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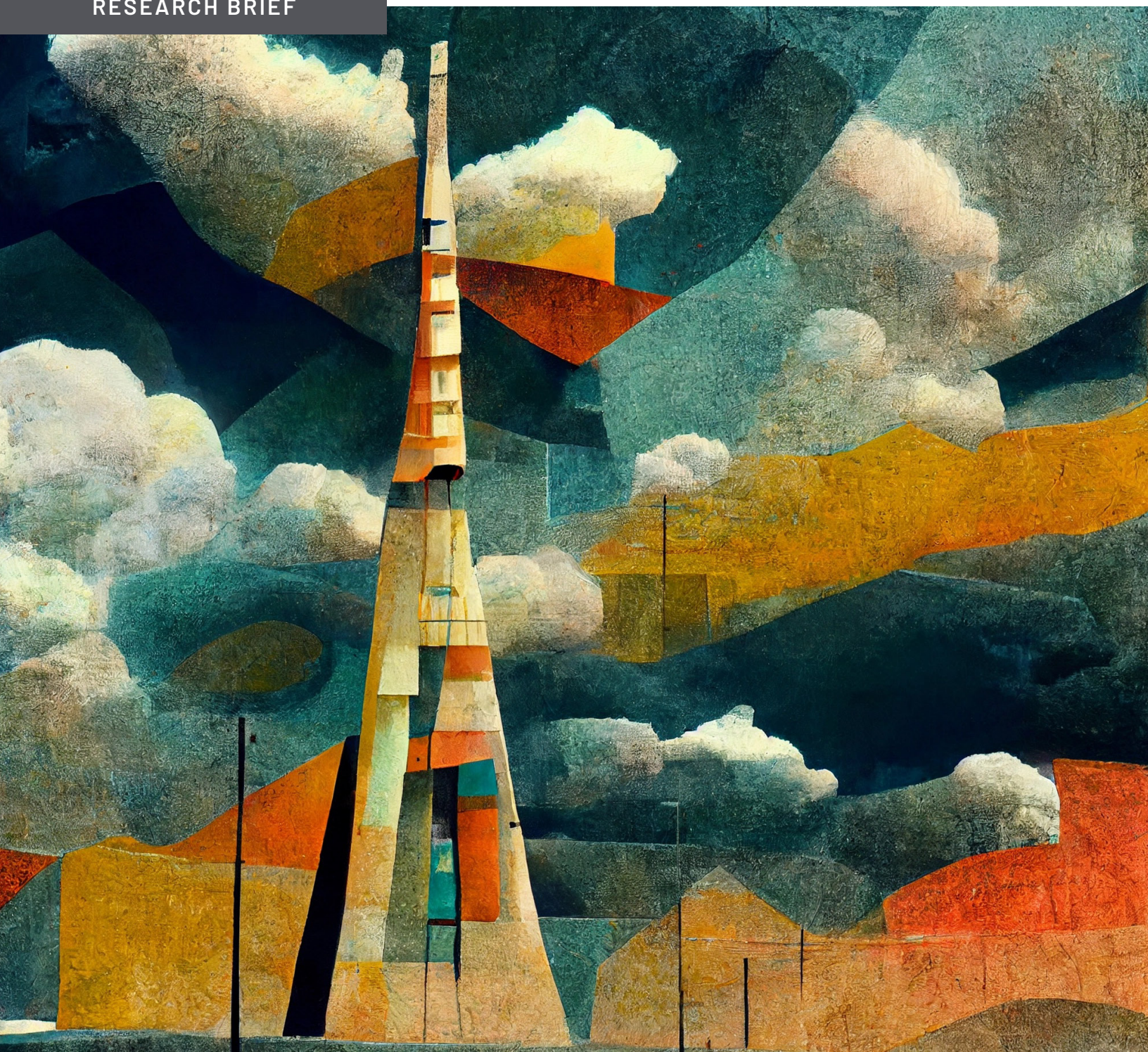
# Telco Cloud and Edge Report 2023

## Next-generation foundations for communication workloads

RESEARCH BRIEF



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RESEARCH BRIEF

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## Next-generation foundations for communication workloads

### Introduction - One (Telco) Cloud to Rule them All?

As we kick off 2023, communication service providers (CSPs) continue to aggressively push wireless and wireline infrastructure upgrades and buildouts. A few are even tying up with satellite providers. However, CSPs will need to innovate to thrive as access to capital becomes more expensive and markets demand a higher return on invested capital (ROIC) on both 5G and fiber buildouts.

While CSPs seek new and profitable services, they are called upon to expand last-mile connectivity to serve work-from-home (WFH) and work-from-anywhere (WFA) workers and to bridge the digital divide. And business customers want CSPs to support their digital transformation and internet of things (IoT) initiatives. Furthermore, enterprise cloud transformation relies on CSPs providing wide-and-fast data pipes to public and private cloud data centers.

CSPs are building out underlying infrastructure capabilities to supply these popular services and to ensure a foundation for ongoing service innovation. This next-generation infrastructure foundation must exhibit scalability, flexibility, and reliability while remaining cost-effective.

