Executive Summary on Cloud Native Enabling Future Telco Platforms

v2.1

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by NGMN Alliance

Version:	**2.1**
Date:	**17 May 2021**
Document Type:	**Final Deliverable (approved)**
Confidentiality Class:	**P-Public**

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Abstract: Short introduction and purpose of document

This document provides an executive summary of the NGMN deliverable "Cloud Native Enabling Future Telco Platforms" [1] which analyses the transformation toward Cloud Native in the main network domains of the Telco infrastructure. The goal is to define a holistic view on the Cloud Native transformation framed in an Edge Hybrid Cloud scenario. This transformation is mainly perceived by the Telcos as an important driver for internal optimization, cost savings and to speed up vertical solution. From a broader perspective, it is also an enabler, for the Telcos, to join a wider ecosystem where Telcos, technology suppliers, developers and Hyperscale Cloud Providers work together embracing new business opportunities leveraging on their own specific and unique assets.

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1 INTRODUCTION

NGMN published [1] a comprehensive and detailed view on the Cloud Native evolution with evidence of the support of SDOs, Fora and Open Source communities and **the technical details of the innovation in the different Telco domains. This document provides an executive summary of that analysis**. The focus is on the main innovation and enablers for the Telco Platform to be open and flexible, and to leverage the technological evolution, to embrace new business models in an open ecosystem.

The evolution of 5G Networks is based on technological and modelling approaches such as cloudification, service-based architecture, network capabilities exposure, network as a service, zero touch management, just to name some of the main ones. This evolution is introducing a big technological challenge, giving hype to a paradigm change with new opportunities for a Telco. Being actively and centrally involved in a wider ecosystem of application service offering is, more than ever, an expanded role and opportunity for Telcos, to create and deliver value, along with partners. It is important, indeed, to view 5G Networks not as predesigned and static Telco infrastructure but as a flexible and Open Telco Platform.

This transformation is typically perceived by the Telcos as an important driver for agile and efficient architecture and operation, to create value and speed up vertical solutions. From a broader perspective, it is also an enabler, for the Telcos, to join a wider ecosystem where Telcos, the technology suppliers, developers and Hyperscale Cloud Providers work together. The common goal is to embrace new business opportunities leveraging their own specific and unique strength and assets.

Embracing this opportunity, the Telco can leverage these activities to evolve its network toward 5G and can expand its services playing a distinctive role. The Telco network surely has unique assets such as geographical distribution and unique APIs, e.g., to accelerate the network performances of a specific service. This provides to the Telco the opportunity to play an important role in the Hybrid Cloud scenario complementing the current offering of the Hyperscale Cloud Providers (HCP) ~~in a win-win relationship~~.

2 THE OPEN TELCO PLATFORM

The full realization of 5G to enable digital socio-economic transformation involves countless and wide ranges of use cases, many unimagined today, with specific requirements. 5G enablement has thus introduced a big technological gap, demanding a network transformation. A paradigm change is needed in the overall network design, in its operation and in the provided services. This journey is well underway.

This vast heterogeneity, with a wide range of requirements, **demands agile networks**. Full flexibility, scalability and efficiency are key attributes of networks capable of providing dynamic, dedicated, secure, and reliable services offered as a platform. The **network shall provide shared or dedicated resources** for variety of use case scenarios and innovative vertical markets. It is expected to become increasingly dynamic and fully customized, in response to the needs of each service, during its lifecycle. This requires new operational models and modern infrastructures, but it will also be the basis for new business opportunities.

To enable the new business context and the service demands, 5G architecture is expected to be Cloud Native. It is based, by design, on an intelligent and dynamic multi-access core. It is designed over a service-based control-plane architecture, separate from a flexible user plane, and with the exposure of functions through open interfaces. The cloudification, virtualization / containerization of Telco networks is evolving and requires E2E orchestration, increasing automation and enhanced lifecycle management for a more flexible and programmable platform.

Enhanced by this evolution the Telco Platform **is not only evolving to simplify operation. It is becoming closer and closer, in terms of technology and automation, to the cloud platforms the developers are currently using to deploy their applications.** The enhancement of the 5G network in terms of performance and deployment flexibility allows the Telcos to surely support new vertical applications. The technological evolution underneath also supports new models where those services can be more and more integrated in the Telco Platform. New services can indeed leverage on unique Telco assets from one side and on common IT/Telco technologies from the other side.

