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2020 State of NFV Report

RESEARCH BRIEF

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2020 State of NFV Report

Introduction

In October 2012, seven leading communications service providers (CSP): AT&T, BT, CenturyLink, Colt, Deutsche Telekom, KDDI, NTT, Orange, Telecom Italia (TIM), Telefónica, Telstra and Verizon teamed up under the auspices of ETSI to launch network functions virtualization (NFV). The subsequent years have seen much progress in the adoption of virtualization at CSPs, but also much confusion and frustration. Many networking solution vendors and CSPs alike are still coming to grips with adopting virtualization across their entire infrastructure, and with 5G rollouts on the horizon for those who are also mobile network operators (MNO), virtualization and the move to cloud architecture has become urgent.

This AvidThink research brief looks at the overall state of NFV in the market today and the major trends and challenges. It also presents exclusive viewpoints from ten leading CSPs worldwide on the results of their current NFV deployments, their expectations for next-generation services especially those leveraging 5G, the benefits of open-source initiatives, and their views on key challenges ahead. The viewpoints represent a combination of recent conversations with CSP executives and publicly available information. We will conclude with a series of recommendations for CSPs today as they continue their march towards full virtualization.

Overview — NFV Today

State of NFV in 2019/2020

Most CSPs have virtualized at least part of their network, deploying core functions like virtual evolved packet core (vEPC), virtual IP Multimedia Subsystem (vIMS), and virtual session border controller (vSBC) as well as edge services like virtual content delivery network (vCDN) and software-defined wide area network (SD-WAN). In fact, SD-WAN has been a boon for both CSPs and NFV, with a second wave of deployments utilizing white-box universal CPE platforms in conjunction with SD-WAN virtual network functions (VNFs). These second generation of SD-WAN deployments are built on NFV infrastructure (NFVI) foundations and leverage NFV orchestration models.

One of the key realizations across all major CSPs is that the primary business benefits of NFV center around improved service agility rather than cost savings. However, many CSPs realize that increased automation is needed to realize the full business potential of NFV, hence the increased focus on orchestration and automation last year in 2019, with continued investments in 2020.

Industry Trends

With the success of cloud-native and container-based infrastructure in cloud and SaaS over-the-top (OTT) providers, CSPs are looking to adapt and adopt similar architecture in their next-generation of NFV buildout. In many cases, CSPs are eschewing NFV terminology and embracing cloud native instead, with visions of building a telco cloud.

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Cloud-native architectures, including cloud-native network functions (CNFs), are seen as critical in the longer term for deployment agility, rapid service customization, high reliability, and comprehensive automation. Edge services, some enabled by 5G network slicing, will offer new revenue opportunities in both

consumer and enterprise segments. Through collaboration with public cloud providers, CSPs will accelerate their service deployments via NFV-as-a-Service offerings while utilizing cloud-bursting to optimize capacity. Machine learning (ML) and artificial intelligence (AI) will be key to a frictionless customer experience while also contributing to OPEX reductions.

The next wave of change at CSPs as we kick-off 2020, particularly for the mobile network operators, will be driven by 5G. 5G should enable new types of services which could boost average revenue per user (ARPU) or average revenue per account (ARPA). Beyond enhanced mobile broadband, consumer applications include cloud gaming, AR, and VR, while CSPs anticipate revenue-generating enterprise opportunities in healthcare, manufacturing, transportation, retail and IoT. To help defray the costs of building out 5G infrastructure, MNOs are still experimenting with business cases and marketable services that will drive ARPA up.

While the initial premise of NFV involved running virtualized workloads on standard servers, there is now a focus on accelerated platforms comprising Smart NICs and/or GPUs. These enable significant reductions in resource requirements leading to major CAPEX and OPEX savings. This, along with SD-WAN/uCPE, has led to a resurgence of interest in NFVI.

Key Challenges

CSPs now compete with the web-scale giants for team members with the necessary software skills. They are also challenged to retrain their existing workforces — not just to develop relevant software expertise within a DevOps culture but also to master emerging technologies such as AI, ML, and data science.

With a lack of collaboration between vendors and limited availability of functional, high-performance cloud-native products, CSPs report significant challenges in integrating, troubleshooting, and deploying multivendor solutions. Pay-as-you-go licensing models are immature and show little consistency between vendors' business models.

CSPs have embraced open-source software, both as a development methodology and to leverage standardization enabled by the plethora of telco-focused communities that have emerged over the past few years, not to mention the numerous edge-focused projects springing up. Particular examples include Linux Foundation and GSMA's Common NFVI Telco Task Force (CNTT), Linux Foundation's Open Networking Automation Platform (ONAP), and the O-RAN alliance. However, there is concern about sustaining too many overlapping projects which tend to become more complex over time.

Service Provider Viewpoints

To get a better handle on the current state of NFV, we engaged a selection of major CSPs worldwide. The following analyses are based on responses from CSPs as well as available public information. We welcome feedback from CSPs directly — we can be reached at **research@avidthink.com**. And we express our gratitude to the CSPs who spent time updating us on their NFV deployments.

AT&T

AT&T has several current deployments of virtualized services throughout its network. Key examples include Mobile Packet Core, SD-WAN, VoLTE, vCDN and Flexware uCPE. The company reached 65% of virtualization at the end of 2019, slightly missing their original goal of 75% before 2020. However, they are continuing their efforts and aim to reach 75% by the end of 2020. AT&T has essentially met all its outlined business targets since the initial NFV rollout in 2014.