CSPs believe these infrastructure goals are achievable if they adopt virtualized, disaggregated, open, and software-defined architectures. The journey to this new architecture started ten years ago with the embrace of network functions virtualization (NFV), which has since evolved into the telco cloud initiative. The telco cloud is now part of CSPs' ongoing transformation into digital service providers (DSPs) and the appropriately-named aspirational TechCos (technology-first organizations). Telcos expect the DSP and TechCo transformations to unlock innovation and improve margins.

**Unlike the NFVI layer defined by ETSI, the term telco cloud has no official definition. As an evolution of NFVI, the telco cloud is understood to be a virtualized and abstracted hardware and software platform that includes orchestration and monitoring services.**

AvidThink's research brief on the telco and edge cloud is an update to our previous **telco infrastructure** and **edge reports**. CSPs continue their struggle to build a unified telco cloud that spans telco IT, network core, network edge, and even enterprise customer premises workloads. Our report will discuss ongoing drivers for this telco cloud, challenges CSPs face, and our observations on the current state of the market.

### The Elusive Telco Cloud

Unlike the NFV infrastructure (NFVI) layer defined by ETSI, the term **telco cloud** has no official definition. As an evolution of NFVI, the telco cloud is understood to be a virtualized and abstracted hardware and software platform that includes orchestration and monitoring services.

The journey to the telco cloud started with the NFV initiative of disaggregating and moving appliance-based, proprietary, physical network functions (PNFs) into virtual network functions (VNF) running on white box servers, aided by hypervisor technology (KVM and ESXi) and virtualized infrastructure managers (VIMs) like OpenStack and VMware vCloud NFV.

CSPs, reluctantly aided by incumbent network equipment providers (NEPs), attempted the transition from PNF to VNF. VNF onboarding, cross-vendor, and performance tweaking challenges (managing huge memory pages, CPU pinning, DPDK[1] software acceleration, and SR-IOV[2] slowed NFV adoption. Compounding problems included inconsistency in pricing and business models.

Midway through the ten-year journey, cloud-native network functions (CNFs), Linux containers, and the Kubernetes orchestrator showed up, seducing many telcos and distracting them even before they had completed their NFV transitions.

Today CSPs seek a unified telco cloud that spans legacy PNFs, VM-based VNFs, and container-based and Kubernetes-managed CNFs on bare-metal machines. Other telco cloud features CSPs expect include auto-scaling, auto-healing, and support for intelligent workload placement.

An increasing number of CSPs have recognized that hyperscalers like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) are better than they are at managing and scaling up computing and storage infrastructure. Co-location providers like Equinix offer bare metal services as an additional option to its many CSP customers. Public clouds, hyperscaler-powered private cloud platforms, and co-location facilities are now part of the extended telco cloud. CSPs have even extended the telco cloud to run edge workloads on customer premises.

Since starting their NFV journey, CSPs have dreamt of a unified platform capable of hosting CSP workloads everywhere. Unfortunately, despite ongoing progress, a single horizontal platform that spans all telco domains is unachievable today.

## Telco Cloud Workloads

We'll continue examining the telco cloud and edge platform in detail, but before we do that, let's take a quick look at the workloads CSPs want to host on telco clouds. The needs of these workloads drive the requirements for the telco cloud.

Even as we transition into a new year in 2023, many initiatives listed below have mostly stayed the same since our **2021 Telco Infrastructure** report. We'll highlight any updates below.

### IT Applications

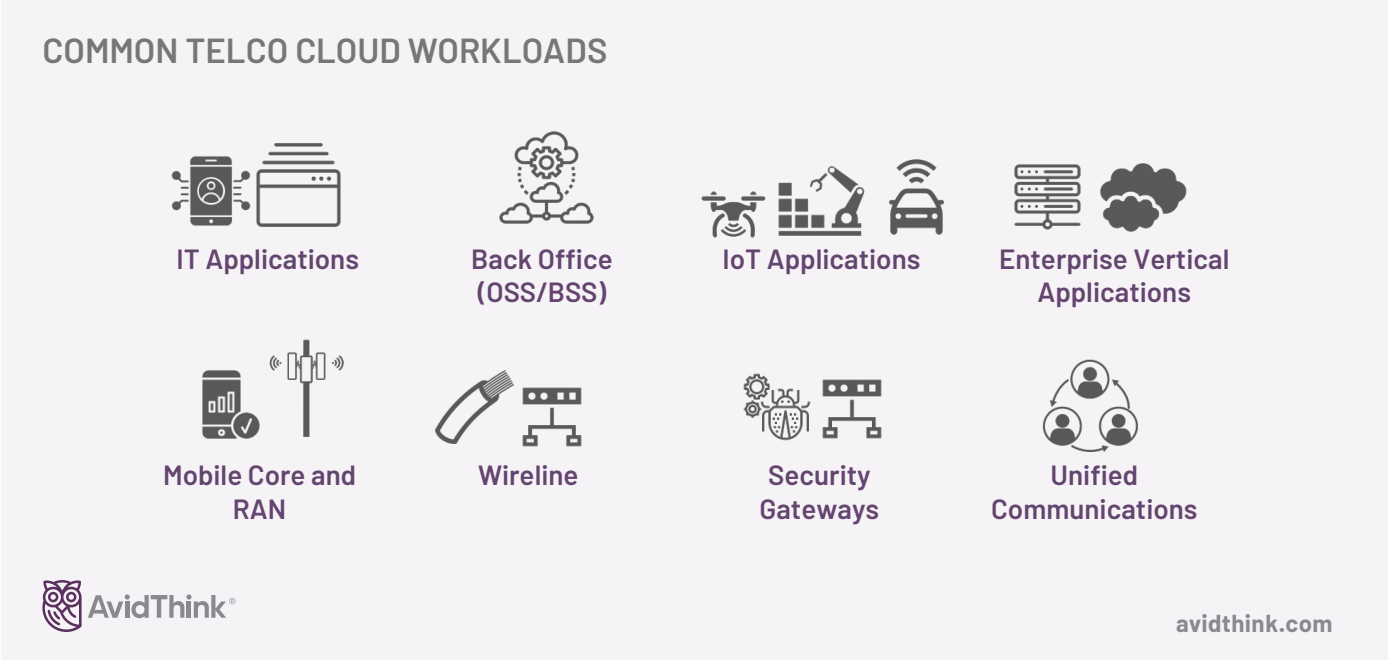
The earliest workloads to virtualize within CSPs were the IT systems similar to those running in non-CSP enterprises. Customer relationship management, finance, accounting, human resources, and other IT systems were virtualized and placed on VM clusters, often managed by VMware vSphere. Today, many of those systems have migrated to cloud-based software-as-a-service (SaaS), but the telco cloud will have to support some remaining IT software stacks.

