further disaggregating the management and control planes from the data plane of the vRAN functions. It replaces proprietary vendor interfaces with open standards-based interfaces,

enabling the vCUs and vDUs to interoperate with control and management units from different vendors, thus delivering a fully open and programmable RAN. Consequentially, 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 vendor diversity is key, introducing new sets of operating arrangements for cost-effective end-to-end coverage.

TIP

The advantages of Open RAN include the following:

- Disaggregated software and hardware with open interfaces will enable multivendor compatibility. That means new and innovative RAN vendors can enter the market.
- CSPs can deploy new services with ease because vRAN is built on a software-based architecture. Flexibility increases because the CSP can "spin up" and "spin down" RAN capabilities with relative ease.
- The highly programmable infrastructure enables dynamic responses to fluctuating demand and eliminates inefficient use of spare capacity.
- The multivendor environment encourages competition and innovation with best-of-breed solutions from different RAN vendors.
- Disaggregation of management and control planes from the vRAN functions (basically handling the data plane) allows the RAN intelligence to be managed and controlled, more centrally, by a newly introduced entity called RAN Intelligent Controller (RIC), making the RAN programable.
- The RIC's ability to host RAN-centric applications enables new application vendors to enter the RAN market, bringing new innovation to CSPs.
- Strong relationships between RIC vendors and application vendors enhances rapid innovation propelled by an open ecosystem.

The Open RAN represents a shift from traditional RAN architectures dominated by a small ecosystem toward a disaggregated, multi-vendor environment with modular elements, open interfaces, and programmable infrastructure. The O-RAN Alliance (O-RAN) is an operator-led forum borne out of CSPs' needs for

better economics and choice. O-RAN, the Telecom Infrastructure Project (TIP), and other industry bodies are all about driving an open, disaggregated, and programmable RAN that accelerates innovation, monetization, and a new economic cost structure. O-RAN is a specific architecture that guides the standards for an Open RAN. To enable network programmability, the O-RAN Alliance's architecture introduces the RIC (see Figure 1-3).

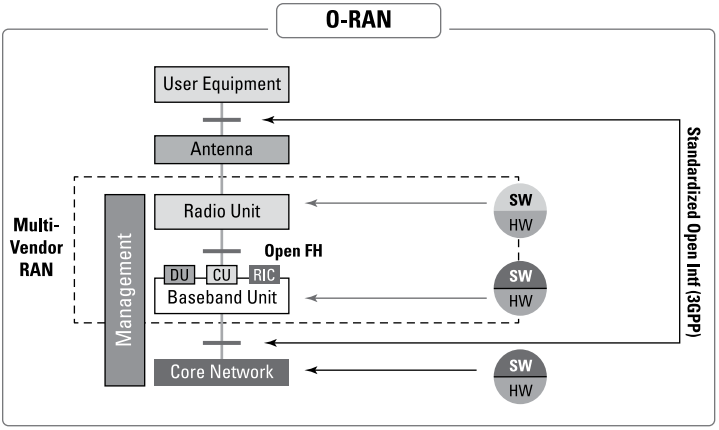


**FIGURE 1-3:** The O-RAN Alliance Open RAN architecture.

REMEMBER

Open RAN comprises an evolving set of industry standards for RAN interfaces that support interoperability across equipment from multiple vendors with the potential to reduce existing constraints through centralized automation that simplifies RAN operations. The O-RAN Alliance is a worldwide community of mobile network operators, vendors, and research and academic institutions operating in the RAN industry to develop the O-RAN architecture and standards.

IN THIS CHAPTER

- Recognizing the need for change
- Exploring new capabilities and functionality
- Addressing RAN challenges on the journey to the cloud

# Chapter 2
# Solving Legacy RAN Challenges with a Modern RAN

Communication service providers (CSPs) must quickly innovate and then rapidly and economically deploy new services to capitalize on the 5G opportunity. However, the legacy radio access network (RAN) deployment model — running on purpose-built hardware — is too inflexible in terms of cost and time to market to enable efficient delivery of innovative new 5G services.

In this chapter, you find out why and how the RAN is changing and the challenges that must be addressed by CSPs and vendors in the RAN journey to the cloud.

# Understanding Why the RAN Is Changing Today

The days when a mobile phone was just a phone are long gone. So, too, are the days when a smartphone was "smart" simply because it could download email and send text messages. Today, people rely on their smartphones and other personal mobile devices to navigate from point A to point B, stream their favorite TV shows and music, pay bills, and much more. There's an app for practically everything, and consumers have an insatiable appetite for "more" and "faster."

It probably wouldn't be much of a stretch to suggest that more people would panic at the thought of accidentally leaving their smartphones at home than the realization that they left home without putting on their pants. For many people, a broken or lost smartphone would be cataclysmic — their bills wouldn't get paid, they wouldn't be able to find their way to a new restaurant, and their friends and followers on social media would worry incessantly that they hadn't posted a funny cat video in the past six hours!

But smartphones are just one example of how technology is changing society. Today's homes are equipped with smart doorbells and security cameras, smart thermostats, smart lights, smart appliances, and more. Wearables track people's activity levels and notify them (and perhaps their healthcare providers) when their blood sugar level is too low or their heartbeat is irregular.

Technology enabled remote working and remote learning at massive scale during the COVID-19 pandemic. For many businesses, remote working has become normal, and it will be an indelible model for work — either entirely or as a benefit (for example, being able to work from home a couple days a week) — for the foreseeable future.

New use cases for consumers will soon include more immersive stadium experiences that allow spectators to view the action up close in real time by selecting the camera angles they prefer from their smartphones. Augmented reality will enable customers to try out products or try on clothes before they make a purchase — whether shopping in a brick-and-mortar store or online. And semiautonomous smart vehicles will become more prevalent,

helping to increase energy efficiency, reduce traffic jams, and improve safety.

For business and industry, municipalities will connect smart homes to smart meters in smart grids, smart agriculture will leverage advanced sensors to monitor irrigation and soil quality, and remote medical services (including remote surgery) will deliver lifesaving medical care to patients in remote areas.

From the most basic applications to the most sophisticated use cases, wireless connectivity is becoming ever more crucial to delivering the digital experiences that define modern society. CSPs need a modern, Open RAN that provides the flexibility to deliver customizable services and support unique application requirements for performance, latency, reliability, security, manageability, and scalability.

## Looking at New Capabilities and Functionality

The RAN is the on-ramp to the Internet for billions of mobile devices, including smartphones and Internet of Things (IoT) sensors and devices. To support new and evolving applications and use cases, CSPs must enable new capabilities and functionality in a modern RAN, including the following:

- **Performance:** New applications and use cases for enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC), and massive machine-type communications (mMTC) have different requirements for speed, latency, availability, capacity, and throughput. Advances in beamforming and multiple-input/multiple-output (MIMO) technologies, among others, will enable these diverse requirements.
- **Scalability:** The RAN will need the ability to scale massively to support billions of mobile devices and IoT devices, particularly for mMTC use cases potentially requiring thousands of sensors and devices in a relatively small geographic area to connect to the network.

- **Security:** The scale, sophistication, and potential damage of cyberattacks continues to grow, and endpoints — including mobile and IoT devices — represent a large attack surface for cybercriminals. Zero Trust, certificate authentication, isolation between functions, and user data encryption are all important controls that need to be considered to protect the RAN.
- **Quality of service (QoS):** Network slicing in 5G effectively enables QoS for different use cases, particularly URLLC, including admission control, load balancing, and better customer experiences.
- **Built-in intelligence:** Artificial intelligence (AI), machine learning (ML), autonomy, and intent-based networks will enable a more customizable user experience and help to maximize both value and revenue.
- **Multivendor support:** Open application programming interfaces (APIs), improved life-cycle management, and new service management and orchestration capabilities will lead to lower cost of ownership and simplified paths to new revenue opportunities.
- **Greater manageability:** Simplified operations will reduce operational management costs such as onboarding and troubleshooting and enable efficient spectrum management, improved service management and orchestration, network resiliency, and guaranteed performance/reliability for specific applications using new capabilities such as network slicing.