AT&T highlights four key lessons learned from its NFV deployments. First, move to an open-source-first development approach. Second, standardize the hardware platform; this leads to fewer flavors and a single host profile. Third, automated life-cycle management of the platform is foundational to the ability to scale. Fourth, security must be built in from day one and continuously assessed.

AT&T will continue to use virtualization to move toward the network edge and work with cloud providers. It will continue exploring other new use cases for virtualization but is not ready to discuss any publicly at this time. The company expects that next-generation deployments will allow it to continue improving its network, as it works to provide simple, frictionless and rewarding customer experiences while leading in connectivity and integrated solutions.

As with other carriers, AT&T anticipates 5G will have a significant impact on how businesses work and engage with customers. New experiences and technologies such as AR/VR and machine learning offer great potential but require high bandwidth and low latency to achieve optimal performance — problems that 5G will be well suited to address. Virtualization with 5G will allow AT&T to rapidly activate new services for enterprise customers, like network slicing and other software-defined network capabilities.

By utilizing the Airship open source project, AT&T is ensuring that its NFVI platform is cloud native. This will allow its network cloud to evolve in place and move from supporting VNFs to VNFs plus CNFs and finally exclusively CNFs.

AT&T expects its software vendors to support CNTT efforts, as well as complementary communities like OPNFV and Airship. This will simplify the NFVI landscape and enable suppliers to deliver VNFs and CNFs with higher quality and lower cost.

AT&T's private cloud NFVI will be core to delivering SDN. However, in most cases for non-network workloads, the plan is to use native tools for public cloud applications. In instances where there are hybrid applications inside cloud providers, AT&T's native SDN tools allow for common network function deployment, such as through bursting.

Contributing over 10 million lines of code just in the past two years to the open source communities, AT&T is one of the leading players in open source software. AT&T plays key leadership roles in several of the largest open source foundations, such as The Linux Foundation, Open Network Foundation, and OpenStack Foundation. The company has also been instrumental in launching several major open source initiatives, such as ONAP, Airship, Akraino, Acumos, O-RAN, and OpenROADM.

100% of AT&T's NFVI software and 40% of the software developed internally is based on open source. AT&T leverages open source in order to work together as a community to innovate and deploy faster, without starting from scratch every time. AT&T believes this allows their teams to focus on building new technology instead of reinventing technologies others have already built. It also focuses on the creation of industry standards that enable suppliers to collaborate much earlier.

AT&T has indicated a willingness to use system integrators (SI) where needed in continuing to deploy next generation networks. For example, as AT&T moves toward white box technology, it is using post-production integrators to integrate software and hardware.

AT&T realized that being successful in changing from a hardware company to a software company would require different skills and significant retraining within their existing workforce. AT&T has made this transition primarily by developing extensive internal training opportunities and courses in all areas of technology so that employees have the opportunity to reskill. The company offers coursework and training on software-defined networks, virtual networks, and big data, among others. It has also partnered with various universities on master's programs for a variety of degrees, including computer science and data science. Working in open source has also exposed its software engineers to a global peer group and opportunities to collaborate remotely via IRC and code reviews. Additionally, attending in-person open source forums, e.g., Open Infrastructure Summits, has helped to rapidly strengthen the AT&T workforce.

AT&T highlights three key industry challenges around NFV:

- Maintaining a healthy ecosystem of suppliers that embraces and actively contributes to open source.
- Sustaining open source communities once the hype has died down and projects mature.
- Helping internal network teams pivot from integrating full stack products to developing open source disaggregated stacks (owning the product).

China Mobile

China Mobile is the world's largest mobile network operator by total number of subscribers, with over 902 million subscribers as of June 2018. It has been working on the concept of a three-layer decoupled network architecture. This enables more efficient running of applications, cloud operating systems and bare metal hardware, as each layer can evolve and develop independently. Executives expect NFV and SDN to continuously enhance network resource utilization efficiency and increase network agility in various service automation scenarios.

China Mobile has publicly announced that it is working with Huawei, Nokia, Ericsson and ZTE in the deployment of its 5G network. The China Mobile Open NFV Lab, founded in 2015, involves multiple partners including ARM, Cavium, Enea, Ericsson, H3C, Huawei, Mirantis, Red Hat, and Wind River.

In 2018, China Mobile conducted field trials in four provinces with more than ten OpenStack vendors as a test bed for new technologies such as NFVI, MANO and VNFs. While most of the OpenStack platforms delivered good results on functional testing, China Mobile found wide variations in system-level performance as well as in high availability support beyond the scope of standard open-source distributions. It identified significant challenges in integrating OpenStack, virtual switches and SDN controllers from different vendors. It also found a wide variation in the maturity of VNFs from different vendors.

China Mobile is exploring opportunities to extend their services into vertical markets such as smart cities, smart transportation, and intelligent video analytics.

China Mobile has unveiled its 5G network in 50 cities including Beijing, Shanghai, and Shenzhen, with packages priced as low as 128 yuan ($18) per month. It is planning to offer network slicing services by the middle of 2020 when the standalone 5G network achieves commercial scale. To achieve this, it is developing a one-stop cloud-network convergence platform that can provide customized service capabilities in both centralized data centers and data centers. It has also issued network slicing templates for six industry verticals: power grid, autonomous driving, gaming, entertainment, banking and medical.