### Back Office Systems

CSP operations support system (OSS) and business support system (BSS) stacks were virtualized early in the NFV journey. These systems are similar to enterprise software and thus lent themselves to a quick transition. As CSPs look to embrace public cloud-hosted workloads, the OSS and BSS stacks are again among the first to transition to hyperscaler clouds. Independent software vendors (ISVs) like Amdocs, Netcracker, and Ericsson are certifying and offering their OSS/BSS stacks on public clouds.

[1] The Data Plane Development Kit (DPDK) is an open-source set of libraries for acceleration packet processing on multiple CPU architectures.

[2] Single-Root Input/Output Virtualization allows PCI Express resources like NIC cards to create multiple virtual functions (VFs) that are isolated from each other and that can be attached to different VMs.




## Mobile Core and RAN Infrastructure Services

Global 5G rollouts continue, with more 5G standalone (5G SA) networks being established. The 2022 November Ericsson Mobility Report forecasts worldwide 5G subscriptions will reach 5B by the end of 2028 (55% of total mobile subscriptions). Ericsson shared that 5G global subscriptions from 5G devices grew by 110M in 2022 Q3 to 870M and were expected to reach 1B by the end of 2022.

For mobile network operators (MNOs), 5G workloads are a large proportion of services on telco clouds. The 5G mobile core and the virtualized (and disaggregated) 5G radio access network (RAN) will require significant telco cloud resources. The 5G core (5GC)'s move to a service-based architecture (SBA) has driven mobile core vendors to micro-services architectures running on containers orchestrated by Kubernetes. Further, parts of the 5G core (e.g., user plane function or UPF) and virtual RAN distributed unit (vDU) that need to be located closer to subscribers for performance will likely be hosted by a telco cloud's edge platforms.

Regardless of the rate of uptake of ORAN Alliance-compliant open RAN, the ongoing virtualization and disaggregation of 5G RAN into disparate units, such as O-RAN's centralized units (CUs), distributed units (DUs), and radio units (RUs), implies more telco cloud workloads at the network edge. The telco cloud must support hardware (HW) acceleration for these RAN workloads.

For instance, the DU must perform real-time signal processing functions like transforms, filtering, and channel coding. Servers running the DU will need HW assistance in the form of plug-in acceleration cards (SmartNICs, data processing units, infrastructure processing units) that enable real-time handling of the RAN traffic.

Another component of the RAN that is evolving is the cell-site gateway (CSG) router. These devices are migrating to white box platforms running disaggregated software stacks. General-purpose CPUs coupled with merchant silicon application-specific integrated circuits (ASICs) and hardware network timing and synchronization support provide necessary performance with lower costs. The Open Compute Project (OCP) and Telco Infra Project (TIP) have defined the underlying open HW platforms for these devices through the disaggregated cell site gateway (DCSG) project. However, it's unclear whether the telco cloud will be tasked to host CSG workloads.

## Wireline Infrastructure Services

Wireline infrastructure is undergoing the same virtualization and cloud-native transformation. The telco cloud is expected to host virtual broadband network gateways (vBNG), virtual cable management termination systems (vCMTS), and even converged wireless-wireline gateways with a 5G virtual access gateway function (vAGF).

## Security and Networking Edge Gateways

Enterprise edge network and security functions are popular managed services that CSPs are eager to offer — software-defined wide area networks (SD-WAN), secure access service edge (SASE), and security service edge (SSE). These services have gateways hosted by the vendor in data centers (public or private clouds) or installed at the edge of CSP networks. Depending on the service type, the telco cloud platform could be called upon to host the security gateway or networking functions at the CSP network edge. And if the telco cloud supports universal customer premises equipment (uCPE) platforms, the uCPE-based telco cloud may run on-site software security services.