The key components of a modern RAN include the following (see Figure 2-1):

- **Distributed base stations:** Instead of deploying cumbersome custom rack-based systems, a distributed base station consists of two components that offer flexibility and a new paradigm for building mobile networks: A baseband unit (BBU) is connected to the remote radio head (RRH) via the CPRI interface through optical links. Distributed base stations deliver many advantages over traditional base station deployments including:
  - *Reduced CapEx* for building high-density, high-capacity mobile networks

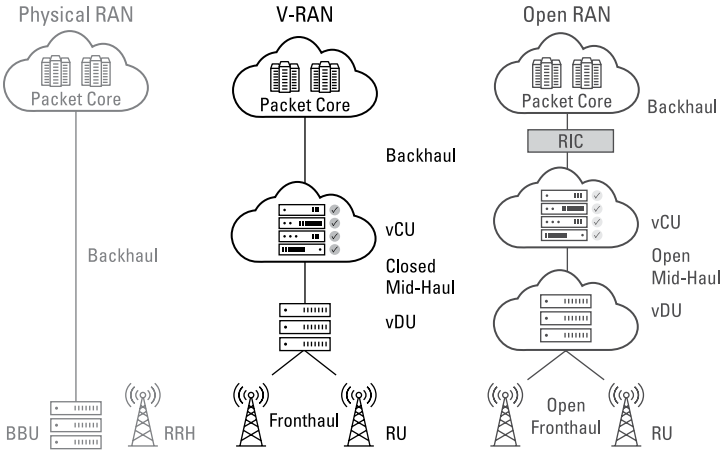


**FIGURE 2-1:** Key components of a modern RAN.

- *Reduced OpEx* due to lower site leasing costs and reduced power consumption
- *Greater flexibility* in software configuration and management, including support for the Cloud Radio Access Network (C-RAN) architecture

» **Radio unit (RU) or remote radio unit (RRU):** The RU or RRU processes digital radio signals and transmits, receives, and converts the signals for the RAN base station. When the RU receives signal information from the antennas, it uses the Open Front Haul (OFH) interface to communicate with the Distributed Unit (DU). The reverse of this process returns data to the user. OFH is an Open RAN standard that allows CSPs to source DU from one vendor and RU from another.

» **Distributed unit (DU):** The DU is controlled by the centralized unit (CU) and runs the Radio Link Control (RLC), Medium Access Control (MAC), and parts of the physical (PHY) layer at a base station. The DU is deployed at the cell site and reduces workload processing time at the RAN's far edge.

- **Centralized unit (CU):** The CU implements the higher layers of the 3GPP stack, including the Radio Resource Control (RRC) to manage the life cycle of the connection, Service Data Adaptation Protocol (SDAP) to manage QoS of the traffic flows, and Packet Data Convergence Protocol (PDCP) to manage reordering, packet duplication, and encryption for the air interface. The CU also runs the packet data convergence protocol, which performs numerous technical functions including compressing and decompressing IP data stream headers and transferring user data. The CU can be deployed at the cell site or at a central aggregation site. The control plane and user plane functions of the CU can also be separated using software-defined networking (SDN) principles.


TECHNICAL STUFF

The DU and CU are disaggregated from legacy baseband units (BBUs) where they were combined to process signal information from the RU (or RRU) so it can be forwarded to the core network.


TIP

Virtualized RAN (vRAN) virtualizes the baseband functions in the DU and CU. A virtualized DU and CU architecture can reduce the cost of deployments, enable flexibility in RAN infrastructure design, and support C-RAN infrastructure.

- **Open and standardized interfaces:** Interfaces in place in an Open RAN network are defined by the O-RAN Alliance and include O1, O2, A1, E1, F1 and E2. This is key to secure the interoperability between different vendors, foster innovation, and provide network flexibility.
- **Service, management, and orchestration:** O-RAN Alliance has architected the Service, Management and Orchestration (SMO) framework with three key capabilities:
  - Cloud infrastructure management and orchestration.
  - Fault, configuration, accounting, performance, and security (FCAPS) management of the 3GPP aligned RAN element management for O-RAN network functions.
  - Non-real-time RAN Intelligent Controller performs non-real time (less than 1 second) intelligent radio resource management and supports intelligent RAN optimization by providing policy-based guidance, data analytics, AI/ML model management, and enrichment information to underlying Open RAN elements (see Figure 2-2).

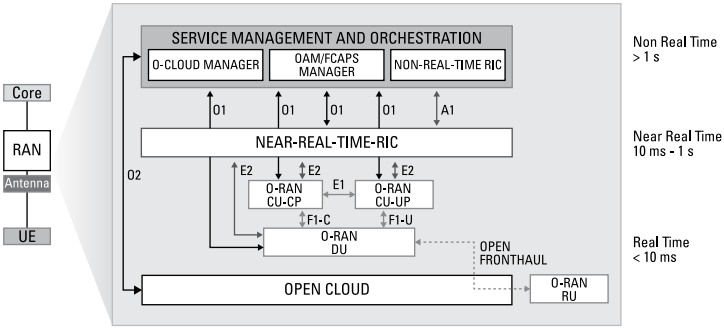


**FIGURE 2-2:** Service Management and Orchestration in a modern RAN architecture.

» **RAN Intelligent Controller (RIC):** The RIC is responsible for enhancing capabilities for traditional and virtualized RAN solutions management and control plane functions, and further disaggregating them from the data plane function. By disaggregating these functions, the RIC abstracts the complexities inherent with the RAN and enables programmability. The RIC is a software platform with open interfaces that can host xApps and rApps (see later in this list), developed by third-party software providers (not limited to RIC vendors, network equipment providers [NEPs] or CSPs) for automated network intelligence and RAN innovation. Two types of RICs are defined by the O-RAN Alliance reference architecture:

- *Non-real-time (non-RT) RIC:* The non-RT RIC is considered a management plane entity. It hosts rApps, which enable control and optimization of Open RAN elements and resources with control loop response times that are greater than 1 second. It is typically located centrally in the CSP's RAN network and provides instructions and policies to the near-real-time RIC (rApps to xApps) to ensure that the RAN is optimized, like spectrum orchestration, to meet customer requirements.
- *Near-real-time (near-RT) RIC:* The near-RT RIC is considered a control plane entity and is typically deployed in a more distributed manner than the non-RT RIC. The near-RT RIC hosts xApps that enable programmatic control of CU and DU functions with control loop response times less than 1 second, and more typically on the order of tens of milliseconds.

TIP

TECHNICAL STUFF

Through the programmability that it provides, VMware's near-real-time RIC modernizes the RAN to be open and modular. This modern RAN is built with best-of-breed solutions from a rich and vibrant ecosystem of partners and provides the RAN intelligence to assure all the solutions work together.

VMware RIC consists of two individual products:

- *VMware Centralized RIC:* VMware Centralized RIC is an implementation of the non-RT RIC in the O-RAN Alliance reference architecture and hosts rApps.
- *VMware Distributed RIC:* VMware Distributed RIC is an implementation of the near-RT RIC in the O-RAN Alliance reference architecture and hosts xApps.

- **rApps:** rApps provide management plane related features and functionalities, developed by third-party software providers, providing policy guidance to the underpinning RAN infrastructure. rApps can utilize AI/ML to learn intricate traffic patterns and instruct VMware Distributed RIC to perform certain RAN optimization tasks.
- **xApps:** xApps provide control plane related features and functionalities, developed by third-party software providers, and interact directly with underpinning RAN infrastructure (DU, CU, and so on) to perform, for example, optimized use of radio spectrum.
- **Open Cloud:** VMware Telco Cloud Platform RAN is a horizontal platform, leveraging Intel's FlexRAN reference software, that enables automation and consistent operability across different NEPs' vRAN functions deployed in the best geographical locations to perform their functional purposes. This flexible design increases performance, coverage, and capacity while improving quality of experience (QoE) without having to linearly scale the entire RAN. A horizontal platform provides better security protection than conventional parameter-based and reactive security approaches. It also provides vRAN investment protection by allowing CSPs to run vRAN functions now and evolve to Open RAN using the same platform as Open RAN standards and technologies mature. Finally, a horizontal platform provides the ability to host custom 5G applications alongside vRAN functions to monetize vRAN investments.