Cloud-native support is a key element within China Mobile's Telecom Integrated Cloud (TIC) architecture. It expects its vendor community to collaborate in order to solve integration problems, especially around the efficient integration of MANO, OpenStack, virtual switches, and VNFs.

China Mobile itself offers public, private, and hybrid cloud services, such as hosting workloads on either Kubernetes containers or bare metal servers, in addition to partnering with other public cloud providers, such as AWS.

China Mobile has long demonstrated its commitment to NFV. It was a founder member of CNTT, along with AT&T, Bell Canada, Deutsche Telekom, Jio, Orange, SK Telecom, Telstra, Verizon and Vodafone. In Beijing, it hosts one of the ONAP labs, which was an Open-O lab prior to the merger of Open-O and ECOMP to form ONAP. Also in Beijing, they provide a test lab for OPNFV. They were a founder member of O-RAN and deployed an O-RAN based 4G indoor distributed base station in JiangSu Province. Through their Suzhou R&D Center, China Mobile participates in the StarlingX community.

In terms of key industry challenges around NFV, China Mobile has publicly discussed:

- Concerns around system-level performance differences between different infrastructure vendors as well limitations in service assurance.
- Difficulties in integrating multi-vendor solutions into an overall architecture that matches a standard three-layer decoupled framework.

Colt

With a global footprint that includes Asia, Europe, and North America, Colt's primary use case for virtualized services is SD-WAN. It has also deployed a virtual firewall as well as a uCPE based on ADVA's platform and is about to launch a multi-cloud gateway with direct connect to AWS and Google Cloud. Colt's business focus is on introducing new services, such as SD-WAN, rather than cost reductions which are challenging given the learning curve for new technologies like NFV. Virtualization has enabled it to acquire new categories of customers that purchase flexible services.

Colt has publicly announced the selection of ADVA's uCPE platform, running on Advantech's white box hardware, as well as VNFs from Check Point, Juniper, Palo Alto, and Versa Networks. The central challenge Colt faced in the move to virtualization was the disaggregation of hardware from software, which placed the integration burden on the company despite support from their vendors. A key lesson learned here is that nothing is plug-and-play, despite claims made by vendors.

In the uCPE space, Colt plans to add WAN acceleration as part of its SD-WAN package and offer on-demand services via a VNF marketplace. In the infrastructure space, the company is exploring new use cases such as a virtual provider edge and virtual CPE. It will also enable customers to run their own applications on the Colt uCPE platform. While its initial deployments of virtualized services enabled new sources of revenue, the next wave will bring cost reductions resulting from the integration of multiple functions onto a single platform.

Colt anticipates a significant new business opportunity by leveraging its infrastructure to support 5G deployments for multiple CSPs. In one example engagement with a specific CSP, Colt determined that its fiber can reach to within 48 meters of all the CSP's planned 5G radios in London. This presents a major opportunity for new backhaul business.

Although Colt agrees that the future of network virtualization will be for the industry to evolve towards cloud-native architecture, executives don't see this as a priority at the moment. The Colt team are currently focused on delivering the first wave in terms of an NFV architecture that is VM-based. This is sufficient to deliver it's current use cases, from both customer-facing and infrastructure-based applications.

Colt's biggest expectation for its software vendors is to align with the industry VNF onboarding standards (ETSI/ONAP) so that the time and cost of onboarding new VNF vendors and applications can be dramatically reduced. The current industry status, with long onboarding times and high support costs, will not be sustainable in the future.

Colt already partners with most public cloud providers to offer direct cloud access propositions to customers. It aims to extend this partnership beyond just connectivity to explore collaboration around edge cloud customer propositions, where public clouds could extend their cloud offerings on-premise by using Colt's edge cloud platform initially based on its already launched uCPE technology.

Colt believes there should be much more harmonization and rationalization in terms of open-source initiatives as well as standardization efforts. The industry needs to merge and combine some of the overlapping existing initiatives in order to foster de-facto industry standards. One clear case is ONAP and OSM. Additionally, Colt would like to see the industry to focus on initiatives to simplify the overall NFV architecture, Lean NFV being an example.

The ongoing transition in the telecom industry towards a new software world is demanding more and more support from external parties and system integrators. Colt recognizes this and is exploring partnerships for extended vendor support as well as engagements with pure SIs to help with the initial NFV developments. A good start would be around the validation and onboarding of new VNFs.

Colt's skills development strategy is built around two axes. One is to promote internal transformation by defining the right organization and bringing the right profiles and skills in joint teams, e.g., network and IT profiles, while defining upskill programs where required. The second strategy is to acquire new talent in areas like software development to help deliver the on-demand customer experience.

Colt highlights two key industry challenges around NFV:

- A lack of accepted standards leading to manual, long, and costly VNF onboarding.
- A need to reduce the overall complexity of the NFV architecture while at the same time helping interworking of the different NFV layers.

DISH Network

DISH Network is a US pay-TV company that operates the direct-broadcast satellite DISH service as well as the Sling TV over-the-top (OTT) IPTV service, with around 10 million satellite subscribers. DISH owns a significant amount of wireless spectrum and has deployed a Narrowband-IoT (NB-IoT) network that covers approximately 70% of the US population.