## Unified Communications

Unified communications and collaboration (UC) are another CSP bundled service popular with enterprises and small and medium businesses (SMBs). Many UC solutions are now sold as a service (UCaaS), with the solution provider running the service in the cloud on behalf of the CSP. However, for UC offerings that are packaged as software deployed and managed by the CSP, UC software represents another telco cloud workload.

## IoT Applications and Gateways

One of the critical elements of digital transformation is the digitization of industrial processes and the use of digital sensors in industrial (and consumer) devices. IoT has not been the big bang transformation the industry expected but has plodded its way into a significant market. Smart cities, intelligent buildings, and smart logistics all beckon, with tens of billions of dollars in market size estimates backing these use cases.

CSPs have always played a vital role in the connectivity of IoT devices. Still, they continue to look for ways to increase their share of the value stack beyond the 5-10% slice of the full-stack revenue opportunity. And whether the IoT platform components are at the network edge, on customer premises, or in more centralized locations, CSPs will expect telco clouds to support these workloads.

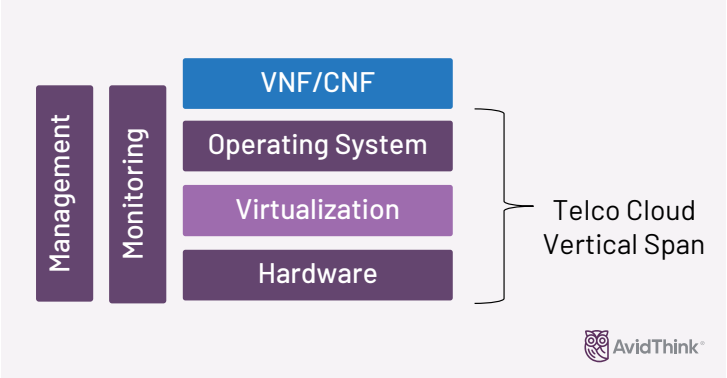
## Vertical Enterprise Applications

Along with a desire to monetize IoT applications, CSPs want to host enterprise applications either on-premises on CSP-managed uCPEs or small form-factor servers or at their network edge. More than a few CSPs are dazzled by the heady market-size projections for edge computing (some analyst project four times the cloud market size). These CSPs believe that controlling the last mile and owning mini-data center locations (mobile switching centers, central offices) near businesses and consumers gives them an edge. CSPs may sell enterprise edge services either on their own, in partnership with hyperscalers, or with other edge computing companies. For instance, Lumen, a US-based CSP, has rolled out edge offerings that span servers hosted in their data centers, hyperscaler-powered options, as well as solutions from edge computing startups. Cox, another US CSP, offers an edge solution targeted at enterprise developers that their partner, StackPath, powers. Verizon, Bell Canada, KDDI, Vodafone, SK Telecom, and other CSPs partner with AWS to provide embedded edge computing (AWS Wavelength) in their mobile switching centers.

Whether CSPs should play the role of the enterprise cloud provider for network edge or on-premises edge workloads and whether they should partner remains an unanswered question. Similarly, what role, if any, should the telco cloud have for enterprise edge workloads?