# Recognizing Challenges in the RAN Path to Cloud

One of 5G's massive performance improvements comes from the introduction of massive multiple-input/multiple-output (MIMO) antenna solutions. Although 5G will operate in traditional 4G bands with dynamic spectrum sharing (DSS) features, the real improvement in mobile broadband experience comes with the further exploitation of the physics of cellular with sophisticated and tightly integrated antennas with radio function. This integration is typically done in higher bands. Even with the introduction of antennas with beamforming capabilities, due to the frequency characteristics of 5G antennas at higher bands, the density of antennas will increase — in turn, increasing cost and complexity. Deployment for 5G includes a variety of centralized models to optimize site architecture to manage the increased site count. These centralized models have led to a significant need to look closely at the compute, storage, and site architectures whenever architectures become centralized. Taking a cue from the evolution toward the IT/enterprise world, operators have pushed that these centralized locations should adopt standard and open hardware/software definitions and, further, that they should be virtualized. This trend has even spread to the physical cell sites with servers/storage now virtualizing the workloads present at physical cell sites that are responsible for RAN network function.

Although the move to cloud-based systems adds performance improvements, it also adds complexity. When you start moving functions to cloud-native and microservices architectures, your network inherently becomes more complex. You no longer have exclusive systems performing a single function with dedicated resources. Instead, numerous functions are stitched together as smaller requests (microservices) that span many resources across multiple public, private, and edge clouds. Automation, orchestration, and intelligence are critical in the modern RAN because manually managing these types of distributed processing systems is difficult, if not impractical.

Additionally, 5G service quality and user experience improves from reduced latency and faster response times if the CSP can host applications close to the end customers. Unfortunately, due to the distributed nature of the modern RAN for 5G, the space and

power supply constraints inherent to traditional RAN makes this a cumbersome and cost-prohibitive proposition.

Some potential challenges associated with legacy RAN deployments include the following (see Figure 2-3):

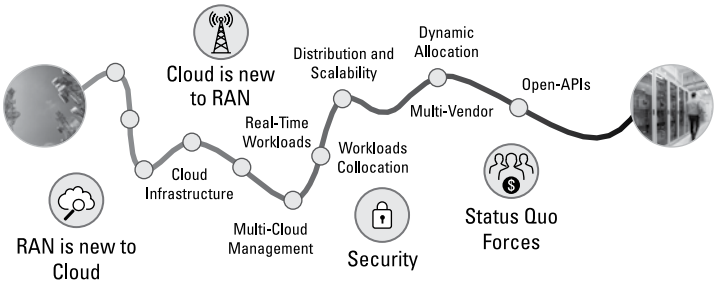


**FIGURE 2-3:** Challenges associated with legacy RAN deployments.

- **Costs and risks:** Building enough RAN sites, especially in urban areas, to support 5G deployments will increase capital expenditures (CapEx) as well as operating expenditures (OpEx). If truck rolls are required to manage the sites, OpEx goes up all the more. The cumulative cost of the real estate required for a big increase in RAN sites will drive CapEx or OpEx costs higher, too, depending on whether the CSP buys or leases the land. In addition to towers, 5G will be deployed in parking garages, on the sides of tall buildings, and in other locations. Because of the limited distances 5G signals can travel, especially with higher frequency bands, the number of distributed resources compared to 4G is going to multiply. Providing power to these sites will also be costly, with geographic spread potentially pushing power costs higher in more remote locations.
- **Operational complexity:** Introducing new services in more RAN sites adds complexity to their operation, as well as higher operational costs, especially if they're built using purpose-built hardware. There are zero efficiencies because rollouts and updates are manual and require truck rolls to every site.
- **Multivendor interoperability:** Vendors must shift from homogenous fixed-function systems to heterogeneous software-based architectures and APIs to enable greater interoperability and agility in the RAN.

- **Inadequate security:** Adding more RAN sites, with COTS hardware, which is highly disaggregated and hosted on multiple clouds, coupled with an increase in connected devices, expands the mobile network's cyberattack surface. Conventional parameter-based and reactive security countermeasures are increasingly deficient in a 5G threat environment, which calls for a Zero Trust architecture that automates the provisioning and management of security controls and dynamic, built-in security that adapts to changing threats. Enhancing security in a traditional RAN environment is possible, but the extra processing involved can negatively affect latency.

REMEMBER

CSPs are highly focused on monetizing their significant investments with 5G. In order to do this, they must host an array of new services driving immense opportunities in their consumer and commercial business portfolios. However, traditional RAN infrastructure deployments (3G, 4G, and early 5G, RAN network[s]) have experienced flexibility, cost, and adaptability obstacles in support of outside-in innovation. vRAN and ultimately Open RAN represent the future. However, the choice of vRAN platform is critical to success with 5G. A secure, high-performing, and highly automated vRAN platform provides a common horizontal basis for deploying 5G and traditional services. Chapter 3 explains how to unify the RAN with the network by building a horizontal vRAN platform.

IN THIS CHAPTER

- Laying the foundation with a horizontal platform
- Using a cloud-first approach
- Aligning key stakeholders
- Realizing new revenue growth opportunities
- Optimizing performance in the evolving RAN
- Looking at cloud-first RAN

# Chapter 3
# Unifying the RAN with the Network

In this chapter, you see how a common horizontal platform can help communication service providers (CSPs) unify networks and clouds to eliminate silos, what operational considerations need to be addressed among your different stakeholders, and how to get the most value out of a monetized Radio Access Network (RAN).

## Building a Horizontal Platform

The possibilities for tomorrow's 5G networks and services are seemingly limitless: network slices tuned to the applications running on them, ultra-low-latency consumer and business experiences, mass-scale Internet of Things (IoT) deployments, and much more. CSPs are well on their way to delivering these 5G experiences, but there is still work to do to fully realize their 5G visions.

Every approach to realize the full benefits of 5G will be different and there are many moving pieces to support the 5G transformation. Some common core ingredients are needed, including cloud-native technology and cloud-first automation. The best way to adopt these core ingredients is with a common horizontal architecture that unites all multi-vendor networks and clouds in a single platform. A fully modular and multitenant platform should integrate field-proven compute, storage, networking, management, and operations products across domains — core, RAN, edge, and public cloud.


TIP

By embracing this horizontal platform approach, operators can avoid creating new network silos when building out 5G. At the same time, they gain a simplified, consistent overlay across their complex heterogeneous environments, making them much easier to manage, scale, and secure.

Virtualized RAN (vRAN) deploys RAN functions on a horizontal platform so those functions can leverage multicloud resources. RAN controller functions are moved to centralized servers, enabling the CSP to optimally pool and adjust RAN resources to accommodate traffic and service delivery needs.

To meet the requirements for a next-generation RAN platform, vRAN must do the following:

- **Provide a common horizontal platform.** Flexibility and agility are key goals for implementing vRAN. Ideally, a CSP will be able to deploy vRAN and non-RAN workloads on the same platform. The common platform approach also provides the potential for a smooth evolution toward future services without disrupting operations or requiring an overhaul of network design.
- **Deliver high performance.** CSPs can run vRAN functions alongside 5G services at the RAN sites, physically close to their customers, to deliver the low latency and high throughput required by 5G services. By virtualizing the RAN, CSPs will also see performance increases as every component in the stack is continuously optimized to achieve peak performance.
- **Enable automation.** The vRAN platform must be able to automate infrastructure deployment and offer programmable provisioning of the underpinning infrastructure and network services, and enable network slicing across an

end-to-end network, as well as specific vRAN functionality across the service life cycle.

- **Offer a flexible, RAN-focused ecosystem.** The new generation of vRAN platforms has to be designed to leverage the skills and strengths of disruptive operator planning organizations, as well as the experienced operator that is balancing a "brownfield" network against a new virtualized network. This might mean creating integrations between the virtualized platform and vRAN functions and legacy and traditional RAN network functions.
- **Reduce total cost of ownership (TCO).** By disaggregating network software and hardware, management across multi-vendor resources is simplified, reducing costs.
- **Ensure strong security.** Security is integral to success with a new vRAN platform. It's a multidimensional issue that spans identity management and access control for users, as well as endpoint protection, network security, and more. Automation and artificial intelligence (AI) are essential for security because advanced 5G and future 6G networks will be far too large, fast-moving, and complex to defend with manual processes. The right platform will integrate with advanced incident response solutions and security operations (SecOps) tools, as well.

By unifying networks and clouds on a common horizontal platform, CSPs can optimize practically every aspect of deploying and operating their 5G networks, including the following:

- **Design:** CSPs have spent too long letting vendors dictate the timing and capabilities of their services. Moving to an agile, cloud-native platform will simplify the tooling across multi-vendor, multicloud domains. With a single set of tools, designing and developing new services is far easier.
- **Deploy:** Cloud-first automation empowers CSPs to deploy new infrastructure and services at thousands of distributed locations, while minimizing costs. Predefined templates and zero-touch provisioning in a common platform allows CSPs to quickly deploy new network functions and new services consistently. They can draw on a common virtualization layer to apply consistent security policies across all sites. And they can continually deploy innovative new capabilities at the edge, while managing everything centrally.