Courtesy of the impending merger between Sprint and T-Mobile, DISH could be positioned to become the fourth-largest wireless carrier in the US, the other three being AT&T, Verizon and the new T-Mobile (that includes Sprint).

Under the terms of the potential merger, DISH will acquire Sprint's prepaid mobile businesses under the Boost, Sprint Prepaid and Virgin brands, as well as 800MHz of spectrum. They will also take over thousands of Sprint and T-Mobile cell sites and hundreds of their retail locations. DISH will become a Mobile Virtual Network Operator (MVNO) of the new T-Mobile, with access to the combined Sprint – T-Mobile network, including 5G. In return, DISH has committed to build its own 5G network, leveraging its spectrum purchased over many years, that meets specific schedules for geographical coverage.

However, the Sprint – T-Mobile merger was challenged by Attorneys General in 13 states and final approval is delayed until the conclusion of that trial.

As a greenfield network deployment, DISH expects to enjoy significant business and technical advantages in comparison with its rivals who operate legacy networks. Similar to Rakuten in Japan, they expect to fully leverage cloud computing and virtualization from the outset. They issued three RFPs during 2019: one for network equipment vendors in July, another for software and project management vendors in September and the third for cell site construction in October. While no vendor selections have been announced at the time this report is published, DISH did name Altiostar, Cisco and Red Hat as vendors used by Rakuten that DISH would also consider for their network.

As Dish builds out its wireless network, its MVNO engagements with the new T-Mobile will decrease. This transition should be transparent to DISH's subscribers, however, because under the terms of the companies' deal customers will be able to seamlessly roam between the T-Mobile network to the DISH network.

DISH has stated publicly that its 5G ambitions extend beyond smartphones, pointing to potential use cases such as autonomous vehicles, robots, smart city applications and drones. DISH would also be able to launch 5G services on other brands, such as potentially "Sling Wireless" to complement the Sling TV business.

Deutsche Telekom

Deutsche Telekom has ongoing virtualization projects in multiple areas. A major project in Germany is virtualizing the IMS core, which will go live in 2020. vEPCs are in progress in multiple countries, as well as some minor back end functions and portals. These functions are still implemented as virtualized silos rather than a complete virtualized cloud platform.

Deutsche Telekom is meeting its initial business goals for NFV thanks to price competition, for example between multiple vEPC vendors as they replace physical EPCs. Full automation will be required in order to achieve the maximum potential cost savings. None of its selected NFV vendors are public yet, as it looks to ensure that the solutions it selects are fully open.

From the Pan-Net project, Deutsche Telekom has learned that it is important to take small steps along the journey to full network virtualization and to avoid being over-ambitious. The overall organization needs time for hands-on learning to absorb

the necessary new skills: hiring people with the right expertise has proved insufficient. Virtualization is a highly iterative process. As for cloud-native platforms, Deutsche Telekom feels that the OpenStack lifecycle management environment for VNFs still isn't stable enough, let alone able to support CNFs. As such, its view is that migration to CNF will take some time.

Many cloud-native projects are focused on easing development rather than improving operations, so it's important to analyze the costs and benefits carefully. Networking is a big challenge because it wasn't a priority for Facebook and Google when they initiated Kubernetes. Deutsche Telekom expects cloud-native to bring flexibility to services deployed for specific industry verticals.

While virtualization of existing workloads will continue over the next couple of years, Deutsche Telekom believes the virtualized 5G core will represent the first telco workload redesigned from scratch for a cloud-native environment. Deutsche Telekom will extend virtualization into disaggregation of access, with O-RAN being a prime influence. Automation will be critical for all these programs and the company believes new mobile carriers, such as Rakuten in Japan, have taken the right approach with their greenfield deployments. Next-generation deployments will continue to deliver on-going OPEX reductions through automation, as well as new revenues through the introduction of new services enabled by 5G.

5G network slicing, together with modular building blocks, will enable Deutsche Telekom to open up application APIs to third-party developers under a revenue-sharing model. Deutsche Telekom expects to host third-party applications for edge use cases like AR, industrial IoT, and offloading compute from devices to the edge to extend battery life. Time to market will be critical for these cloudified applications: customers won't tolerate a long wait after placing an order.

On the topic of open source, Deutsche Telekom believes there are so many open source projects that it is hard to figure out which to build on. Some, like ONAP, represent good ideas but are overly complex while others are impacted by poor execution. Cloud-native, open-source projects are especially valuable thanks to the heavy investment by companies like Google. All open source projects tend to become more complex over time.

Open source or not, Deutsche Telekom expects to continue to deploy multivendor solutions. And system integrators will play an important role in the integration of multivendor solutions, since some glue is almost always required and engaging an SI enables Deutsche Telekom to focus their own resources elsewhere. The focus is increasingly on software integration rather than hardware. Cloud providers can also play a role here.

With regard to public cloud engagements, the balance between collaboration and competition is critical and Deutsche Telekom already has reseller agreements with AWS and Microsoft. As public cloud vendors deploy edge services it's important for Deutsche Telekom to understand how to differentiate. Partnerships such as the AWS-Affirmed Networks vEPC collaboration represent new options that are potentially valuable.

Whether the vendor is a cloud provider or network solution provider, Deutsche Telekom needs high quality from its vendors so it doesn't end up as a beta tester. At the same time, speed of execution and agility is important, especially for services that represent differentiation visible to customers rather than functions in the core network. Since all deployments are implemented as multivendor solutions, an open ecosystem with clear APIs is critical.