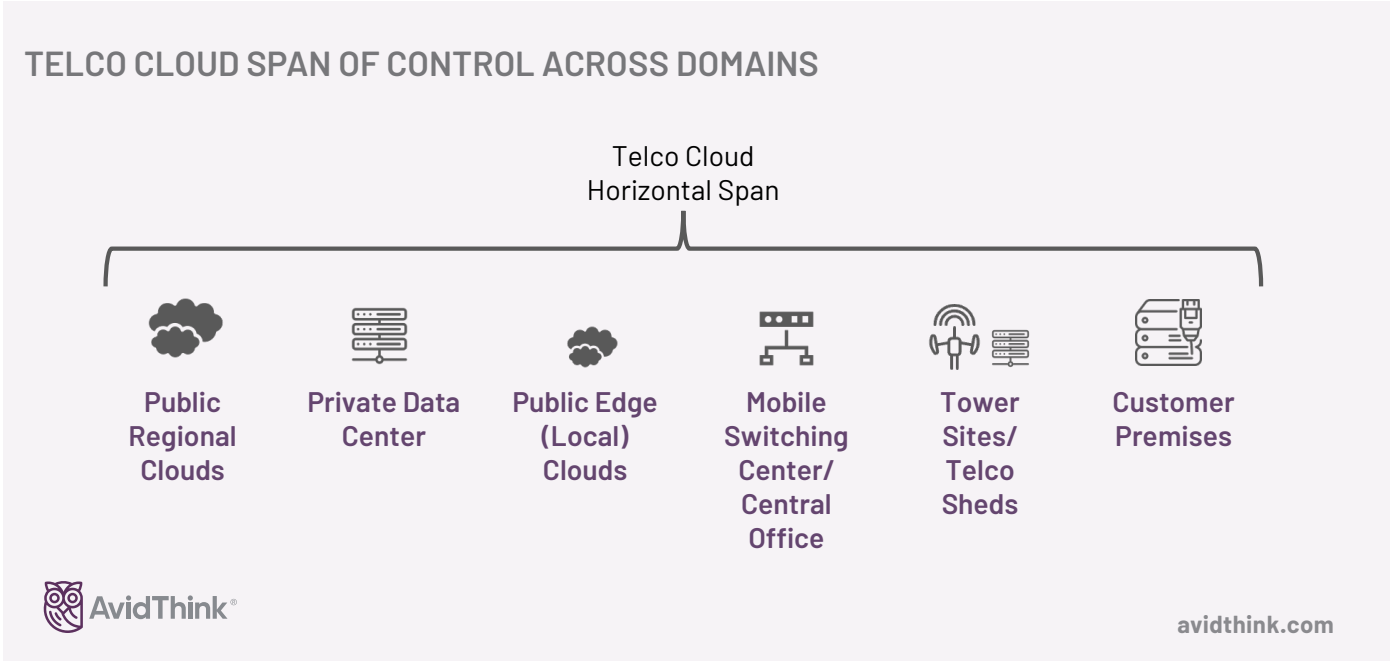
## Telco Cloud Spectrum

To understand the range of options available to a CSP for the telco cloud, we need to recognize the enormity of the telco cloud decision. Picking a telco cloud is a full-stack and multi-domain decision. The primary interaction point between the telco cloud and the workload application may be at the virtualization or at the operating system layer (depending on the application package).




However, under the tip of that iceberg is a collection of layers and systems: hardware, firmware management, virtualization management, application deployment, lifecycle management, monitoring, and orchestration. All these capabilities are now expected to be part of the telco cloud.

Similarly, telco clouds may be expected to provide support across multiple domains. From managing workloads within public clouds, to managing applications across private data centers, mobile switching centers, central offices, tower sites, and customer premises. This desired wide span of control creates significant requirements for a single unified telco cloud.




## DIY Telco Cloud

CSPs who feel they need to own the telco cloud from top to bottom may take a do-it-yourself approach. On this end of the spectrum, a CSP that builds from scratch will need to pick their server hardware vendor (e.g., Dell, HPE, Huawei, IBM, Inspur, Lenovo, QCT, WiWynn or other white box providers), a hardware or bare metal management system (often provided by the hardware vendor), and a hypervisor (e.g., KVM, VMware ESXi) or operating system (e.g., Red Hat, SUSE, Canonical Ubuntu) distribution. Next will be a VM management solution (may be dictated by the hypervisor) and a container orchestration system (Kubernetes - generic or commercial derivative). Following that, the CSP will need to decide what their monitoring, load management, and scaling strategy are and how they will manage application deployment and lifecycle.

## Full-Service Telco Cloud

On the other end of the spectrum, the CSP might choose a managed telco cloud service from a vendor like Rakuten Symphony, which has bundled its recently-acquired Robin.io cloud platform with a fully-managed stack and a telco application marketplace. In this case, the CSP doesn't choose the platform or management tools for the platform but relies on the vendor to handle all decisions.

## Somewhere-in-Between Telco Cloud

Our engagements with CSPs, hyperscalers, networking equipment providers (NEPs), ISVs, and other solution providers indicate that the telco cloud situation is evolving and complicated. Tier-1 CSPs like Orange have **lamented the nightmare that is telco cloud** — pointing out Orange was stuck in cloud-native vertical silos with vendor network services running on compartmentalized telco cloud instances, with no unification in sight.

## Living in The Messy Middle

Meanwhile, greenfield operators like Rakuten Mobile and DISH tout cloud-native advantages and efficiencies. Rakuten has the benefit of a unified platform which they own and operate, and now offer as a service to other CSPs. DISH achieved substantial operational efficiencies despite running on a mix of AWS Cloud for parts of its 5G core and RAN, and VMware Telco Cloud on Dell servers for aspects of its O-RAN implementation — DISH attributes its advantage to its focus on automation and an overarching DevOps pipeline.

Many other CSPs run their back office and IT operations on hyperscaler clouds (AWS, Azure, GCP) — the number of announcements of CSPs migrating to IT in clouds has been growing. Even for more rigorous network function workloads, Analyst firm **Omdia shared in July 2022** that of 49 surveyed telco operators, 70% used AWS and 57% relied on Azure for networking workloads (less than 20% of CSPs were using Oracle, GCP, and IBM clouds).

Based on recent announcements and end of 2022 traction, AvidThink expects that, in time and across the broader CSP market, GCP's share will grow, and both Azure and AWS will see incremental gains. Nevertheless, larger CSPs will transact with all three hyperscalers because their business customers already do so. Plus, having multiple hyperscaler relationships could give CSPs more negotiation leverage. The depth and areas of partnership will shift based on the hyperscalers' ongoing investments and execution success across the CSP landscape.

**Over the next 3-5 years, most CSPs will live in the messy middle of the telco cloud spectrum while the market sorts out the best model. A few dominant business models and corresponding architectures will eventually emerge.**

Over the next three to five years, most CSPs will live in the messy middle of the telco cloud spectrum while the market sorts out the best model for different businesses. A few dominant business models and corresponding solution architectures will eventually emerge, but it's too early to call winners.

## Telco Cloud Platform Options

Outside outsourcing the entire telco cloud decision to an external party (vendor or system integrator), CSPs get to pick from a variety of options for the telco cloud — across central data centers, network edge, and customer premises edge.