- **Operate:** Using a shared platform that abstracts the underlying hardware to create a common pool of storage and network resources simplifies complexities of transforming CSP architectures and reduces operating costs. Now, operators can use the same consistent tools and processes for things like patching, monitoring, alarm and fault handling, and troubleshooting — even across a heterogeneous multivendor environment. And automating the life-cycle management of infrastructure, Kubernetes clusters, network functions, and 5G services becomes much easier.
- **Optimize:** The same shared horizontal platform also makes it easier to continually optimize CSP networks and services. Drawing on machine learning and AI, operators can monitor the entire 5G environment, predict the impacts of network changes, and continually analyze and optimize the network with closed-loop operations.

## Adopting a Cloud-First Approach

Building a telco cloud to empower a modern RAN requires unique expertise. Service providers have been operating with single, or at least limited, vendor relationships in the past, so moving to a cloud-centric approach will require partners with new skills who support new operating models.

TIP

Chapter 6 goes into detail about how to pick partners capable of supporting a transformation of this significance.

From a platform perspective, one of the most important foundational characteristics is cloud expertise. Aside from the technological reasons for this requirement, finding a partner with cloud expertise will also help service providers redefine the new operational models needed to thrive in these multi-vendor environments.

Included in these new operating models is the shift to a cloud-first approach. As mentioned in the previous section, the capability to remove network silos surrounding the RAN will give service providers the flexibility of delivering services across a unified, single network. That said, with recent advances in networking and compute technologies, the capabilities of cloud-based networks offer many advantages compared to fixed-function network elements.

Fixed-function networks are inflexible and monolithic, but cloud-based networks can scale on demand, mix and match workloads requiring different operating systems on the same server, easily manage application life cycles, and automate service delivery to accelerate time to market — all without overprovisioning, but with additional layers of security and simplified operations across the network.

Therefore, many service providers are moving to a cloud-first operating model to fully realize the benefits of the cloud.

With a unified platform in place, a cloud-first approach allows service providers to dynamically deliver services leveraging the most efficient paths available. This typically means "cloud-first," but with a common platform and the support of system integrators and network function vendors, legacy resources are overlayed and used as needed.

## Bridging RAN Stakeholders

Unifying the RAN also requires CSPs to unify their different RAN stakeholders from an operational perspective, including the following:

- **Strategic commitment:** Network transformation initiatives supported with strong, visible, and vocal executive buy-in generally enjoy greater success. The leaders of the company need to make sure the organization understands and appreciates the vision to provide credibility to all the hard work it will take to implement.
- **Agile development approaches:** If you're building a software-focused network, you need to operate more like a company that builds software, not one that builds networks. This change in approach means starting the move to a flexible and agile DevOps culture. Agile approaches to network transformation enable smaller wins to celebrate momentum internally and help the organization focus on the aspects of the transformation that will bring the most value first.
- **Retraining:** Some teams will inevitably resist change, often because they feel like they're becoming obsolete and being displaced. CSPs need to make it clear that they need teams

who understand their traditional approaches while applying more modern, cloud-native principles — they need the best of both worlds. Proactive training programs allow these teams to learn new technologies and processes, thereby improving their willingness to support the transformation and increasing their value to the organization.

- **External stakeholders:** CSPs historically have not been very vocal within the Information and Communications Technology (ICT) innovation ecosystem. To bring about the needed change, CSPs need to actively participate in the co-innovation practices throughout the market. You need to put value in if you want to extract value. Talk about what's working and what isn't, what you want from the broader ecosystem, and so on.

## Monetizing the RAN

The rollout of new 5G services will intensify the already fierce competition among CSPs and their more agile counterparts. As CSPs innovate in the RAN, they'll build their own services and bring in new best-of-breed partner services.

To capitalize on the 5G opportunity, reduce operating costs, and create revenue from the investment in the RAN, CSPs must

- Break down complex, monolithic software stacks and eliminate silos of network layers and dedicated management tools.
- Reduce their reliance on — and the cost of — specialized physical network appliances.
- Follow a multivendor strategy that prioritizes options and flexibility for CSPs.
- Replace existing hardware-centric operating models with software-defined approaches and agile DevOps practices.
- Develop the agility and automation to respond to changing market conditions by quickly launching or modifying services.
- Improve network efficiencies by delivering the right services using the right resources, to the right place, at the right time.

- Control innovation and proactively manage the customer relationship leveraging a multicloud environment that includes the core, edge, public cloud, and RAN.
- Manage and automate multivendor network functions in a unified way.
- Reduce operational complexity and operating costs.
- Implement new cloud-native approaches to be able to quickly deploy enterprise services like security, network slicing, private cellular networks, and multi-access edge computing (MEC).
- Leverage MEC to address different service requirements and new long-term opportunities, including dynamic content positioning, competition against hyperscalers (like Amazon, Google, and Meta), and conflicting strategies.
- Unlock the full potential of Open RAN with an AI-based RAN Intelligent Controller (RIC) to improve flexibility, customizability, agility, and performance in the RAN. Non-real-time and near-real-time RICs will also bring new technologies to the RAN that the industry hasn't seen yet.

## Managing Performance for a Transforming RAN

There is no question that virtualized environments provide far better capabilities to enable the demands of 5G and beyond. Virtualization with hypervisors gives you the ability to mix and match workloads requiring different operating system (OS) versions on the same server (bare metal does not). This saves an incredible amount of hardware, CPU processing power, cooling resources, and physical space. This is important for cell sites where space is limited and innovative apps are being developed.

Beyond hardware optimization, virtualization also supports automated service delivery. Time to service delivery starting from bare metal can be reduced from days and weeks to mere hours.

Change is inevitable, and agility is key. Software updates are constant, and hypervisors allow apps and OSs to be abstracted from the underlying hardware. This makes for easy OS upgrades and

rollbacks. There is no need to take the asset offline and reroute traffic when doing upgrades as you would have to do with bare metal.

Multi-tenancy, operational consistency, security, and visualization are also all areas where virtualization will enable 5G requirements. The remaining question remains performance.

Performance is king, and resistance to virtualization often rests on the misconception that running Open RAN or vRAN containerized workloads on a hypervisor increases latency and hinders performance. This is simply not the case. Virtualization technologies have matured over the last decade — as does any new technology. Indeed, industry-standard cyclic tests and operating system latency (oslat) performance tests show no performance penalty when using a VMware ESXi hypervisor, and VMware vSphere 7 Update 3 is easily within RAN workload latency requirements (see Figure 3-1).

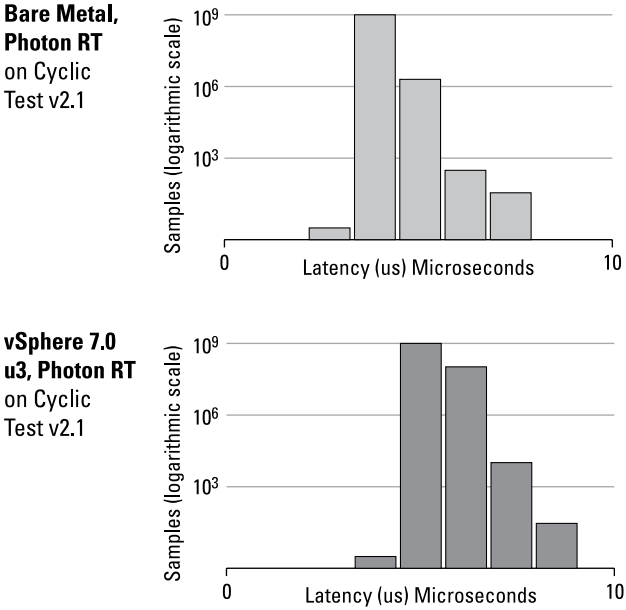


**FIGURE 3-1:** Comparing bare metal and VMware vSphere performance latency.

# Understanding Cloud-First RAN

The way networks were architected in the past won't work for cloudified networks. VMware Telco Cloud Platform RAN provides a way for CSPs to modernize and monetize the RAN by evolving from the traditional RAN to the vRAN. The platform establishes a foundation for eventual migration to Open RAN.