On the topic of virtualization skills and talent, Deutsche Telekom is in competition with the webscale giants — Amazon, Facebook, Google, Microsoft, Netflix, etc. — for people with the necessary software skills. At the same time, there's a focus on retraining its own workforce: a program successful with most people, but not all. Deutsche Telekom has also brokered partnerships with various universities as a pipeline for new talent.

Regarding key industry challenges, Deutsche Telekom feels that:

- The business benefits of NFV have been much lower than expected.
- Even though virtualization is not yet fully leveraged, there is now a need to explore cloud-native solutions.
- The transformation of skills at both CSPs and vendors is not happening as fast as assumed.
- Orchestration and automation are key challenges; however, initiatives like zero touch automation (ZTA) represent good progress.

Equinix

Equinix isn't typically viewed as a CSP, and it isn't one, but NFV plays an important role in its solutions. Equinix operates data centers around the world, tied together by a global high-speed network. Its customers include all the major cloud providers worldwide, who take advantage of the unique interconnections with other cloud providers and carriers. Equinix offers branded VNFs as-a-service, including SD-WAN, routers and firewalls — all without hardware deployment at its colocations. It provides cloud-to-cloud routing for applications that span multiple clouds, e.g., Oracle and AWS, as well as branch-to-cloud SD-WAN and an SD-WAN termination point. In addition, it offers branch-to-corporate WAN connectivity through a virtual firewall.

Customers leverage Equinix's Network Edge (NE) deployment, allowing them a presence at the cloud edge within Equinix and no physical footprint. By providing shared infrastructure, the company has added density to its physical colocation: With Network Edge (NE), the same space that it leases to one customer, can be used for many customers. This results in access to more potential customers while expanding its current customers' footprints on Equinix's platform, helping Equinix scale to new metropolitan areas faster.

Equinix's Network Edge VNF-as-a-Service includes the Cisco CSR1000V router, Cisco/Viptela SD-WAN, CloudGenix SD-WAN, Fortinet Fortigate firewall, Juniper VSRX firewall, Palo Alto VM-series firewall, and Versa Networks FlexVNF SD-WAN.

A significant challenge that Equinix overcame in its current deployment was achieving interoperability between different vendors' VNFs, all running on the same Network Edge (NE). It also piloted a pay-as-you-go (PAYG) licensing model with each VNF vendor, while implementing license verification for both bring your own license (BYOL) and PAYG for different vendors. A key technical decision was the tradeoff between a VM-based and cloud-native architecture. For now, Equinix is taking a VM-centric approach as CNFs mature. Within the next two years, Equinix expects to launch several more VNF types to service other network functions and applications as well as security and management/monitoring functions.

Equinix does participate in open-source projects such as ONAP and industry consortia like MEF.

Equinix believes that it is important for more system integrators to offer new services around NFV. The biggest challenge it sees is the lack of skills at enterprise customers to deploy and manage NFV architectures. NFV deployments are typically part of a large network refresh for enterprises; the move from legacy core deployments to distributed infrastructures represents a very complex challenge.

In terms of skills development and workforce retraining, Equinix continues to add overlay technical sales resources and to offer deployment services for its customers to help get them started.

Equinix perceives the key industry-wide challenges around NFV as:

- The lack of experience with virtual networking.
- The cost of deploying a new network architecture.
- The lack of in-house talent to evaluate, deploy, and manage this technology.

Orange

Orange SA is a French multinational CSP. With 256 million customers worldwide, it is the tenth largest mobile network operator in the world and the fourth largest in Europe. Among other use cases for virtualization, SD-WAN has been a major focus for Orange Business Services: it recently announced a deployment for Sony covering more than 500 locations in over 50 countries. Orange has also deployed a vEPC in its Spanish mobile operator.

Sony represents an excellent example of the benefit of SD-WAN/NFV deployment to customers. Sony expects its deployment of SD-WAN from Orange Business Services to enable the company to share IT talent and increase visibility across continents. Sony intends to make enterprise applications virtually available across all business lines and regions in the cloud. The adoption of SD-WAN will also enable streamlined onboarding of Sony's IT service suppliers through a single user interface.

Orange Business Services publicly announced its adoption of SD-WAN solutions from both Cisco (Viptela) and Riverbed. A central challenge faced by Orange has been that different operating units are running different variants of NFVI. This adds complexity for Orange's selected VNF vendors, who need to test software against each organization's unique NFVI. If it proves incompatible, modifications could be needed just to serve the needs of one particular team.

Concurrent with their virtualization initiative, Orange is also exploring the use of AI/ML algorithms to improve customer experience and reduce costs. To support its machine learning and analytics initiatives, Orange has created a big data lake fed with network data from multiple sources. This data is analyzed by both marketing and network management teams for different purposes. This enables those teams to correlate mobile call quality with the contract value of customers on an individual basis rather than on broad averages.

Orange expects its network to become increasingly complex, especially with the introduction of 5G. Business needs are driving the demand for different levels of quality of service to be enabled for different customer segments. It expects 5G to open up a new range of possibilities in terms of consumer services. Increased speeds and reduced latency will favor the development of more interactive multimedia experiences, in very high definition (VHD) or virtual reality (VR). These new capabilities will also avoid the network congestion that sometimes occurs when many people are trying to use a network at the same time and in the same place, for example during festivals or sporting events.