Hybrid Cloud and Edge Computing create significant opportunities within a wide range of business models. The mobile network operators, with Open Telco Platform, have expanded roles in these models, creating and delivering value with their partners. Hybrid Cloud architecture is a flexible paradigm mixing public and private Clouds exploiting Telco and Application functions. Different possible technological and partnership models can be foreseen in this context.

Different aspects of this evolution are already well defined while others are currently under discussion in different bodies within the ecosystem. There is increasing synergy and joint development within these bodies; however, much is yet to be concretely realized and tested in real production environment. There is a need to leverage and further harmonize the variety of developments defined within different bodies also to simplify the work of integration Telcos need to do. The target is a well-defined Cloud Native open and interoperable platform. It shall be increasingly cognitive, programmable, and autonomous, in order to design, orchestrate and dynamically manage the delivery of value for each use case and user scenario.

A fundamental aspect of 5G is the distributed, interoperable and multi-vendor capability and service delivery, through disaggregation and open interfaces. **These aspects well match a Cloud Native approach**. RAN disaggregation, with interoperable interfaces, enables much flexibility, scalability, efficiency, and choice within a broad and expanded ecosystem. Distributed intelligence in a Cloud Native 5G system is a key factor leveraging Hybrid Cloud and enabling multi-access edge computing and local context analysis.

The road to open, flexible, and agile networks, is expected to **continue reducing environmental footprint and total cost of ownership, as well as time to market**. It is imperative that this journey maintains a clear focus on social responsibility, sustainability, and significant energy efficiency.

A Telco Platform must exploit openness both internally and toward the external ecosystems. The basic characteristics for such an openness are the same whenever you are considering internal optimization or external federation and interoperability. The traditional mantra supporting open and standard interfaces is more than ever sided by the adoption of standard de facto open source software especially for the management layer. **The new 3GPP 5G mobile network** indeed foresees a microservices based architecture that aligns the different domains and vendors' solutions. **Meanwhile Open Source communities** are delivering IT solutions supporting this evolution on top of the experience made on cloud architecture management.

From physical to Cloud Native Network Functions the current evolution path is fostering Cloud Native concepts deeply in the Telco world, from the central data centres to the regional and edge ones. This enriches the Telco's value chain including also distinctive assets such as the edge infrastructure. This cloudified and open Telco Edge becomes a unique selling point in the Telco proposition for the ecosystem towards developers and HCP.

Cloudified Open Infrastructure (e.g., IaaS and CaaS) and Architecture (e.g., Service Based approach) are the main technological enablers for the overall evolution.

The infrastructure cloudification is fundamental considering the evolution of NFs from physical (PNF), to virtualised (VNF) to container base Cloud Native Functions (CNF). **It is interesting to notice the difference between Cloud Native and Cloudified NFs.** There are indeed NFs that, for their nature, can't be compliant with all the characteristics a CNF must have [2]. For these NFs, however, a certain degree of cloudification is still possible even if not with a complete microservice decomposition. These NFs can be defined as cloudified VNFs (cVNFs). Since containers are not only used to create Cloud Native Apps but also to transform legacy applications the cVNF is a very valid and effective method to move established legacy telco applications onto the same platform and into the same ecosystem as newly developed 5G Cloud Native functions.

A key enabler for tailored evolving networks supporting both NFs and applications **is Cloud Native orchestration**. It has the capability to support standardised deployment and operational procedures across various cloud data centres leveraging open multi-vendor infrastructure. This disaggregated model allows an independent **deployment paradigm without having dependencies on hardware and applications** typical of a legacy, single vendor solution. Cloud Native service orchestration within the Telco world triggers possibilities that are beyond efficiency or agility. **This evolution has impacts on the value chain**, including the Telco exploiting Edge capabilities and disregarding today's Over the Top (OTT) business proposition. From a value chain perspective, it can be stated that (public cloud) Platform-as-a-Service (PaaS) offerings like Google and Azure as well as (public cloud) Infrastructure as a Service (IaaS) offerings like Amazon Web Services (AWS) have become the norm with service providers like SAP and Salesforce being able to scale their offerings based on the cloud value chain [3]. **Adding vertical services into Telco networks requires economic and technological advances to integrate both value chains, the ISP/operator's, and the vertical's one.** The current approach to on-board Verticals into the Telco world is a bottom-up approach (technologically speaking) where it is expected that services integrate into an existing Telco system following frameworks like ETSI Multi-access Edge Computing (MEC) or 3GPP's Common API Framework (CAPIF); not to mention that all services end up becoming a VNF/CNF orchestrated via the infrastructure orchestrator, i.e. not location-aware and does add additional complexity for Telco-Verticals to bring their service to the edge or just closer to the required consumption point. However, when turning the approach upside down and putting the vertical service provider at the starting point, it becomes apparent that challenges around **building scalable services and following state of the art programming and library usage paradigms are key for Verticals**, as outlined by the Cloud Native Computing Foundation (CNCF) [4].