VMware Telco Cloud Platform RAN helps CSPs virtualize RAN functions on a horizontal platform that is specifically optimized for RAN. VMware Telco Cloud Platform RAN is a RAN-optimized horizontal platform that has been hardened through strenuous testing and integration work with key RAN vendors. VMware and Intel provide hardware and software integrations that have been proven in the field. Customers can rely on the experience and expertise of both companies, plus pre-validated optimized architectures and orchestration scenarios that are proven to work outside of the lab, in real-world environments. These processes help to maximize performance and improve resource utilization, meeting and exceeding stringent requirements inherent to the RAN.

The platform is designed so CSPs and their customers can easily develop custom 5G services at RAN sites. It provides tooling that lets the CSP offer edge computing services. This is possible because 5G services, developed on and delivered from VMware Telco Cloud Platform RAN, can directly access ultra-high-speed 5G networks end-to-end — from the service consumer to the core of the network.

Here are the key capabilities and benefits of VMware Telco Cloud Platform RAN (see Figure 3-2):

- Intel FlexRAN reference architecture and the Intel Select Solution for vRAN on VMware Telco Cloud Platform accelerate and ease the adoption of the vRAN.
- Cloud-native and full virtualization deployments are supported.
- Complexity from cloud-native and virtualized environments are simplified with full automation and orchestration — capabilities that are essential to a modern RAN.
- Broad RAN use cases (such as indoor to macro, cloud to distributed RAN, and rural) are enabled.
- Flexible licensing allows customers to use software for tests and/or in commercial products.

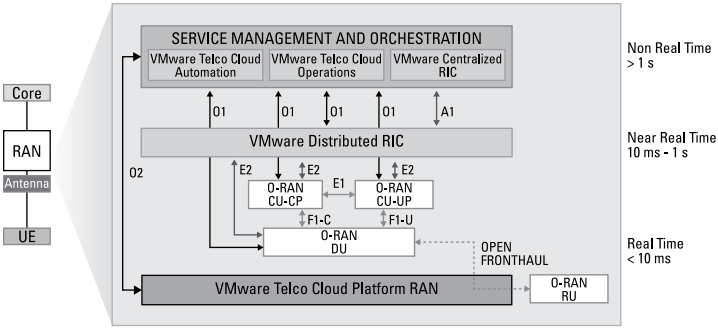


**FIGURE 3-2:** VMware Telco Cloud Platform RAN.

IN THIS CHAPTER

- Enabling innovative new applications
- Defining the cloud-optimized RAN
- Working together at the edge
- Getting new features to market faster
- Leveraging the RAN Intelligent Controller (RIC)
- Looking at the rise of community-driven networks

# Chapter 4
# Exploring Future Use Cases for a Modern RAN

This chapter explores how a modern RAN will enable innovative new applications, the role of the cloud and the edge in a modern RAN, how a modern RAN enables greater agility, RIC use cases, and community-driven networks.

## Supporting Evolving Applications

The evolution from 3G to 4G to 5G was driven by two entangled forces: technology and societal evolutions. As the technology advances, societal responses and demands realign and change. As society's behaviors change, then changes come to the technology. This cyclical relationship will continue into 6G and beyond.

As the relationship between these two forces continues and the technology matures, creating features and services will become more surgical. Next-generation services will be tailored based on the detailed data that advanced networks will tender. Services and features will no longer be monolithic. Instead, they'll be disaggregated from the resources that serve them. By extension, the

RAN will adjust accordingly to fulfill these advancing requirements. With this new level of network finesse, communication service providers (CSPs) will pinpoint users and help improve their quality of service instead of treating users all the same, as networks do today.

To enable this level of control, networks will be self-optimizing with closed-loop control. No longer will we have cell-specific control. We're moving to more fine-tuned control in every aspect of network management.

This level of dynamic network control, and on-demand service creation will require artificial intelligence (AI) and machine learning (ML). This increased intelligence will not only support automation, but improve service assurance and enable new resource-demanding services like spatial compute and holographic communications.

## The Role of Cloud

Running a large-scale network operation has always been expensive, and 5G hasn't changed that equation — at least not yet. 5G has already begun unlocking more efficient operating models and lucrative new services, but the journey is still underway, so most CSPs are en route to realizing significant value from their 5G investments. One of the largest opportunities to reduce operating expenditures (OpEx) and increase operational agility for 5G is in the RAN.

The RAN currently makes up more than half of a CSP's costs. By leveraging the efficiencies of cloud-native deployments, operators can drive down these costs and accelerate the time to value of their network investments. At the same time, future innovations will place ever higher demands on the RAN, requiring the flexibility of the cloud, the performance of virtualization, and the simplicity of automation.

With containerized 5G network components leveraging the Open RAN architecture, CSPs can now disaggregate previously monolithic RAN components. They can optimize their operations by running RAN functions on commercial off-the-shelf (COTS) hardware (with specific hardware configurations) and software in distributed locations. The Open RAN enables the intelligence

to use the appropriate resource based on the use case to guarantee performance and increase operational efficiencies for an ever-growing range of future application use cases.

However, not all RAN functions are cloud-ready yet. Although we can disaggregate and "cloudify" more parts of the network than ever, many RAN workloads still have inherent limitations on where they can be deployed. For example, the extreme performance and low-latency requirements of some RAN workloads mean they still have to run close to cell sites, either directly at base stations or at nearby far-edge data centers. A flexible virtualized and distributed infrastructure that can run on either CSP- or hyperscale-owned infrastructure deployed within 6 to 9 miles from the cell site is needed. Complete RAN workloads can't be processed in the public cloud — at least not yet — because public cloud SLAs aren't stringent enough to meet the requirements of the RAN.

## Progressing Alliance Work at the Edge

The Open Grid is a great example of the potential of community-driven networks (discussed later in this chapter) in which stakeholders at all levels of the hardware and software stack work together to unleash innovation at the edge. vRAN, and later Open RAN, enable RAN functions to be deployed at the edge to deliver high-performance, low-latency services in near-real-time. The Open Grid will be a software-defined system that stretches across the globe to support multi-cloud services via complementary resources that are employed when and where they're needed, on-demand, and with guarantees and service-level agreements (SLAs). The Open Grid combines all the necessary components to support the next generation of applications. It spans the complete stack, from the fiber in the ground to the AI and applications that deliver value to the end user.

What can you do with the Open Grid? For example:

- **Access state-of-the-art compute capabilities anywhere and everywhere becomes much easier.** This will be particularly important in places farthest away from major urban hubs, or in markets like Europe and the Middle East, where many more parties are involved in the infrastructure underpinning new services.

- **Maximize utilization of available compute capacity.** Imagine a next-generation sports stadium that offers state-of-the-art streaming digital experiences for tens of thousands of spectators — at least, on gameday. But what happens to all those edge resources on the many days of the month when the stadium sits empty? With the Open Grid, that spare edge compute capacity can be dynamically reallocated, even as the system ensures the stadium always has the guaranteed resources it needs.
- **Create massive distributed digital representations of the physical world with new emerging technologies.** Effectively, the Open Grid becomes the plumbing for ubiquitous, highly accurate global real-time augmented reality (AR) experiences.

## Rapid Future Releases

Open RAN also enables a shift from traditional waterfall development life cycles operating in closed, proprietary shops with rigid processes and three-year release cycles to a more agile DevOps methodology that leverages infrastructure-as-code and automation to drive continuous integration/continuous deployment (CI/CD) pipelines with frequent releases that are less disruptive.

By abstracting the underlying hardware layer from the software stack and providing a common tool set across network resources, the Open RAN allows developers to focus on innovation, interoperability testing, and automation to simplify operations across the network. This, in turn, enables further monetization of the RAN with innovative new service offerings that feed the consumer desire to always have the "latest and greatest" features and capabilities, as well as the need for business customers to leverage the RAN to pursue new revenue opportunities themselves.


TIP

Over-the-top (OTT) providers have been disrupting the telecommunications industry for years with voice–over–Internet Protocol (VoIP) services that focus on innovation and customer experience in the software stack leveraging existing infrastructure. CSPs must adopt this model to increase agility and compete effectively in the future.

# Enabling Next-Generation Services in the RIC

An important part of the RAN transformation journey moves beyond disaggregation to network programmability. To enable programmability of the RAN, CSPs are looking to the RAN Intelligent Controller (RIC).