Rather than incrementally evolve its existing infrastructure based on legacy hardware, Orange chose to create a separate platform, culminating with the launch of its software-based, cloud-native subsidiary, X by Orange. Focusing on the needs of business customers, X by Orange aims to provide digital services and solutions to improve productivity for enterprises in the areas of collaboration, privacy and security, and cloudification of infrastructure. Initial offerings cover unified communications, data privacy based on SD-WAN, and legal music for retail stores, while the company plans to grow its services portfolio progressively.

Since network-intensive applications generally require high throughput and low latency, Orange expects its NFVI vendors to support acceleration technologies like Smart NICs and DPDK that VNFs can access in a standard way. Similarly, for compute-intensive applications, Orange anticipates the infrastructure will need standardized support for FPGAs and GPUs.

Orange is an active participant in standards and open source ecosystems. In early 2019, Orange and Vodafone agreed to work with GSMA on a common approach to NFVI to address the difficulty of VNF testing across myriad NFVI environments. Subsequently, Linux Foundation Networking and GSMA made the creation of CNTT official, with both Orange and Vodafone amongst the founder members. Orange currently hosts a community lab for ONAP. It is also a founding member of O-RAN and in June 2019 announced the completion of an implementation test showing O-RAN interoperability of the 3GPP LTE X2 interface between equipment from Nokia and Ericsson.

Orange sees key industry challenges around:

- Management of open systems.
- API incompatibilities and integration.
- Orchestration as well as multi-tenant management and isolation.
- IaaS standardization.
- Lack of cloud-native VNFs and maturity of CNFs.
- Evolution of uCPE support for edge computing.

Rakuten

Rakuten, Inc. is a Japanese electronic commerce and online retailing company often referred to as the Amazon of Japan. After growing to become the largest MVNO in Japan, Rakuten Mobile Inc. secured bandwidth approval in April 2018 to construct its own mobile network, implemented as an end-to-end fully virtualized cloud-native 5G network.

Rakuten expects NFV to leverage the principles of cloud computing to create service delivery platforms with greater agility and customization. Its plan is to use edge computing, network slicing, extreme automation, an IPv6-based transport network, a single OSS layer, and a packet core that fully separates the control and user planes. The reduction in the signaling delay that comes with this network could enable important 5G opportunities.

Rakuten's announced hardware and software vendor list includes Allot, Altiostar, Ciena, Cisco, Innoeye, Mavenir, Netcracker, Netrounds, OKI, Qualcomm, Quanta, RADCOM, Red Hat, Tech Mahindra and Viavi.

The launch of Rakuten's network was originally scheduled for October 2019 but has been postponed to April 2020; this comes as the result of delays in installing its 3,000 plus base stations. The network will initially use 4G LTE cell sites and WiFi to serve customers, with 5G planned for early 2020. A multi-access edge computing (MEC) architecture will be used to support 5G fixed wireless and low-latency services such as augmented reality and virtual reality.

Rakuten estimates that about 60% of all CSP CAPEX is traditionally spent on the RAN. In Rakuten's RAN, each mobile site comprises a Nokia remote radio head running software from Altiostar. This can be installed in approximately 15 minutes, quick compared with the days required for a traditional mobile site. Other functions are executed in 4,000 edge data centers that feature no maintenance staff. Rakuten expects their costs for 5G to be 50-60% cheaper than traditional telecom networks. Cost efficiency could translate into a big advantage in Japan's crowded mobile market, and these savings could allow Rakuten to undercut its rivals on price without damaging profitability.

In Rakuten's world, the entire core technology, including the RAN, is fully ready for 5G. Rakuten has a significant advantage in that, unlike existing telecommunication companies, it has no outdated and legacy infrastructure to maintain. Its network is based on a cloud-native architecture that should provide greater agility and customization. Rakuten believes that once a monolithic software code base is broken into small modules and then run on thousands of servers, it is far more reliable than an architecture with tightly coupled hardware and software. The company's expectation is that a cloud native deployment will have better reliability than a traditional telco architecture.

To support Rakkuten's efforts, SI Tech Mahindra opened a 4G and 5G SDN laboratory in Tokyo. The Rakuten Cloud Innovation Laboratory will be used to test RAN, mobile edge, evolved packet core (EPC), virtualized core, and business and operations support systems (BSS/OSS). DevOps principles will be used to test and deploy new features.

Rakuten is convinced that its biggest advantage is its people and work culture. It views itself not as a traditional telecommunications company, but an IT company with highly skilled engineers.

A key challenge for Rakuten was finding suppliers who were willing to challenge the status quo of traditional architectures and approaches. Netcracker was only selected as Rakuten's business and operational support systems (B/OSS) vendor because it was committed to work on massive internal changes to achieve results.

Telefónica

Through its Unica project, Telefónica had introduced virtualization technologies into 25 data centers around the world by February 2019; it has plans to hit a final target of 50 by the year end. With a focus on virtualizing the IMS and EPC, 10 functions were certified by February 2019 and a total of 54 are expected by the end of the year. Instead of prematurely displacing physical equipment, which will eventually be phased out when it comes due for renewal, the company is leveraging virtual functions to address additional capacity demands.