A key characteristic of Cloud Native concepts for orchestration is the ability to follow standardised deployment and operational procedures across various cloud data centres. The orchestration procedures are fully decoupled from the service that implements how to respond to requests. In more detail, for both operations the key is the separation of deploying and managing service instances, and the operation of the service itself inside an instance. **In a Cloud Native world, services are pre-packaged images that have no notion of the deployment and operational procedures** required to orchestrate them. **The ability to build services in such a way is what the paradigm shift from monolithic functions to microservices entails**. When mapping this to the Telco, it means that a service is simply waiting for a service request to arrive. It processes it without any additional interaction with the underlying services such as orchestration, identity management. Other microservices, autonomously, take care of those tasks.

Scaling is key feature for a cloud service. Cloud providers such as AWS, Google or Azure allow service providers to define Service Level Agreements (SLAs) under which services must be able to scale in (less instances of the same service) or out (more instances of the same service). The underlying scheduler monitors instances and takes respective decisions on what to scale when and where, within the data centres. A major challenge for the Telco Platform is to adopt that approach **enabling location-aware orchestration** including scaling in all three dimensions, i.e., up/down, out/in vertically, and out/in horizontally with the clear separation of the management operations from the operations of the service itself.

With 5G and the evolution to NF Virtualization, including Cloud Native, for every parts of the network, except maybe the antennas, the **5G virtual infrastructure becomes a set of 'data centres'**, Network Function Virtualization Infrastructure (NFVI), distributed across the Edge. These different instances of NFVI are managed by providing an abstraction of these physical data centres into a set of virtual data centres with a mix of physical and virtual resources.

Different aspects, at different layers of the Telco Platform, concur to the Cloudification process. The innovation at infrastructure level, described previously, is one of the main pillars of this evolution. **The Cloudification process also includes architectural aspects relevant for the openness, flexibility, and programmability of the Telco Platform such as the adoption of a Service Based Architecture (SBA).** This leads to modularity, interoperability, adopting standardized interfaces, and an open and multi-vendor ecosystem. Operating an open platform comprising of different modules and functions is a challenge that requires the adoption of modern and Cloud based management solutions. Orchestration, for this reason, is a fundamental factor for a platform to manage this complexity. This is a key enabler for an open integration of new components provided not only by different network vendors but also by developers and Verticals.

The ability to offer open APIs is fundamental for the cloudification of an infrastructure, enabling e.g. Infrastructure-as-a-Service (IaaS) or Container-as-a-Service (CaaS). This demands resource isolation and resource configuration with exposed APIs in a **multi tenancy solution**. The API exposure itself must be coherent with the tenancy approach providing API isolation. In an Open Telco Platform specific attention is required for the orchestration of its basic components, the NFs, considering their different deployment options as VNFs, cVNFs or CNFs. In Open architecture, with open APIs enabling programmability and multi tenancy, compute, networking and storage **resources will be sliced**. **Slicing also provides resource isolation and QoS enforcement** allowing infrastructure providers to assure service-level agreements. Tenants can work freely within the constraints attached to the acquired slice. However, when aiming for the operation of VNFs in a cloudified infrastructure, a requirement for the tenant is to be able to program the resources within the given slice. This requirement poses a critical challenge as many resources are currently managed by admins in a rather manual fashion and are usually not programmable by the tenant, for example, (c)VNF flavors or locations where it should be initiated. **A possible requirement for the tenant is to have some management control over the slice** and the VNF of a slice: location placement of the VNF, configuration of the VNF, etc.

The orchestration of vertical applications deployed in a Telco Edge, poses the challenge of integrating it with a 3GPP system. The establishment of a session from a UE to a vertical application is indeed always handled by a 3GPP Core Network. The CN takes cares of the configuration of the user plane between the UE and the vertical application located in a Data Network (DN). This is enabled by the framework specified in 3GPP allowing an Application Function (AF) to communicate with a 5G Core registering the application including its services. ETSI MEC [5] and 3GPP [6] are defining specifications and APIs for Telco edge application management and orchestration and federation mechanisms for these APIs. **The scenario foresees application providers to deploy and to orchestrate applications seamlessly across multiple operators** and offering to end users roaming on Telco edge applications. This scenario is also promoted by GSMA [7].

