



## Executive Summary

Communications service providers are engaged in a strategic evolution of their infrastructures using virtualized and cloud-native designs. This effort has been underway for several years in both their IT data center and core network operating sites. Innovations in both end-users' applications and related mobile networking technologies are motivating CSPs now to expand their use of virtualization to highly distributed network edge application and service delivery sites.

Mobile operators in all regions are deeply engaged in taking further advantage of open-source cloud-native and microservices software innovations as they grow the service capacity of their networks and plan for deployment of next-generation 5G architectures. These deployments will expand their use of virtualization beyond centralized core operating sites and into the enterprise edge and radio access network (RAN) application sites they will operate. In developing their infrastructure evolution plans there are several key architectural and economic considerations to address. Service providers must decide whether to begin their virtualized RAN (vRAN) deployments in existing 4G/LTE networks and carry these designs forward into 5G. They also need to decide whether to employ one type of virtualized infrastructure in core locations and a different one in distributed sites or to use a horizontally integrated cloud across both core and distributed sites. They must examine the economic implications of each choice.

As a leading participant in the global ecosystem for virtual system infrastructures in CSPs, Red Hat decided to explore these implications in depth with ACG and determine which scenarios offer the greatest advantages to CSPs. Our findings clearly indicate that distributed virtual infrastructures for CSPs will benefit materially from the use of elastic, horizontal cloud designs. They enable a 30% lower total cost of ownership (TCO) than silo based deployments in 4G mobile core deployments. In distributed implementations, centralized vRAN designs enable up to 44% lower TCO than conventional distributed RAN deployments.

## Key Insights

- Virtualized system infrastructures will be increasingly critical in CSPs' deployments from core to edge as mobile networks grow and 5G implementations begin.
- Horizontally integrated telco clouds enable a 30% lower TCO than silo-based deployments in 4G core applications (vEPC/vIMS).
- Centralized vRAN architectures enable up to 44% lower TCO than conventional distributed RANs.
- Red Hat's supported open source solutions for telco cloud deployments compared with do-it-yourself approaches have shown improved TCO advantages of up to 35%.
- Next-gen 5G will rely on virtualized cloud-native distributed infrastructures using containerized networking apps and modular microservices, increasing the value of open horizontal cloud platforms.

## Building on the Strengths of the Cloud and Existing Virtualization Initiatives

The power of cloud-native application design and software-driven infrastructures has had a profound effect on telecommunications service providers' architecture and service delivery planning efforts over the past several years. This is partially based on the impressive results web scale operators have achieved by relying on these designs in areas ranging from continuous integration and deployment (CI/CD, which allows for always on, in-service updates to services around the clock) to dramatic improvements in the efficiency of operations, where automation and microservices designs have increased the size of the infrastructure pools each engineering team can manage by an order of magnitude compared with conventional operations practices. There is a strong belief among telecom providers that the costs of their operations can be minimized, the agility of their service introductions increased, and their competitiveness in target markets improved by embracing the same approach.

Work by providers toward this goal began in 2012 with the activation of the network functions virtualization (NFV) industry specifications initiative. This effort has continued since then with steady focus on improving the performance and scalability of designs and the gradual adoption of cloud-native technologies in support of network and application workloads within service offerings. As with many large technology transformations, progress toward evolving these goals has been measured and has occurred in pockets across a variety of provider use cases (enterprise, mobile, video, and consumer). Still, the motivations for adopting cloud-native designs and the evidence of the flexibility that can be achieved have been compelling. In fact, the number of applications dubbed cloud-native and cloud-based in descriptions of service offerings has increased dramatically over the past year alone.

## Mobile Networks Are Perfect Candidates for Virtualized and Cloud-Native Designs

During the time since work on NFV began in 2012, the growth of mobile networks and applications has continued unabated with mobile data usage growing globally at nearly 100% per year.<sup>1</sup> To manage this growth, operators are looking to cloud-native designs to support growth at lower overall costs while providing greater flexibility.

### Tracing the Path of Economic Gains from Virtualization in Mobile Networks Starting at the Core

Although 5G is the focus of significant work in standards development, R&D, and early solution trials today, the 4G/LTE packet core was among the first use cases to be implemented using NFV. Substantial early learnings in the transformation of operators' infrastructures to a virtualized mode of operation have been gained from the industry's work in 4G/LTE packet core.