### NEP Telco Clouds

For many CSPs, rolling out a new 5G core and RAN will necessitate an underlying cloud platform. NEPs like Ericsson and Huawei provide accompanying cloud solutions, tested and certified with their mobile software stacks. Ericsson claims 260 cloud infrastructure customers, including well-known CSPs like Swisscom, Telefónica, and Telstra. Whether these vendor-maintained cloud platforms can eventually check all the boxes needed for a unified telco cloud spanning public cloud and edge locations remains unclear.

The other challenge with NEP cloud platforms is their support for competing vendor solutions. Almost all CSPs run multi-vendor networks, and it's unlikely a NEP cloud platform team will put much effort into supporting a competing network function. CSPs who stick with a vendor-provided telco cloud should expect to manage multiple telco cloud platforms — each aligned with a set of vendor network functions.

### Hyperscaler Telco Clouds

What was unthinkable a few years ago — CSPs depending on hyperscaler clouds to run their network functions — is now embraced by an increasing number of CSPs. Two prominent examples of CSPs using hyperscaler-managed telco clouds are **DISH's 5G network** running their 5G core and parts of their 5G O-RAN on AWS's regional cloud and AWS Local Zone edge clouds, and **AT&T turning to Microsoft Azure to manage and run their 5G core**, including the underlying cloud platform. The AT&T transaction included Microsoft acquiring AT&T's Network Cloud technology and development teams and migrating the IP into their Azure for Operators Distributed Services offering.

More recently, **Deutsche Telekom indicated it would run a 5G SA core on GCP** and use GCP to host remote packet gateway functions, leveraging both regional clouds and Google Distributed Cloud Edge.

Numerous other announcements on CSP and hyperscaler partnerships have been made, and we expect this trend to continue. Hyperscalers continue to court NEPs and ISVs to port and certify their OSS, BSS, and network functions on hyperscale cloud platforms — aiming to lower the risks and effort for CSPs to adopt public clouds as telco clouds.

### VMware and Red Hat Multi-Cloud Solutions

VMware (soon to be part of Broadcom) and Red Hat (part of IBM) are the two major platform providers touting independent hardware-platform agnostic (and cloud agnostic) telco cloud solutions. VMware Telco Cloud Platform, powered by their ESXi hypervisor and Tanzu Kubernetes Grid, and Red Hat's OpenShift solution are pitched as preventing lock-in by hyperscalers. VMware and Red Hat support on-premises server hardware, bare metal offerings from co-location providers like Equinix, and all major public hyperscale clouds. Likewise, both vendors have recently extended their cloud platforms to address small footprint edge workloads at both the CSP network edge and the enterprise customer premises. In addition, VMware has invested in ensuring their ESXi hypervisor supports the **high-throughput and near-real-time performance requirements** of telco workloads — this is to convince CSPs to run their containers on a hypervisor layer (with attendant benefits) instead of on bare metal with a minimal operating system. A prime example of VMware powering a latency-sensitive workload is DISH's use of VMware on Dell platforms to run Mavenir's 5G open RAN software.

While both vendors tout their multi-cloud orchestration, hyperscalers have their own hybrid cross-cloud orchestration solutions: AWS EKS-Anywhere, Azure Arc, and Google Anthos. All of these support on-premises or private-center-hosted third-party servers (or hyperscalers' on-premises managed hardware). More importantly, they support container workloads competing for infrastructure-as-a-service (IaaS) offerings (e.g., Anthos managing workloads on AWS or Azure). Nevertheless, CSPs seeking multi-cloud management solutions are skeptical about hyperscalers providing ongoing comprehensive support for competitor platforms.

### OpenStack — Alive and Kicking

While OpenStack has lost its "cool platform" status after dominating early NFV implementations, it continues to power many in-house telco cloud stacks. The Open Infra Foundation (OIF)'s **2022 survey shows that OpenStack is deployed on 40M CPU cores in production**, a 60% increase over 2021 (and 166% since 2020). It's present in over 300 cloud data centers worldwide. Unsurprisingly, OpenStack is now primarily used as a container host, with over 85% of OpenStack installations acting as Kubernetes containers.

### Other Telco Cloud Options

Another notable telco cloud option comes from Wind River. Based on the open-source StarlingX project (hosted by OIF), Wind River Studio Cloud Platform is a Kubernetes solution for managing edge cloud infrastructure. Wind River has found a niche in hosting virtual RAN workloads, and its announced customers include Verizon, Vodafone, and KDDI. Wind River has partnered with Dell to offer an integrated pre-installed SKU that CSPs can order directly from Dell, expanding Wind River's distribution.

Other options in the ecosystem include Canonical (Unbuntu), offering their Charmed Kubernetes on OpenStack, VMware, bare metal, and OpenStack for VM workloads. SUSE/Rancher is also pushing their offerings into telcos, hoping their SUSE Edge platform will gain traction. To date, customers like Dutch operator KPN and Brazilian Algar Telecom are running IT workloads on SUSE/Rancher cloud.

And finally, we have two startups in the telco cloud market. Platform 9 provides a cloud-managed Kubernetes platform and has partnered with Mavenir to host Mavenir's Telco Platform-as-a-service (PaaS) for a near-turnkey offering for CSPs. Rafay Systems powers Verizon's uCPE platforms (Verizon VNS Application Edge) with an on-premise edge computing option that bridges into public clouds.