Telefónica initially selected HPE as its lead virtualization partner for Unica but subsequently announced HPE's replacement by Ericsson. In addition to Ericsson (vIMS), Huawei (vEPC), Nokia (vCSR), and ZTE (vIMS) have been disclosed as VNF vendors. Telefónica also announced that it validated Wind River's NFVI platform for Unica, citing its ability to work within a multi-VIM environment.

One of Telefónica's main NFV challenges has been management and network orchestration (MANO). Although it has become the main sponsor of the ETSI-backed Open Source MANO (OSM) project, by March 2019 the project had not yet reached the production readiness level required for Unica.

Telefónica expects the rollout of virtualized central offices, based on Unica, to start in 2020. By moving IT resources out of the main data centers and into virtualized central offices, it expects to reduce latency and thereby enable the launch of services such as virtual reality and other new applications.

The new business opportunities enabled by 5G are exemplified by a project Telefónica undertook with a hospital in Malaga to demonstrate an expert assistance system for medical interventions. As part of the IV Advanced Digestive Endoscopy Conference, medical training sessions at the Quirónsalud Málaga Hospital were broadcast with almost no latency, enabling doctors and conference attendees to interact. Augmented reality displayed essential information throughout an operation and was updated in real time.

Telefónica was a major contributor of code to OSM and is one of the most active service providers within the ETSI NFV initiative. It is also a member of the O-RAN alliance.

In addition to being named an NFVI supplier for Unica, Ericsson was also selected as Telefónica's provider of system integration and support services. In 2018, Telefónica announced the process to select an integrator for the OSM MANO platform with responsibility for integrating OSM with pre-existing systems.

Telefónica has discussed a plan to retrain 6,000 employees in areas such as security, robotization, analytics, web development, business consulting, IT, and agile methodology capabilities. It has planned to double its training budget and increase the training hours per employee by 40%. This overhaul was necessary because Telefónica still employed too many analog workers in a digitizing world. Its expectation is that digital channels will account for 50% of sales in the next few years and that many customers will prefer the MiMovistar app to interaction with other humans. The shutdown of copper and legacy mobile-phone networks will also have an impact in this area.

In a joint white paper published with Analysys Mason, Telefónica publicly stated its concerns about vendors' OpenStack implementations. Specifically, both companies felt that the vendors' cloud technologies did not support the specific performance and distribution requirements of network functions. They stressed that they would continue to collaborate with multiple technology partners and influential industry organizations to ensure their requirements were reflected in the appropriate roadmaps.

Verizon

Verizon launched its virtual network services (VNS) portfolio in 2015 and has deployed several customer-facing products including a premise-based uCPE as well as a hosted platform. These provide multivendor SD-WAN solutions (Versa, Viptela) as white box-hosted VNFs. The key business benefits that Verizon has derived from virtualization are agility, the ability to perform efficient technology refreshes, and the accelerated rollout of new services such as SD-WAN. It has maintained a consistent architecture over four years, supporting a single platform across all environments.

With a significant presence in North America, Europe, and Asia, Verizon is one of the few CSPs to offer the same services globally. It provides a wide range of services that include unified communications, managed security, forensics, and data breach mitigation. It has a sizeable call center business as well as a professional services team that provides networking services for customers without an in-house IT department.

Verizon has publicly announced Ericsson as its partner for multidomain service orchestration, ADVA for uCPE management, and Check Point, Fortinet, Versa Networks, and others for VNFs. Multiple NFVI software platforms are in use across its whole environment.

Being early to market with virtualized services, Verizon faced the challenge of explaining its strategies to vendors, for some of whom this was their first NFV experience. In doing so, Verizon became its own system integrator, which represented a challenge for several internal teams. Unable to use existing internal tools for operations and services, those teams needed to create new solutions. Disaggregation presented several challenges including optimization around technologies such as DPDK and the test environment for the transition from physical network functions to VNFs.

In response to customers wanting new options for managing their own VNFs, Verizon has recently implemented a co-management solution architecture that allows it to quickly add customer requested features, such as co-management or monitor only.

Over the next couple of years, Verizon expects to deploy tenant-space virtualization. This will enable its customers to run other workloads on Verizon's uCPE platforms, as well as additional IoT services and edge applications. Moving up the value chain and offering services such as SD-WAN with more value than baseline connectivity, Verizon has boosted its ARPU and acquired new categories of customers.

In providing a cost-effective solution to the last mile problem, Verizon expects 5G to expand its footprint by delivering fixed wireless access in areas not served by FIOS.

On the topic of cloud-native, Verizon will roll-out internally developed cloud-native applications first. This is due to delays in the availability of CNFs from the vendor community that meet its requirements. Over time, Verizon expects cloud-native applications to become available via open source communities initially and then be adopted by vendors. The company is concerned, however, that vendors of telecom applications — particularly the VNF providers — do not yet understand the complexity of cloud-native solutions. The challenges for OSS/BSS vendors are less severe and Verizon expects those products to be commercially available as cloud-native implementations soon.

Verizon is a contributor to CNTT: it drove the original VM architecture definition and contributed to the governance model while co-leading the operations reference model. In the orchestration space, it contributes to both ONAP and OSM. It is a long-time contributor to OpenStack.

Some system integrators, such as Tech Mahindra, are resellers of Verizon's security and connectivity services.

To help build its internal capabilities on the path to cloud native, Verizon has been hiring extensively for networking and DevOps. It has also developed a new platform for training its workforce, including videos and just-in-time training.