A study by ACG Research in 2015 compared the use of virtual infrastructures to using purpose-built platforms in the mobile packet core. It found the capex of the virtual implementation to be **68% lower** than that of the purpose-built solution; the opex to be **67% lower**; and the cumulative TCO to be **67% lower** than the alternatives.<sup>2</sup> Although these benefits were important, this did not mean that deployments were without their challenges. It was difficult to achieve the industry's goal of mix and match, plug and

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<sup>1</sup> [The Mobile Economy 2019, GSM Association, 2019.](#)

<sup>2</sup> [ACG Research, The Business Case for a Common NFV Platform, October 2015.](#)

play deployment of VNFs into virtual system infrastructures because of the differences in implementation of many VNFs and the lack of a widely understood and implemented APIs for integrating VNFs into their underlying infrastructures, as well as their orchestration environments. Many offerings supported a limited range of VNF combinations, creating silos that constrained the innovation and flexibility that providers could achieve.

This led to a focus in the NFV community on creating implementations that overcome the limitations of silo-based deployments and achieve greater flexibilities at scale. Many enhancements have been made, including deploying services using more consistent configuration models to onboard VNFs at installation time. One prominent initiative, the Common NFVI Telco Task Force (or CNTT)<sup>3</sup>, is working on limiting the degree of variation in VNF and NFVI implementations and arriving at a joint operator, vendor, and open source community agreement on more consistent implementation designs. Although these efforts toward architectural stabilization are substantive, operators have in parallel started to converge on the path of using an open, horizontally scalable platform to support their virtual function deployments. With the advent of 5G, the industry is focused on enhancing its virtual infrastructures to expand horizontally to run as a distributed cloud fabric at scale for virtualized and cloud-native network functions.

### **The Economics of vEPC and vIMS in a Horizontal Design versus a Silo-Based Implementation**

Using ACG Research's Business Analytics Engine (BAE), we recently compared the total cost of ownership (TCO) of running a mobile operator's virtual evolved packet core (vEPC) and virtualized IP Multimedia Subsystem (vIMS) implementation using multiple vertically integrated (silo-based) solutions versus deploying all services and applications in an integrated horizontal cloud.

The infrastructures we compared were sized based on a representative national/Tier 1 operator's mobile network in three (3) metropolitan regions, approximately twelve (12) million subscribers, and five (5) thousand cell sites between urban and rural areas. To arrive at the total TCO we analyzed both capital expense (capex) and operation expense (opex) of each alternative over five years. Because the deployments are each in the telco's core network operating locations and are supporting the same number of subscribers with the same cell site population, the capex of the alternatives compared is the same. That includes the cost of the servers, the network switches, the racks and the perpetual software licenses for the software elements employed in the two designs.

The opex of the alternatives, however, is significantly different. In the siloed case, the operator needs to design and run four separate infrastructure silos, versus a single integrated infrastructure in the horizontal case. The areas of greatest difference in the opex are the amount of engineering and planning required to manage the four silos versus the single horizontal infrastructure (which is 2x), the greater number of virtual infrastructure software licenses required in the multiple silos case (1.5x the cost), the increased cost of securing the multiple silos (3x), and the higher cost of on-boarding new hardware in the multiple silo infrastructures (3x) versus on-boarding new hardware in the horizontal cloud.

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<sup>3</sup> <https://events.linuxfoundation.org/events/cntt-f2f/>.

As shown in Figure 1, the opex of the horizontal infrastructure is 41% more efficient than the opex of the siloed deployment, and the total TCO over five years is 30% lower.