## Shifting Sands in Telco Infrastructure

In the ten years since laying down the foundations for NFV and NFVI, CSPs are still trying to achieve a horizontal NFVI platform, now redefined as the unified telco cloud. And as an industry, we have collectively evolved and matured the telco cloud architecture. The best evidence is in the detailed reference model of the **Linux Foundation's Anuket project**.

### Project Anuket and Project Sylva

The Anuket project is the result of the merger of the Open Platform for NFV (OPNFV) project from the Linux Foundation and the Cloud iNfrastructure Telco Taskforce (CNTT) hosted by the GSMA. Anuket aims to establish a standard model, reference infrastructure specifications, and conformance and performance frameworks for virtualized and cloud-native network functions.

More recently, several notable European CSPs, in conjunction with Ericsson and Nokia, established **Project Sylva** (based on Anuket) under Linux Foundation Europe, to create a new telco cloud stack for the EU and other markets. This cloud stack aims to meet the EU's privacy, security, and energy efficiency requirements while serving centralized and edge cloud workloads.

The Anuket model lays out a federated telco cloud model, spanning customer premises to data center workloads. It establishes the capabilities and requirements for multiple cloud domains to be managed and orchestrated — including hyperscale public cloud capabilities for discovery and management. Likewise, it continues to mature the APIs necessary for smarter workload placement (exposing underlying platform capabilities like GPUs or SmartNICs for hardware acceleration or memory architecture). The adoption of Anuket is a work in process, but it serves as a forum for active discussion, innovation, and integration testing between CSPs and telecom vendors.

An essential constituent — the hyperscalers — don't actively participate. Still, given Google's contribution of the Nephio orchestration software to open-source (hosted by Linux Foundation) and Project Sylva's intention to participate in both Anuket and Nephio, we could see this change.

## AvidThink's Read on the Telco Cloud Winds

Even though we can't precisely predict how the telco cloud sands will shift, we will provide our observations and thoughts on current developments. For brevity, we'll list key ones here and are glad to discuss details on request.

- **#1: Workloads rule and pragmatism wins.** Given the economic landscape as we transition into 2023 and large CSPs investing tens of billions of dollars in investments in 5G and wireline infrastructure, not to mention multiple tens of billions on spectrum licenses, the market will be looking for returns on investment. The need to show revenue and profitability for wireless and wireline services will tilt decisions toward faster time-to-market and lower CapEx choices for the telco cloud. Pragmatism may dominate over the long-term vision for a unified telco cloud. CSP leadership will not take kindly to those who stubbornly mandate a unified, cohesive telco cloud platform that blocks other revenue-enhancing or cost-reducing initiatives — since we've been beating the unified NFVI drum for ten years now with limited success.

- **#2: Unified telco cloud is not a well-defined end-state (yet).** High-level conversation and presentations from CSPs paint visions of a single unified telco cloud. However, many elements of the telco cloud are yet to be understood and communicated. Efforts across GSMA and Linux Foundation around Anuket is promising. Collaboration between the experts at APIs and scale (the hyperscalers) with ISVs and CSPs will result in practical production-grade architectures and interfaces. We recommend looking at **Anuket's reference documents** and digging into **AWS and DISH's description of their hybrid architecture**. Nevertheless, it should be clear that the unified telco cloud is a work-in-progress.

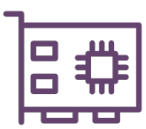
- **#3: Loosely federated siloed islands are the realistic outcome today.** Many telco stacks (OSS, BSS, VNFs, CNFs) today are certified on specific cloud platforms (NEP telco cloud, Red Hat, or VMware), with an increasing number of stacks qualified to run on hyperscaler clouds (AWS, Azure, GCP). The current fragmentation of the space and the need to show immediate business results will mean that carriers roll out cloud-native vertical silos domain-by-domain for rapid service turn-up. CSPs should lay down unified policies and frameworks and invest in end-to-end hierarchical orchestration solutions (multi-domain services orchestration tied to domain orchestrators) as a stopgap measure. The stopgap will invariably last longer than anyone anticipates while we navigate the telco cloud journey.

- **#4: Hyperscalers should be embraced, not avoided**. CSPs understand the need to go cloud-native. NEPs and the global SIs that service the CSP market have made the push, partially in response to 5G SBA but also due to application development evolution. Cloud-native is not solely an architecture but brings process and cultural changes with it. The DevOps and continuous integration/continuous deployment (CI/CD), canary test, blue/green deployments, micro-services architectures, automation-first, and API-centric mindsets and practices have yielded improved agility, time-to-market, and higher quality for organizations embracing them. Hyperscalers and big SaaS players lead in cloud-native, and their services embody this mindset. CSPs can accelerate their cultural and DNA change by engaging closely with hyperscalers — pick one and get started. Lock-in fears at this stage make little sense. CSPs particularly concerned about being held hostage by a hyperscaler can always engage vendors like Red Hat, VMware, or other multi-cloud solutions to add a portable abstraction layer. Ironically, the better CSPs that understand cloud-native and hyperscaler services and platforms, the more agile and flexible they can be in switching cloud platforms later.