Vertical service providers (e.g., OTT service providers**) expect APIs and on-boarding procedures that are coherent with how their services are designed**, implemented, and orchestrated in the Cloud service providers**. It is of paramount importance to offer orchestration** and lifecycle management APIs to the Verticals allowing them to programmatically utilize the Telco Edge in a similar fashion as public Clouds do. Current approaches have followed a rather strict client – server principle, with the UE always being the client. APKs built into the UE's application usually interact with server components that manage and control the application instances in the DNs. Current OTT implementation of most applications available to UEs (smartphones, tablets, laptop/desktops, TVs, wearables) have a very minimal (not to say zero) interaction with a 3GPP system to locate a specific server-side instance in the Cloud (as promoted by 3GPP SA6 for instance). **Ideally, the orchestration of a vertical application into the Telco Cloud (into a local DN) should follow similar principles** as the orchestration into one of the big cloud providers. Ultimately a **convergence of Telco Edge API and public cloud API** could simplify management and orchestration of vertical applications across those hybrid clouds.

Intelligence is a key factor for both Network Functions and application life cycle management and service assurance. Artificial intelligence capabilities are urgently needed to enable flexible network automation and network augmentation and support application deployment with guaranteed QoS especially at the Edge. To do so, the intelligent mechanisms that efficiently exploit the decoupling of control plane and data plane under a software-defined architecture must be developed to achieve optimized radio resource utilization across logically independent RAN slices.

Hybrid is a key word in the cloudification process of the Telco Platform, and it covers different aspects. One aspect is the **coexistence of VM based and Containers based NFs deployments**. Another one is the **coexistence of Telco oriented and Service oriented Cloud Native** integrated environments. Centralized, Edge and Cloud based deployments coexistence and integration is another hybrid scenario. Edge data centres are key assets for Telcos and an important component of the Open Telco Platform. Hybrid Cloud at the edge represents a concrete opportunity for the Telco to be part of an ecosystem where developers and Hyperscale Cloud Providers collaborate to enrich Communication Services leveraging on 5G distinctive features. They include such features as low-latency radio optimization and Core Network local breakout toward Edge Data Networks.

There are challenges for a Unified 5G Hybrid Cloud. There is indeed a rich and often crowded landscape of technologies defined by various architecture groups. As a result, the realization of an architectural model via a multi-vendor solution is very often prone to interface incompatibilities and reveals the complexity of feature-rich interfaces.

There are apparent differences such as virtual machine vs containers with dependencies on the underlying technology enabling an automated and programmable environment. **The interoperability of hybrid cloud solutions is of paramount importance with the need to intermix different Cloud solutions**. Certainly, this playing field has less stringent standardization specifications compared to 3GPP Core Network or RAN. For this reason, it poses a very steep burden on the cloud providers to find the right balance of openness and interoperability and key differentiators. In the end, how to mix-up Hybrid Cloud is more a business decision than a technological one.

When it comes to Cloudification in the Telco platform, a special attention is due to the most characteristic Telco domain. A vRAN already describes a concept of decoupling the infrastructure running the RAN and the SW-components that provide the RAN functions (DU, CU) and protocol stacks for the transport interfaces. This enables network functions to run as VNFs or CNFs on a commodity HW that forms the base station.

A RAN where software functions are disaggregated from the underlying infrastructure (as described in vRAN) is a prerequisite for virtualisation. But in addition to virtualisation it is required that the network functions are delivered **as micro services** which can scale independently and be supervised by a cloud management and orchestration framework. A cloudified vRAN means that cloud technologies and hyper-scale models known from web-services are applied to the RAN. This scale is seen as a requirement to enable the full potential of 5G.

A Cloud Native Radio Access Network enables RAN network functions delivered as microservices in containers over bare metal servers, supported by dynamic orchestration such as e.g., Kubernetes. Software application life cycle management **relies on DevOps principles and Continuous Integration and Continuous Delivery** (CI/CD).