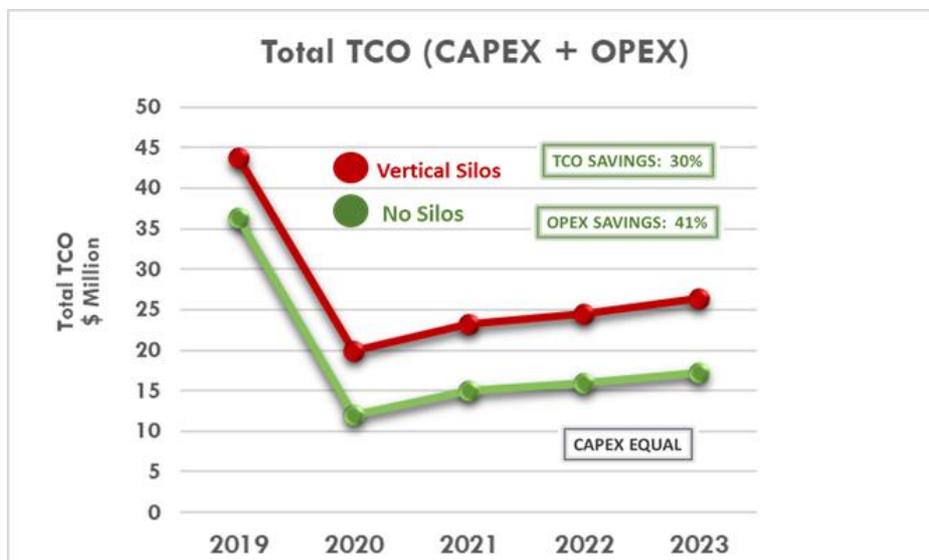


Figure 1. Savings from Using Horizontally Integrated Cloud in the Mobile Packet Core (vEPC/vIMS)<sup>4</sup>

These results show that although earlier implementations of NFV could achieve important benefits compared with purpose-built platforms, the capabilities of virtual infrastructures have evolved to deliver benefits beyond that original design, using an elastic, horizontal cloud as a shared operational environment for service deployments.

Looking forward, with the rapidly approaching implementation of next-generation 5G architectures, the industry is looking at the potential for the radio access network (RAN) in addition to the network core to benefit from similar gains with virtualized processing of key RAN functions, increased adoption of containers and microservices, and the support of distributed edge applications.

### Operational Context for Virtualization in the RAN

To set context for considering virtualization in the RAN, let us highlight the role and composition of the RAN in mobile networks so we can assess the economics of using virtualization in them.

Radio units (RUs) provide the radio frequency (RF) interfaces over which user equipment (UE) connects to a mobile operator network. RUs and their controllers operate at points of subscriber access to the network around a provider's infrastructure. These elements are always placed in close proximity to where users make their network access, because of the limited distances over which the radios of mobile networks operate.

Components of the RAN that are candidates for virtualization are both architecturally and topologically separate from the mobile network core. Figure 2 illustrates a 4G/LTE network, including remote radio and

<sup>4</sup> Data source: ACG Analytics, Business Analytics Engine (BAE), 2019.

control units (labelled eNodeB), connected via backhaul to the mobile core where Mobility Management and Evolved Packet Core (EPC) functions are deployed.

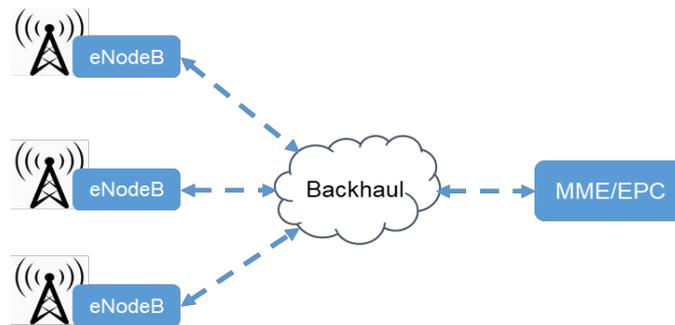


Figure 2. 4G/LTE RAN Backhaul to Mobile Core

The benefits of virtualization we identified in the mobile core can also be extended to the RAN. As we previously mentioned, radio sites are composed of RUs and their controllers. RUs handle RF communication with UE or handsets, and controllers manage the connection of the UEs and the radio site to the rest of the operator network. This includes converting payloads moving in either direction between packet-based and radio frequency-defined data streams, handling mobility and security for mobile users' connections, and managing the quality of users' connections. Much of this is referred to as baseband processing. The elements supporting baseband processing are referred to as baseband units (BBUs). This general separation of network and control between RU and BBU is true in both 3G, 4G, and emerging 5G RANs, though the composition varies based on architecture.