- **#5: Don't let the shiny edge cloud (*verb*) telco platform decisions.** Many on-premises edge workloads are updated versions of applications previously running on servers or virtual machines in what were termed "computer rooms." Cloud-based orchestration and practices applied to these workloads allow them to be termed "edge" workloads, inflating the estimates for edge computing market size. Nevertheless, there are net new applications in IoT and industrial IoT as businesses digitize previously analog processes, and onsite video processing for safety, health, security, and marketing will generate opportunities. For CSPs who will host networking and security applications onsite in specialized appliances or on universal CPEs (uCPE), it's tempting to address these workloads via a comprehensive telco cloud edge platform. However, it's not clear yet that CSPs are the best route to market for these applications, nor are they the natural owner or operators of on-premises enterprise edge platforms. We recommend taking a cautious approach and fielding uCPE solutions as a separate domain hosting SD-WAN, SASE, SSE, firewall, Private Wireless Networks-as-a-Service, and WiFi applications first, with the ability to host limited enterprise applications. Trying to solve for an end-to-end telco cloud that can address both on-premises and cloud data centers is premature.

- **#6: Focus on DevOps, orchestration, monitoring, and assurance.** In our conversations with CSPs further along in their telco cloud journey, they emphasize the importance of driving cultural change over picking the perfect telco cloud candidate. Learning and adopting a DevOps mindset, putting in place a pipeline process from development to staging to production, focusing on automation and assurance — these elements are adaptable and necessary regardless of which vendor(s) are picked. These enlightened CSPs point out that legacy processes of upgrading vendor appliances and loading new software every 6-9 months are dramatically different from pushing out releases every day or week — and integrating onsite pipelines with software vendor pipelines. Whether AWS, Azure, GCP, VMware, Red Hat, Wind River, or other cloud platforms, managing containers, Kubernetes, and GitOps is similar. Each vendor has specific implementations, but peculiarities represent less than 10-20% of the difference — we advise CSPs to look at the bigger picture.

- **#7: Don't let security be a blocker or an afterthought .** Several CSPs have expressed concerns that the move to cloud platforms increases their attack surface and exposes them to hackers well-versed in finding exploits in typical cloud architecture and popular open-source software. These CSPs felt more secure in their walled enclaves of proprietary dedicated hardware appliances. The reality is that critical industries and companies handling sensitive data have adopted cloud platforms — banking, finance, insurance, healthcare, government, and military. Best practices for ensuring a secure cloud foundation and secure DevOps practices exist. CSPs should look to adopt these practices and not use security as an excuse to delay cloud adoption. On the flip side, CSPs need to lay down secure cloud practices at the beginning of their cloud-native journeys — adding security after the fact is too late.



- **#8: Recognize hardware diversity and architectural evolution.** Further complicating telco cloud hardware management is the arrival of other hardware options for edge computing. These include hyper-converged infrastructure, which collapses computing, storage, and networking elements into Lego-type bricks. There are also SmartNICs and HW boards that provide strong networking and AI performance per unit power/space for constrained edge footprints. Likewise, there's a surge of interest in composable systems that manifest dynamic configurations out of underlying pools of CPUs, storage, GPUs, and FPGAs. These composable systems make efficient use of underlying hardware and ensure the "composed" server is well-matched to its software workload. Faced with hardware diversity, CSPs will need to figure out how to manage and monitor hardware platforms either via vendor-specific HW management software or Distributed Management Task Force (DMTF) Redfish standards specifications. There are ongoing efforts to extend Redfish to scale better to large numbers of edge locations. One example is Linux Foundation's Open Distributed Infrastructure Management (ODIM) project,

- **#9: Pay attention to data sovereignty, efficiency, and sustainability.** We discussed data sovereignty earlier when describing Linux Foundation's Project Sylva. In the EU, and likely for other markets, we expect data residency and sovereignty to be recurring topics. Privacy and consumer protection laws may dictate where certain data types can be processed and stored. Telco cloud platform choices that involve data centers outside of CSP control (e.g., hyperscaler public clouds, co-location facilities, fully-managed telco clouds) will need to be cognizant of the impact on data residency. Many of these offerings have started to provide localized options — e.g., AWS Local Zones, AWS Outposts for regional and private data center deployments; Azure Stack Edge, and Google Distributed Cloud Edge from the other hyperscalers play similar roles. Other increasingly essential attributes for telco clouds (especially at the edge) are efficiency and sustainability — both in bits processed per unit power (and space) and impact on the environment.

## Conclusion — Inching Our Way to the Telco Cloud

CSPs today don't just face simple decisions of what, when, and how to virtualize and deploy VMs, or whether and when to embrace cloud-native and container-based offerings. CSPs are under pressure to determine which parts of their infrastructure are core, whom to partner with, when and where to use public clouds, and how much to extend their infrastructure to the edge and into customer premises. The telco cloud decision is a complex, strategic, business decision.

However, as we've detailed above, the unified telco cloud that can serve from core to edge is an aspirational end goal that is unachievable today. Nevertheless, there are key strategies that CSPs worldwide can implement even as they move step by step towards cloud-native telco architectures. We hope this report has provided you with a window into the state of the industry today, and that you take away a checklist of elements to consider in your telco cloud strategy.

We're open to feedback and discussion. You can always reach us at **research@avidthink.com**.

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Rev A