3GPP has defined network slicing with end-to-end network slicing spanning across devices, access, transport and core networks. A UE is associated with an NSSAI and connects to a slice, up to 8 slices per UE. A given network can support many slices. **The NG-RAN shall support slicing** [8], **multiple slices and isolatio**n, leveraging Radio Resource Management (RRM) policies but the way slicing is performed in the NG-RAN, which functions are selecting slice resources in the NG-RAN or which resource are restricted to a given slice, are implementation specific, which may be a challenge for designing multi-vendor Cloud Native environment if no further standard is defined. **Depending on the split option**, the number of functions to be performed in a given entity, the traffic load, the latency requirements or the slicing and isolation requirements, the design of the virtualized or Cloud Native infrastructure for these disaggregated vRAN network functions will be different.

3 ECONOMICAL DRIVERS

Cloud Native practices can help Telcos address CAPEX and OPEX pressures from customer data growth and 5G deployment. 5G is also the foremost opportunity for Telcos to develop new revenue streams beyond communication services - edge services enabled by 5G are predicted to become a significant proportion of a Telco's overall revenue. Furthermore, emerging business models and partnerships enable collaboration between Telcos and Hyperscalers to stimulate this market.

Based on predicted public cloud and communications services revenue, the addressable edge opportunity for Telcos is thought to be in the order of 700 billion USD in 2030, as indicated on the figure below.

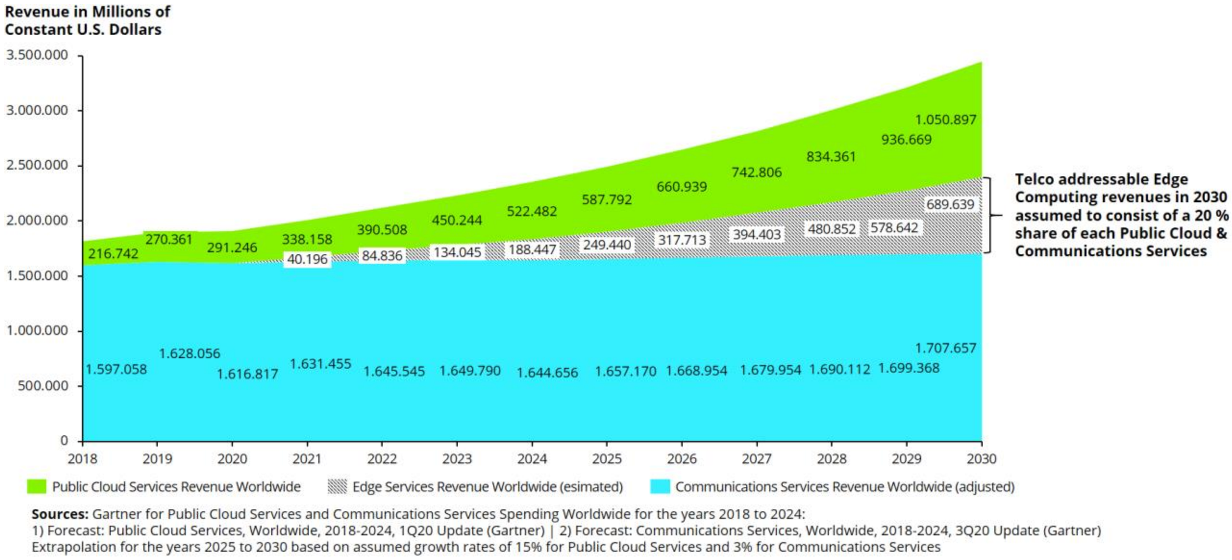

Figure 1: Assumed Revenues for Edge Computing in 2030

In the Telco supplier eco-system open, software-defined systems using vendor-neutral hardware can be a spring-board for vendor diversity, increased competition and for fostering innovation, providing benefits to Telcos, partners and customers.

As stated, the market opportunity in providing and enabling “5G Edge services” has been identified as a major opportunity for Telcos, but this is new business territory for Telcos and demands a Cloud Native, service-oriented capability for the technology architecture to deliver Edge services. Further, customers will expect a fully digital experience to set-up, pay for and manage their services and will expect the service levels, service visibility, availability and elasticity that are offered currently by Hyperscaler cloud services. Telcos can view Hyperscalers as partners and models of the capabilities they need to develop so they can be part of the emerging opportunity for 5G edge services.