In a virtualized RAN (vRAN), the processing that is executable in general-purpose processors can be decoupled from the radio elements (RUs) and performed in a pool of computing resources known as a virtualized baseband unit (vBBU) computing pool.

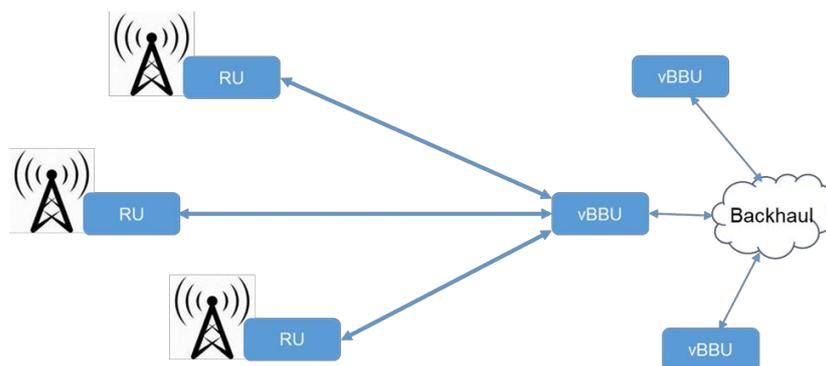


Figure 3. vBBU Pool Serving a Set of Remotely Located Radio Sites

The topology of these vRAN sites varies based on where the operator has deployed its network. In urban areas, the number of radio sites per vBBU may approach 100, while in suburban areas it may be closer to 50, and in rural areas only 10 or 15 sites. In most cases, the connection of the vRAN site to the network core is made over the operator's backhaul network. With this approach, the cost of BBU processing for

each radio site can be reduced, while idle capacities in the processing for a given site can be reused in the computing pool, improving the efficiency of the overall operator infrastructure.

In our analysis of the economics of virtualization in the RAN, we compared the TCO of a vRAN to the TCO of a conventionally distributed RAN (DRAN) that places RU and BBU components at each radio site. Figure 4 gives a high-level illustration of the two designs.

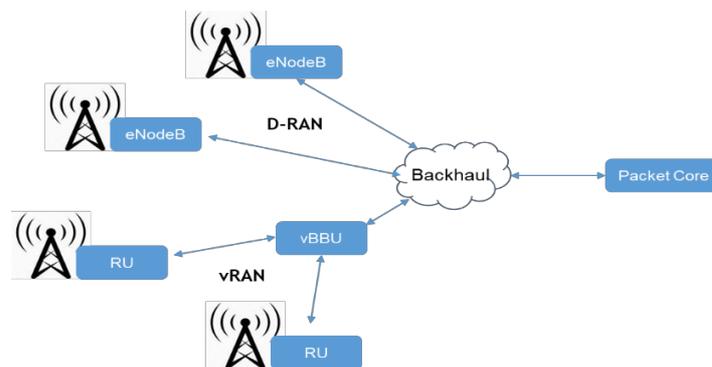


Figure 4. vRAN and DRAN Architectures

## Economic Benefits of Virtualization in the RAN

The cases addressable using vRAN designs **today** are based on 4G/LTE. Although 5G implementations are receiving a great deal of R&D and early stage trial work, practical experience in production deployments is possible already based on 4G/LTE. Some operators have begun virtualizing in their 4G/LTE RANs as a means of improving the economics of their networks. In additional cases they are focusing on areas where their networks are growing or where they are introducing new service offerings. In each case it is possible to examine the economics of using a vRAN-based configuration versus using a conventional DRAN based design.

To analyze the economics of the alternative designs, we modeled the life cycle of RAN deployments in a Tier 1 mobile operator environment over five years using our BAE. The network in this case supports 10 million subscribers and has an existing deployment of 12 thousand radio sites. Over the course of five years, growth in traffic will increase the coverage of the network in urban, suburban, and rural areas, expanding to an additional 11 thousand radio sites.

We compared the capex and opex of each design and calculated its total TCO over five years. The capex of the DRAN option in this case was twice (2x) the capex of the vRAN design. The sources of this difference are primarily in the cost of the BBU equipment installed at each cell site in the DRAN design, compared with the cost of the servers and related infrastructure deployed being used for BBU processing at the smaller number of server sites in the vRAN design.