The RIC is responsible for the control and management functions of the disaggregated Open RAN, which decouples the control and management functions of the RAN infrastructure from its data plane functions. There are two RICs in an Open RAN architecture, as defined by the O-RAN Alliance:

- **Near-RT RIC:** O-RAN near-real-time RAN Intelligent Controller is a logical function that enables near-real-time control and optimization of O-RAN elements and resources, via fine-grained data collection and actions over the E2 interface. It hosts external RAN-focused applications, referred to as xApps, that have control functions with a response time of less than 1 second, typically on the order of tens of milliseconds.
- **Non-RT RIC:** O-RAN non-real-time RAN Intelligent Controller is a logical function that enables non-real-time control and optimization of RAN elements and resources, AI/ML workflow including model training and updates, and policy-based guidance of applications/features in near-RT RIC. It manages rApps, with response times greater than 1 second, which are designed to realize a variety of RAN automation and management use cases. These use cases include network optimization, network healing, and more.

The RIC abstracts the underlying RAN infrastructure and enables programmability of the RAN through the xApps and rApps from application ecosystem partners.

REMEMBER

VMware Centralized RIC and VMware Distributed RIC are modern cloud-native software platforms engineered on a microservices-based architecture and, therefore, designed to run on Kubernetes infrastructure container-as-a-service (CaaS) such as VMware Tanzu and Amazon Web Services (AWS) Elastic Kubernetes Service. The flexible design of VMware Centralized RIC enables VMware to quickly support other Kubernetes CaaS such as Google

Kubernetes Engine, Azure Kubernetes Service, and even Kubernetes on bare metal.

VMware Centralized RIC supports traditional RAN and virtualized RAN environments. This allows CSPs to introduce RAN innovation in the form of rApps now, without making significant changes to their existing RAN architecture. The ability of VMware Centralized RIC to support traditional RAN enables CSPs to take the first step toward the disaggregated RAN and ultimately to the Open RAN, making the RAN modernization journey as smooth a transition as possible.

VMware RIC modernizes the RAN to be truly open and modular, built with best-of-breed solutions from a rich and vibrant ecosystem of partners regardless of the functions they offer, while providing the RAN intelligence to assure all the solutions work harmoniously.

## Community-Driven Networks

An Open RAN eliminates many traditional barriers to entry in the telecommunications industry, enabling greater innovation, particularly in the software stack, among startups and other crowdsourced initiatives. The Open RAN opens the door to innovation spanning global teams, instead of limiting CSPs to the traditional RAN architecture stacks. An Open RAN changes the way service providers engage with the broader community, enabling new partnerships between companies that were once considered competitive threats to each other. CPSs will be able to co-create solutions with ecosystem alliances and participate in standards bodies to ensure continued innovation aligned to their strategic priorities.

Opening up networks, moving to open standards, and leveraging open alliances (such as O-RAN) gives you access to the voice and motivation of an entire community of innovation with many layers of advocacy built into the model driving further competition and innovation. By proactively participating in the development of standards and leadership of alliances, you can ensure your needs are represented in the way forward. As opposed to the legacy approach of demanding a new feature or capability from your vendor and hoping they can (or will) deliver, community-driven networks allow you to get out there and contribute to the conversation to get what you want.

IN THIS CHAPTER

- Leading a successful digital transformation
- Working with industry standards and alliances
- Promoting sustainability
- Understanding political influences

# Chapter 5
# Mapping the Transformation Journey

In this chapter, you explore several keys to a successful radio access network (RAN) transformation journey, including addressing operational and ecosystem changes, the importance of industry standards and alliances, environmental sustainability considerations, and political influences.

## Understanding Internal Operational and Ecosystem Changes

Digital transformation has been the rallying cry of business and industry for more than a decade. From an ecosystem perspective, shifts are happening that alter the path of transformation. Before, everyone had a clean swim lane and they stayed in it. Now, there is more crossover between functions.

Even the communication service providers (CSPs) themselves are doing things in new ways. They're managing both technological and operational transformations and trying to find the right fit in a rapidly changing ecosystem. They aren't just competing with

other regional CSPs; they're competing with over-the-top (OTT) players, entrepreneurial startups, and more on a global scale.

Traditional business models, driven by digital transformation strategies, are being disrupted in every industry — including telecommunications. Here are three keys that are crucial to any digital transformation initiative:

- **Ensuring appropriate stakeholder support:** From your executives all the way to your field technicians and support personnel, ensuring you have the right level of commitment throughout your organization is critical. How do you get your different teams involved when they're happy with the "way we've always done it"? Explain why you're making the transformation journey, address any retraining concerns and requirements, and provide an "outside-in" industry perspective to help them understand their roles.
- **Adopting an Agile approach to change:** CSPs need to follow the lead of software companies today. Instead of releasing major upgrades every few years, software companies today have embraced a more iterative approach to application development with continuous integration/continuous delivery (CI/CD) pipelines that enable new features and capabilities to be released rapidly — typically every two to three weeks, but potentially several times per day.
- **Focusing on the business rather than the technology:** Too often, digital transformation initiatives focus on the "shiny new thing" rather than the positive changes it will bring about for the business and your customers. Instead of touting the technology itself, let your stakeholders know how the initiative will help streamline business processes, improve efficiency, simplify their work, and deliver a better customer experience.

Change is inevitable and at times uncertain, but several digital transformation trends are evident, including the following:

- **Systems will continue to change.** As technologies advance, the results are compounded by surrounding innovation. This compounding effect increases the average pace of innovation in the industry and ultimately means the pace of innovation continues to accelerate. There are several advancements on

the direct horizon that are expected to impact the future of RAN architecture, including the following:

- *Silicon disaggregation:* Today, silicon chips have central processing units (CPUs) and accelerators for different functions and the system uses the appropriate chip based on what it needs. Within the next few years, increased silicon disaggregation will lead to the development of "chiplets" with large numbers of separate CPUs and accelerators.
- *Application programming interfaces (APIs) between the network and applications:* Today, the RAN is the most complex and challenging network, and the core treats the RAN as an unknown, opaque system. There are opportunities in Open RAN to expand integration. Applications and access networks will increasingly interact in near real-time through APIs. A primitive form of this type of API is network slicing. Supporting developers will be required to deliver successful 5G transformation. CSPs can innovate in-house, but Internet service providers (ISPs) will likely lead — it's cheaper for them to create goods and services because they can build the same service for multiple regions.
- *The role of cloud:* The RAN will be decomposed and deployed in regional clouds, edge clouds, and on premises, based on requirements and efficiency.

» **Models will continue to change.** In order to take advantage of more agile networks and approaches, CSPs need to change the way they operate their networks. There are several models expected to impact the shape that CSPs will take in the future:

- *Telecom is standards driven, but the Internet world is different.* People will build first, see what works, and then standardize — from standard to software, to software to standard.
- *CSPs will move from a client/server model.* From local rendering to self-organizing networks (that is, service meshes and more), a continuum of compute will evolve for devices to access in the network. Part of the inference will happen locally, and part will happen in the cloud, but it will all look like a single instance to the end user. Infrastructure abstracts the network in a fundamental computing paradigm.

- *CSP networks will expose their data.* Network APIs will generate new revenue opportunities by providing access to user data with an opt-in service and restrictions for certain data.

- **Devices will continue to change.** Devices will become smarter, so the context created by the device will have to be absorbed by the RAN. As devices (and applications) become smarter, both devices and the RAN will have to be jointly optimized.
- **Applications will continue to change.** As applications continue to evolve and become smarter, agile system will be needed to adapt to these changes. The RAN needs to be modernized in a way that makes it future-ready, not simply to fulfill the requirements of today.

REMEMBER

Given the cyclical relationship between technology and society (discussed in Chapter 1), technology will have to continually adapt to enable these changes today and in the future.

The key to success through all this change is cultural. CSPs who are succeeding through this transformation have one thing in common: They embrace the changes from the ground up. There must be buy-in and a willingness to transform skills, capabilities, and operations at every level, or no transformation strategy will succeed. It's time to grab a hold of the opportunities the digital era is presenting.

## Leveraging Standards and Alliances

In an open ecosystem, developing and adhering to industry standards is critical to ensure interoperability. CSPs and vendors need to proactively engage with relevant standards bodies and leverage labs and alliances — such as the O-RAN Alliance, NextG Alliance, the Telecom Infra Project (TIP), the 3rd Generation Partnership Project (3GPP), and the GSM Association (GSMA) — to help chart the path forward.