Different business models for Telcos and Hyperscalers in connection with Edge services are possible. In particular, models for consideration can be:

1. Telco as provider for cloud services and connectivity: Telco provides Cloud Native connectivity services and brokers Telco, Hyperscaler and other clouds based on customer requirements
2. Telco/Hyperscaler partnership: Telco provides connectivity services and cloud services are provided by the Hyperscaler platform.
3. Hyperscaler as provider for cloud services and Telco as possible connectivity provider: The Hyperscaler provides cloud services and brokers Telco and Hyperscaler communication services based on customer requirements.

These models reflect different value propositions, end customer relationship and revenue flows. All models require Cloud Native competence. To achieve new revenue and deliver MNO’s value creation, Telcos will need to pursue Model 1 or Model 2.

The above models also illustrate the potential contention between Hyperscalers and Telcos with respect to exploiting the 5G Edge cloud opportunity but at present neither Hyperscalers nor Telcos have the whole set of Cloud Native Edge capabilities. For example, Hyperscalers lack the Telco’s local access assets (sites, fibre, PoPs), field technical support and customer relationships while Telcos lack the Hyperscalers’ cloud expertise, rapid product delivery and developer community engagement. Partnerships are therefore viewed as being positive for both Telcos and Hyperscalers to first stimulate and then deliver Edge service demand.

For Telcos, the Cloud Native path is the natural path for 5G and beyond and promises more favorable cost management to create and deliver value for countless, diverse use cases allowing Telcos to capture new sources of revenue. Challenges and requirements concerning technology maturity, deployment and operations, and organization transformation, however, will need to be managed and addressed for Telcos as regards Hyperscalers. Of these challenges the Telcos organizational transformation to Cloud Native is seen as one of the biggest challenges ahead. A change in talent profile will be needed and Telcos will most likely need to focus on upskilling employees to achieve cloud, DevOps, analytics, and AI expertise.

4 CHALLENGES, CRITICAL SUCCESS FACTORS & DEPENDENCIES

5G and beyond introduces new challenges requiring unprecedented levels of flexibility, agility, scalability, and automation. Cloud Native architecture is a paradigm shift empowering new services from network architecture perspective, requiring the adoption of new operational and organisational models. It also requires new cooperation strategies among stakeholders to fully embrace the business possibilities enabled by such a technological shift.

The evolution toward a Cloud Native network is full of challenges and requirements from architecture, implementation, and security perspectives.

In terms of architecture, considering 3GPP Release 16, some network functions still have some interfaces (not service-based) using protocols which are not compliant with the Cloud Native architecture.

While many vendors claim open interfaces in their network components, they are still limited by their own customized network management tools. Even though a network may have been deployed with multi-vendors elements, it is still not entirely vendor neutral. This is because orchestration and network management software for different components may still be vendor specific.

Aiming a full Cloud Native ecosystem, it is important to notice that it may not be possible to convert every network function into Cloud Native in near term. This can be due to stringent latency and throughput requirements. Heterogenous network architectures will exist for a long time in the network evolution path toward Cloud Native.

Computation-intensive RAN nodes performing Layer1 and Layer2 functions may still need custom hardware accelerators to deliver services for some use cases. These special purpose resources/nodes (e.g., FPGA, SmartNIC) may not be fully optimized according to the Cloud Native principles. Heterogenous network architectures also incur high overhead in network management.

In contrast to core network which has a general accepted nodal structure, RAN architecture has many options to split the protocol stack, each with different demand on the underlying interface and transportation link. This provides flexibility in terms of deployments balancing central and edge distribution of the RAN network elements. This also provides different possibilities on the RAN component that can be Cloud Native.

It is conceivable that Cloud Native transition will be gradual, i.e., VNF and CNF will co-exist in a network for some time. This means that orchestration tools must be able to manage both VM based and container-based NFs. Otherwise, different orchestrators must be used. This coexistence also requires different teams and operational models to coordinate and to manage the network.

Nodes with multiple sockets have different latency, Cloud Native system allocates resources without knowing these variances in latency. This may cause synchronization issues.

Considering the implementation of Cloud Native, migration aspects must be considered. It is indeed important to ensure a smooth migration through analysis of workloads and the inter-dependencies between legacy and hybrid-cloud systems. It is critical to ensure existing services are not interrupted by the development and production of new services.

Considering the opportunity and flexibility a Cloud Native system provides, Network operations and service teams will need to adopt the DevOps mindset and CI/CD processes.

Security for Cloud Native functions must be considered over their whole lifecycle. Development, deployment, and operational cycles must be consistent with a unified security framework (central policy management and visibility) across the system over which the application exists and runs.