The opex of the DRAN implementation is also significantly higher than the opex in the vRAN case. The differences are in higher site rental, BBU maintenance, fiber lease, and power and cooling costs compared with the smaller footprint and costs of the vRAN design.

Although these TCO differences apply fundamentally between the DRAN and the vRAN designs, operators can also decide how extensively they will use either approach (which influences how much they will benefit). They can decide to virtualize their **entire** RAN, including all existing cell sites or they can opt to virtualize only **new** deployments or growth sites. The benefits they can achieve vary based on the choice, with the TCO savings measured at 27% in the growth-focused model and up to 44% when virtualizing the **entire** RAN. These differences are based on achieving the savings in TCO that were previously cited in a larger number of sites in the full RAN virtualization case versus the smaller number of sites included in the growth sites only approach.

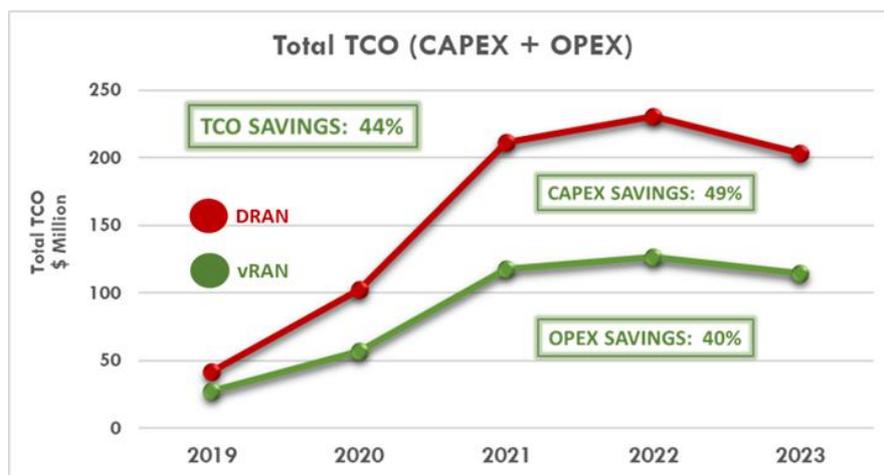


Figure 5. Economic Advantages of Using vRAN Configurations in 4G Deployments<sup>5</sup>

### Virtualization in Next-Generation 5G RANs

5G architectures are well-suited to cloud-native design, distributed functionality, and the opportunity to take further benefits from microservices, and a range of performance acceleration technologies.<sup>6</sup> In addition, 5G introduces new architectural elements in the RAN that will increase operators' motivations for using vRAN designs with the potential to improve their economic benefits.

In 5G, vBBU configurations in many cases will be connected to remote radio sites using a new front-haul communications design (see Figure 6). These are based on the separation of RU to vBBU communications and splitting protocol operations between them between a distributed unit (DU) at the radio site and a centralized unit (CU) at the vBBU site, further back in the topology. This separation of functions is expected to enable greater efficiencies in deployments, as well as being able to support more types of remote radio units, subscriber connections and applications. The use of this split radio access network design across DU and CU will allow vRAN architectures to support larger numbers of radio sites and flexible topologies that create improved economics across each portion of the deployment.

<sup>5</sup> Data Sources: ACG Analytics, Business Analytics Engine, 2019.

<sup>6</sup> See for example, the 3GPP Release 15 specification, <https://www.3gpp.org/release-15>.

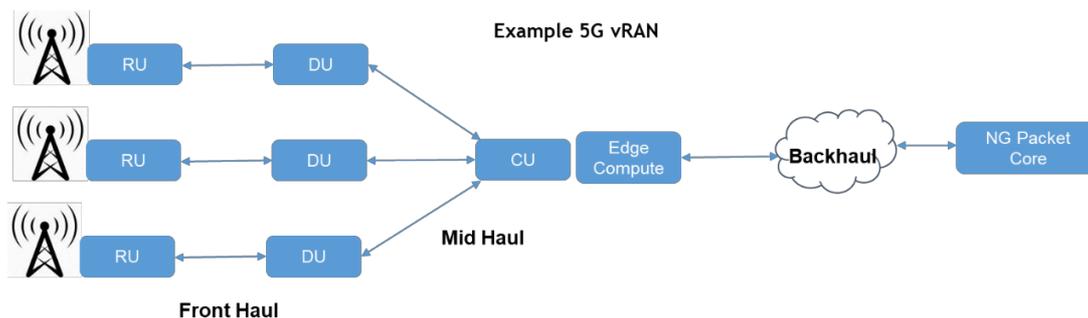


Figure 6. 5G Split vRAN Architecture

This distribution is likely to produce two key benefits:

1. Using the same horizontal infrastructure in both 5G core and edge will allow operators to extend TCO benefits they gain in horizontal designs in the core throughout their network.
2. Deploying horizontal clouds to vRAN sites will allow operators to support new applications and services that have not been possible to deliver in the past, based on the location awareness, reduced latency, and scalability achievable in the distributed cloud.<sup>7</sup>

Although we are still in the early days of 5G deployments, we expect 5G to benefit extensively from the use of edge cloud resources to enable services for business, industrial IoT, telehealth, gaming, AR/VR, public safety, and more. As 5G matures, we will be able to examine its operational and deployment costs in more detail to provide a similar analysis of its economic benefits.

### Benefits of Red Hat's Portfolio in 4G/LTE and 5G Architectures

As a premier supplier of cloud technologies into IT environments, Red Hat has also been a leader in evolving the open source operating system and cloud software distributions it includes in its portfolio to support NFV and cloud-native designs in operators' networks. Red Hat's commitment to open source supports service providers' desires for open, extensible frameworks, and engages a community of contributors to mature the open source initiatives surrounding Linux, KVM, and OVS, and also O-RAN, OpenStack, OPNFV, Kubernetes, Ansible, along with innovations in 4G/LTE, 5G, and real-time edge computing. These efforts have led to Red Hat's involvement in telco cloud deployments for virtualized packet core (vEPC/vIMS) and vRAN. Red Hat has also worked closely with community and ecosystem contributors, including operators, on refining support for higher data plane throughput in VNFs, automation of installation and operations processes across multi-vendor NFV software stacks and evaluating how the distribution of clouds across open horizontal platforms can best be deployed across multiple core and edge sites.

All of these innovative contributions and developments lead to Red Hat supplying a trusted set of open source platforms and tools for production deployments compared to operators building and supporting their own collection of community software elements. Taking on the responsibility of deploying do-it-

<sup>7</sup> See, for example, [Transformation and Opportunity at the Service Provider Edge, ACG Research, November 2018](#), for a discussion of use cases and applications that increasing distributed service provider clouds will make possible.

yourself (DIY) solutions in production involves significant additional cost and risk compared with deploying fully supported open-source solutions such as those supplied by Red Hat. Economic analyses that we have carried out in parallel to the studies outlined in this paper indicate that using Red Hat's supported open source solutions for telco cloud deployments enables TCO advantages of up to 35% over DIY approaches.

Red Hat continues to adapt its cloud platform offerings to the distributed environments that virtualized central offices and smaller distributed edge computing sites will employ. 4G/LTE and 5G vRAN architectures are naturally aligned with deployment environments of these types as operators expand their support for more robust network services and more powerful and flexible RAN designs.

Our view is that Red Hat is well-positioned to enable the elastic, horizontal clouds for vRAN and edge computing deployments at the scale and with the economic benefits our industry is expecting. Its capabilities in the cloud-native and virtualized computing environments required in these clouds and its deep engagement in the open source communities that are evolving the infrastructure designs to meet service providers' requirements are important factors in deploying these infrastructures successfully. Red Hat's close collaboration with many of the cloud, IT and networking ecosystem hardware suppliers, including chip and server suppliers and vendors in specialty categories of equipment such as GPUs, FPGAs and networking, results in a versatility of use cases that is distinctive in the industry. Beyond these initiatives, its engagements with automation and orchestration-related developments contributing to the efficiencies achievable in cloud implementations is also in line with operators' requirements. Each of these is a critical element in creating the offerings required to support an elastic, horizontal cloud, ready to scale from core to edge.

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