In the spirit of openness, many companies are publicly talking about their RAN transformation journeys. This is an essential piece of moving to more open approaches — it's incumbent upon the industry to learn from their shared experiences and leverage the tools they've created to help others on the journey.

TIP

The NTT O-RAN Partner Ecosystem and the 5G Open Innovation Lab are great examples of some of the tools and initiatives available to help you on your RAN transformation journey.

## Addressing Impacts on Sustainability

When it comes to popular perceptions of environmental sustainability, big business often gets a bad rap. For example, according to the GSMA, the telecom industry is responsible for 2 percent to 3 percent of global energy consumption today and 451 Research estimates that global energy consumption will grow 170 percent by 2026 based on the growing worldwide population and the increasing numbers of mobile subscriptions and traffic.

Open RAN provides an opportunity for the telecom industry to slow or reverse some of these unfortunate trends and become leaders in environmental sustainability. For example, one of the core drivers for virtualization technology is the ability to support and grow your business while using less IT hardware, which helps to reduce energy consumption and waste.

TIP

The simplest way to reduce energy consumption in your digital footprint is also the most obvious one: Run less hardware. IDC estimates that from a cumulative standpoint, IT infrastructure efficiency due to VMware virtualization equates to energy savings of 347,968,000 megawatt-hours (MWh) and carbon emissions avoidance of 1.2 billion metric tons from 2003 to 2019.

When it comes to some of the world's biggest users of IT and network hardware — large national and regional CSPs — the benefits of virtualization are just getting started. CSPs provide the connectivity to power enterprise digital transformation initiatives. But inside their own vast networks — sprawling environments with thousands of sites running tens of thousands of devices 24x7 — many CSPs have continued to rely on legacy infrastructure models. As a result, the telecom industry hasn't benefited from modern efficiency advances as much as enterprises have.

Today, CSPs are moving away from dedicated physical hardware in every part of the network and using virtualized network infrastructure instead. This allows them to deploy and upgrade services much more quickly. It also means that the same benefits of

lower power usage and carbon emissions that enterprises have long enjoyed can now extend to CSP networks.

As mobile operators roll out 5G, virtualization becomes a key technology requirement because the automated delivery and scaling enabled by virtualization will be necessary to deliver the on-demand, customizable services expected of 5G — and beyond. In the coming years, CSPs and their partners will use 5G network capabilities to deliver a wide range of new services that enable cleaner, more efficient energy production and distribution, including things such as

- Predictive maintenance for energy generation, storage, and transmission infrastructure to improve efficiency and avoid failures
- Automated control of both renewable and conventional power generation equipment, using more sensors and artificial intelligence to maximize output
- Location-based battery supply systems to track demand for electric vehicle batteries and optimize supply and storage
- Intelligent energy demand/supply management applications that reduce and optimize energy consumption
- Smart grid load balancing that uses real-time data and modeling to balance supply and demand across large-scale consumers and energy resources
- Micro-grids, allowing devices to share and trade low levels of energy to eliminate the need for batteries

These and other new 5G capabilities will help CSPs shake off the legacy hardware models of the past and become standard-bearers for a greener, more sustainable future.

Specifically in the RAN, as the agility of the cloud continues to transform RAN capabilities, we're seeing new use cases pop up to improve green network operations, such as the following:

- Placing and scheduling workloads with the explicit, measurable intention of minimizing energy consumption and reducing emissions
- Reducing energy consumption of the base station by reducing the resources required in the RAN and conducting radio and capacity planning

- Increasing efficiencies with xApps to drain traffic from underutilized cells, managing carbon densification, and managing spectrum efficiencies that influence power consumption
- Automation that can help CSPs reduce the time it takes to deploy cell sites by 10 percent to 20 percent

## Recognizing Political Influences

Government interest in 5G has led to interest in Open RAN as a means to capture economic benefit, advance in the international race for technological innovation, improve network security, minimize supply chain risk, and establish connectivity as basic national infrastructure.

The role of government is continually evolving. Governments have digital sovereignty concerns, which can be overcome by enabling more choice. Governments can accelerate the path to Open RAN by expanding the ecosystem and funding test beds, research incubators, innovation programs, and more. When markets fail, governments can create the conditions necessary to allow the market to flourish once again by encouraging competition. For example, several European telecoms have created memorandums of understanding (MOUs) to work together toward Open RAN, but they need governments to implement policies and create incentives to help drive change quickly in the right direction.

Several examples of government initiatives include the following:

- The U.S. government has partnered with technology leaders from cloud, networking, and wireless industries through the Resilient and Intelligent Next-Generation Systems (RINGS) program, an industry-first initiative that takes a multi-sector, multi-disciplinary approach to building the foundation for the future of communications. It's expected to provide $40 million in grants for advanced studies guided by multi-dimensional research vectors targeting various facets of this foundation. These research vectors range from advancement of enabling technologies — such as terrahertz communication — to embedded security, resiliency, and scalability of the underpinning edge to cloud continuum, and discovery of new applications paradigms taking shape

with the evolution of extended reality (XR), such as the spatial web.

- The U.K. Department for Digital Culture, Media and Sport has announced Future RAN, a competition aimed at helping to incentivize industry to create new products and services to unlock the full potential of Open RAN. The competition will allocate up to £30 million of research and development funding to projects that support the goals of the government's 5G Supply Chain Diversification Strategy.
- The U.K. government has officially launched SmartRAN Open Network Interoperability Centre (SONIC). SONIC will demonstrate and foster an open, disaggregated network ecosystem of large and small suppliers along with the telecom industry in the U.K., helping to develop a supply chain with multiple suppliers for each element in the technology stack. At SONIC, companies will be allowed to collaborate, peer-assist, integrate, and test products and solutions at a pre-commercial development stage to address the challenges of multivendor end-to-end solutions.
- In Germany, O-RAN Town is Europe's first live Open RAN deployment with massive multiple-input, multiple-output (MIMO) radio units for high performance. The German Ministry of Digital and Transport supports research and development activities in three areas with up to 300 million Euros until 2024:
  - The establishment of an Open Lab provides interested parties with a research infrastructure under laboratory conditions.
  - In Open RAN cities, mobile network operators can test Open RAN components in real operation.
  - After summer 2022, companies and research institutes will be supported, especially with regard to manufacturers and service providers, in researching and developing Open RAN–based hardware, software, and services.

Additionally, there are many industry consortiums and alliances that support governments around the world, including the following:

- **Open RAN Policy Coalition:** Promotes policies that will advance the adoption of Open RAN as a means to create

innovation, encourage competition, and expand the supply chain for the Open RAN ecosystem.

- **Global System for Mobile Communications Association (GSMA):** Published the Explanatory Guide for Policymakers which provides an overview of the shift to open and virtualized RAN, and outlines several enablers that support the deployment of open and virtualized RAN elements from disparate vendors.

IN THIS CHAPTER

- Prioritizing security in the RAN
- Working with a RAN partner in the cloud
- Taking on a leadership role within the telco industry
- Putting you (the customer) first
- Eliminating closed hardware and software silos
- Getting help when you need it with 24x7 global expertise
- Ensuring sustainability and social responsibility

# Chapter 6
# Ten (or So) Things to Look for in a RAN Partner

As a communication service provider (CSP), you're heading into new territories that are brimming with opportunity. To get there, you need a partner that understands where you want to go — into a world shaped by software. In this chapter, we present ten (or so) important characteristics to look for in a radio access network (RAN) partner to help guide you on your journey so you can pioneer new business models along the way.

## Security

The RAN in a CSP network is analogous to the wireless access point on a public Wi-Fi network: Both need to be protected from cyber threats.

Although cyber threats to the RAN are not new, the potential speed and scale of a successful cyberattack has grown exponentially. Threat actors — including cybercriminals and nation-states — have become more prevalent and more sophisticated. They also have vast resources available to them and a massive, largely unprotected attack surface that exists in the form of individual user equipment (UE) — the ubiquitous smartphone.


TIP

To help secure your 5G network, look for a RAN and cloud partner like VMware that offers streamlined policies that extend through the software layer (Layers 2 through 7) and provides visibility and control to easily identify and remove threats on the network. Intel helps reduce complexity by delivering a complete and proven set of network technology solutions as the foundation for the industry to build upon, including a full suite of processors, accelerators, Ethernet adapters, software toolkits, and FlexRAN reference architecture.