One key industry challenge is licensing: Verizon believes that vendors need to support subscription-based models. It hopes that the combination of pressure from the CSPs and especially the major cloud providers will eventually get the VNF vendors to change.

Vodafone

Vodafone launched Project Ocean in 2016 to introduce virtualization and cloud technologies into its network. In 2018, Ocean was subsumed into a larger and more ambitious vision as Vodafone started exploring how cloudification could transform and bring consistency and automation to its entire technology estate, which comprises network, IT, and enterprise services. Its virtual systems and network functions span both voice and data areas, including vIMS, virtual diameter routing agent (vDRA), vEPC, messaging and voice over LTE (VoLTE).

Vodafone recognized an industry-wide challenge caused by each CSP selecting different variants of NFVI. VNF vendors need to test their software against each CSP's NFVI platform. Even within Vodafone, there is the possibility of a different NFVI configuration for every VNF deployment. This would result in a multi-silo deployment in their networks, which defeats the purpose of moving to cloud and leveraging a common, shared infrastructure.

Going a step further, Vodafone stated in 2018 that NFV on its own cannot deliver tangible benefits and simply virtualizing legacy or traditional applications will not achieve anything close to the full business objectives that are desired. It believes that real transformation efficiencies will only be gained from truly shared infrastructure, fine-grained component scalability, and advanced automation — all of which require cloud-native architectures to be fully realized.

In 2019, Vodafone announced VMware as it's primary strategic partner for telco cloud infrastructure services, stating that VMware's products and services are live in 15 countries, in more than 50 Vodafone sites, and carry subscriber traffic on more than 300 core network functions. Vodafone has also announced that it selected Netcracker by NEC as its domain orchestrator to support its transition into a telecommunications cloud provider.

Success by some of the leading global CSPs show that it is possible to roll-out NFV implementations at scale, and the learnings from these pioneers will help smooth the path for those who come next.

In the next two years, Vodafone's focus for virtualization and cloudification will be on their 5G core. Vodafone expects significant CAPEX savings from virtualization and cloudification; this will be achieved via a shared infrastructure and shared compute, as opposed to traditional silos with redundancy and space capacity for each service.

Vodafone has established the specifications for its cloud-native environment, and it is working with partners and vendors to ensure applications are designed and delivered into that environment. This includes a definition of its container environment for both network and IT workloads, as it looks to bring as much consistency as possible to its technology estate. In line with its cloud-native strategy, Vodafone expects its software vendors to provide cloud-native implementations of its products.

Vodafone has publicly discussed a range of new business opportunities enabled by 5G. In health and well-being, Vodafone is trialing 5G to enable connected ambulances: these will share real time data and 360 images directly from the ambulance to the hospital to reduce the delay in treatment upon arrival and allow doctors to intervene remotely. The trials also involve connecting the ambulances to the traffic light system, allowing for a safe and fast journey. Another example is the use of drones and wearable cameras within security and surveillance: not only uploading images in real time to a central platform but also using analytics for facial recognition to trigger actions.

Vodafone was an early proponent of the Telecom Infra Project's OpenRAN (O-RAN) initiative and started trialing the technology in the UK. Having already demonstrated O-RAN technology in South Africa and Turkey, it may soon expand the trials to other European countries. The primary goal for Vodafone, at this stage, is to lower the cost of network equipment in a bid to make wireless coverage in rural communities more economically feasible. However, the operator has been trialing O-RAN technology in urban areas as well.

Vodafone believes that its move away from virtualization (VNFs) to cloudification (CNFs) reflects a general sentiment among the rest of the industry.

Conclusions

It is seven years since the seminal white paper from 12 CSPs and NFV can be best characterized as a partial success. The sweeping goal of the original initiative was ambitious given the difficulty of transforming regulated industry giants worldwide. At the same time, all CSPs recognize that in order for them to survive and thrive, they must start virtualization in their infrastructure and adopt cloud-native practices and architectures. To remain competitive in a world where cloud-based OTTs have succeeded in disrupting and capturing many value-added opportunities for CSPs, including unified communications and collaboration, media and entertainment, gaming, and more, CSPs need new strategies to both collaborate and compete with the cloud giants.

Regardless of whether we call it NFV, virtualization is critical to CSPs. Based on our conversations with and analysis of the major CSPs described in this report, here's where we see the state of the industry:

- NFV is underway, although challenges exist around licensing, VNF onboarding, cross-vendor compatibility, and orchestration — especially multi-domain orchestration. However, success by some of the leading global CSPs show that it is possible to roll-out NFV implementations at scale, and the learnings from these pioneers will help smooth the path for those who come next.
- SD-WAN has proved a revenue-generating opportunity that CSPs can use as a platform to build out NFV infrastructure and orchestration frameworks. SD-WAN and uCPE deployments could potentially pave the way for edge strategies, though there's much work to be done on that front and the dots connecting SD-WAN/uCPE to full-blown edge platform aren't quite yet determined.
- Cloud-native infrastructure and CNFs are still a work in progress. Containerization and microservices architectures will show up first in carrier back-office applications, as well as orchestration (OSS and BSS) frameworks. CNFs still have a way to go, while vendors re-architect and rewrite their applications, and the industry as a whole works through ensuring NFVI based on containers and Kubernetes can function with performance and at scale.

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