## Cloud DNA

The future of the RAN is the cloud. But today, RAN is new to the cloud and the cloud is new to RAN. To quickly acclimate to new software-driven environments, you need a RAN partner with deep cloud expertise.


REMEMBER

VMware and Intel have been rooted in the world of hardware disaggregation and cloud-based operations since their inception, while traditional network equipment providers (NEPs) are developing their modern software strategy.

VMware grew up in the world of Agile methodologies and DevOps, which informs every aspect of how they approach customer challenges. At the same time, VMware has combined its cloud software DNA with extensive telco experience that no hyperscale provider can bring, which means they understand what's actually needed to build agility in multicloud, multivendor CSP environments.

Meanwhile, Intel led the transformation of networks with network functions virtualization (NFV), disaggregating hardware and software to deliver wide-ranging benefits such as helping to increase total cost of ownership (TCO) savings and proliferating the network applications software ecosystem. In this next phase of network transformation, Intel is driving software disaggregation and the adoption of cloud-native software practices for network applications, providing optimized building blocks for cloud-native and microservices architectures with Kubernetes.

## Multicloud

In the last few years, it seems like a dam has finally broken, with CSPs now demanding open, multivendor-capable solutions. This is great news! You can be more innovative, more secure, and more in control of the prices you pay when you can work with any vendor. But just as this is the case for virtualized network functions (VNFs) and containerized network functions (CNFs), it also holds true for clouds.

Too many parts of the network still function in silos, operating within one vendor's self-contained cloud. The problem is even worse when it comes to public cloud resources.


TIP

According to the *Economic Benefits of the VMware Telco Cloud Automation and Horizontal Infrastructure* study, CSPs benefit from an average of 38 percent operational expenditure (OpEx) savings by removing siloed operations.


TIP

VMware is cloud agnostic and has been bringing multicloud environments to enterprises for years. VMware combines its multicloud approach with deep telco network expertise and enables carrier-grade service delivery from core to edge to RAN to public cloud, working with whichever vendors you choose.

Intel laid the groundwork when it helped to drive the transition to NFV with CSPs. Leveraging a decade of innovation and optimization with the world's leading technology and service providers means Intel not only has a deep understanding of network and edge use cases and needs, but also a fine-tuned, globally deployed architecture you can count on to deliver cloud scale and agility to the world of networking.

VMware hypervisors provide CSPs with a clear upgrade path when OS and security patches are issues, as well as the ability to relocate workloads across locations without imposing a performance toll when using Intel hardware.

## Leadership

The Open RAN is more of a journey than a destination, and it's still evolving. You need to look for a partner that's committed to the O-RAN Alliance's vision, among others, and works with other industry leaders and groups in the broader telecom industry to help ensure that emerging standards reflect the open ecosystems and multivendor approaches that will empower the software-based networks of the future.

TIP

VMware and Intel work with many industry groups, including (among others):

- 5G Open Innovation Lab (`https://5goilab.com`)
- GSM Association (`https://gsma.com`)
- Next G Alliance (`https://nextgalliance.org`)
- OpenInfra Foundation (`https://openinfra.dev`)
- O-RAN Alliance (`https://o-ran.org`)

VMware and Intel make it easier to develop new solutions, services, integrations, and features. Together, they co-innovate with customers to deliver the best of both worlds: flexibility with an open platform and integrated, supported solutions that reduce complexity and hassle.

## Customer First

Every vendor claims to be customer-centric, but that's often not how things play out. When bidding for a project, many vendors start with the technology they want to sell and then back their way into adapting it to the customer's problem.

REMEMBER

VMware starts with your customers and end users and then builds the right solution to meet their needs. This shouldn't be surprising. When you grow up in Agile software development, you just get used to looking at problems from the end user's perspective. Like any Agile "story," you start by expressing what users want to do, and that dictates every choice you make.

Intel is helping the industry power the possibilities of 5G and beyond, working alongside customers as a trusted partner and helping them architect their networks, from core to access to edge. Intel meets CSP needs today while helping to deliver a flexible infrastructure that accounts for unknown demands in the future.

## Open Ecosystems

A key goal of O-RAN is to replace the closed proprietary systems of the legacy RAN architectures with an open ecosystem that promotes interoperability and cooperation across vendors, equipment, networks, and clouds.

## Supportability

No matter what solutions you use to transform your network and operations, they need to be supported. After all, you can't become an Agile business if your people are constantly poring over open-source forums when something goes wrong.

TIP

When you work with VMware, you can draw on a global team of virtualization and telco network experts standing by 24x7 to give you the guidance and support you need for Day 0-1-2 operations when you need it.

## Sustainability

In the last decade, major technology companies have made a concerted effort to become responsible corporate citizens — to take seriously the impact they can have on the environment and the world. As 5G proliferates, significantly reducing energy

consumption and greenhouse gas emissions takes on renewed importance. Look for a vendor that offers sustainability-focused solutions.


TIP

Sustainability has been a top priority for VMware from the beginning. Arguably, VMware exists to help businesses reduce energy consumption and waste. That is, after all, one of the main drivers of virtualization: the ability to grow your business while using less IT hardware. Today, VMware spearheads a wide range of programs to reduce greenhouse gas emissions and a shift to renewable energy. According to VMware's 2021 Environmental Social Governance Report (`www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/company/vmware-esg-report-2021.pdf`), VMware achieved carbon neutrality in 2018 and sources 100 percent of the electricity for its global operations from renewable sources. VMware is on track to radically decarbonize its supply chain, operations, and customers by 2030.

## Social Responsibility

Look for a RAN partner that builds a diverse and inclusive environment that enriches lives — inspiring people to give more than they take.


REMEMBER

VMware invests significant resources into its people and the communities where they work. It has built a company where men and women of all races and ethnicities, in every country where it operates, are compensated with 99 percent to 100 percent parity. VMware also sponsors nearly 8,500 nonprofits in 96 countries through the VMware Foundation, and 74 percent of VMware employees participate in charitable activities in their communities.

Intel's long-standing commitment to corporate responsibility and sustainability — built on a strong foundation of transparency, governance, and ethics — is deeply integrated throughout all aspects of its business.

Intel's commitments to positive global impact include the following:

- **Responsible:** Lead in advancing safety, wellness, and responsible business practices across global manufacturing operations, the value chain, and beyond
- **Inclusive:** Advance inclusion across the global workforce and industry, and expand opportunities for others through technology, inclusion, and digital readiness initiatives
- **Sustainable:** Be a global leader in sustainability and enable customers and others to reduce their environmental impact through their actions and technology
- **Enabling:** Through innovation, technology, and the expertise and passion of its employees, Intel enables positive change within the company, across the industry, and beyond

Intel's more than 116,000 employees are shaping the future with computing and connectivity technologies. Together with partners and customers, Intel powers, connects, and secures infrastructure and billions of devices. According to the 2021–2022 Intel Corporate Responsibility Report (`http://csrreportbuilder.intel.com/pdfbuilder/pdfs/CSR-2021-22-Full-Report.pdf`), these initiatives have achieved the following results:

- In 2020, 94 percent of non-hazardous waste was recycled.
- In 2020, 7.1 billion gallons of water were conserved.
- In 2020, 82 percent of Intel's global power was green power in 2020.

VMware and Intel vRAN solutions empower customers on their journey from traditional to virtualized RAN and Open RAN, allowing the RAN to become a 5G services hub for RAN functions and custom apps. VMware enables the virtualization of RAN functions on a unified platform, and Intel provides pre-validated reference architectures that help accelerate development for virtualized RAN.

VMware and Intel provide hardware and software integrations that have been proven in the field. Customers can rely on the experience and expertise of both companies, plus pre-validated optimized architectures and orchestration scenarios that are proven to work outside of the lab, in real-world environments.

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## Map your RAN transformation journey

5G services present communication service providers (CSPs) with tremendous growth opportunities. However, the traditional radio access network (RAN) infrastructure presents obstacles to realizing 5G-based strategies. Virtualization of RAN functions (vRAN), and eventually the move to open RAN (O-RAN), offer a path forward through the implementation challenges that exist. *RAN Transformation For Dummies* helps guide you past the obstacles and challenges on the journey to your 5G vision and an open, profitable future.

## Inside...

- Reduce network transformation costs and risks
- Simplify multi-cloud operations
- Accelerate time to value
- Enhance security
- Unify the RAN with a horizontal platform

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