To make a smooth and successful evolution to Cloud Native, many factors are critical to embrace this evolution capturing all the possibilities and maintaining the overall cost efficiency of the transition. In the following some of these factors are identified.

- The harmonization of orchestration and other tool sets, such as assurance and analytics, is critical for multiple reasons. From a technical perspective it is required to optimise the service delivery and operation process. From a business point of view, it is important to guarantee the overall SLA agreed with the customer. In terms of costs, it is important to have a coherent and consistent well-defined solution to avoid integration costs that, in such a complex scenario, can be very high considering the many components involved.
- End-to-end global standards including open interfaces need to be in place. This enables the Cloud Native architecture to deliver agile, resilient, flexible, and scalable services. This also enables the integration process in a multi-vendor scenario. Open interfaces, easily accessible and exploitable by other Telcos and HCPs, are mandatory for a Telco to be part of a wider ecosystem.
- Global roaming agreements, edge federation and strong partnerships among the stakeholders need to be established. It is indeed important to ensure the availability of the services at global level. A customer shall experience the same level of services regardless which Cloud Native architecture the services are leveraging on. Developers must be allowed to deploy their application seamlessly over the different Telco Platforms.
- Consistent security policies and capabilities are required. There should be agreement on security policies and capabilities among different infrastructure vendors, network operators, and service providers involved in the delivery of a Cloud Native service.
- Training is a key success factor. Cloud-native service development, network operation and maintenance, and security teams must be aligned with the same mindset and they must augment their skills in Cloud Native architecture and technologies.
- The Cloud Native platform is the natural technological glue allowing different players to integrate their resources. To fully embrace this opportunity, it is important to set up a win-win and shared model among Telcos and HCPs to engage developers and customers to build an ecosystem.

5 CONCLUSIONS

The evolution of the Telco Platform toward Cloud Native is a key innovation process for Telcos. This evolution is well supported by the work done by the international SDOs and Fora. It is already part of the ongoing activities a Telco is facing nowadays to modernize its infrastructure to fully embrace 5G.

This innovation does not start from scratch; it inherits the standard IT components and platforms from IT cloudification. This implies the adoption of open and industry standard interfaces allowing management and operation of NFs and applications from one or more vendors. A Cloud Native standard platform provides Telcos the means to integrate multiple vendors solutions into a software defined pool that can be provisioned, managed, and monitored “as codes”.

An open infrastructure leverages a flexible virtualization layer that entirely abstracts the physical layer. On top of it, Telco services can be deployed fully decoupled, according to disaggregation and control-plane/user-plan separation methodologies. Depending on the level of maturity and technological requirements, virtual machines or containers can be adopted. This will allow Telcos to participate in the innovation cycles of enterprise IT infrastructure. It also is the foundation to create an environment that allows to open the ecosystem for developers. If deployed properly, OPEX of operating the infrastructure and TCO can be reduced by creating a zero-touch orchestration on top of a fully flexible and highly scalable pool of resources.

Leveraging this technological evolution, the network is becoming an Open Telco Platform, both for internal efficiency and to be active actor of an external ecosystem.

The openness of the Telco Platform is defined by the adoption of interfaces for internal usage or to be exposed to the external entities. The current evolution embraces both standardized interfaces as well as those based on well-documented de facto standards. The ability to program the service offered by the platform must be exploited while preserving tenancy relationships without any implication or increasing in security risks.

The cloudification of the Telco Platform is producing a harmonization, driven by the technology, between the centralized Telco infrastructure and the Edge deployments. The adoption of a Cloud Native infrastructure is also bringing the Telco data centres more and more close to the HCP Cloud technology. A Hybrid Cloud model is naturally emerging from the current network evolution and it is going forward the expectation of new business opportunities. Hybrid has different flavors; one aspect is the coexistence of VM and Containers. Another aspect is the coexistence of Telco and Service oriented environments. Edge and Cloud coexistence and integration is another aspect that fits in the Hybrid scenario. The main aspects of this Hybrid Cloud transformation are a stronger focus of enabling a fluid –and potentially seamless – interoperability among the coexisting entities. Cloud solutions allow a Telco to form a single continuous cloud stratum.

When the Cloud Native evolution reaches maturity, the focus must be shifted back to the actual service being virtualized. For cost-effective and agile value creation and delivery, it should not be necessary to spend resources on assessing which cloud solution is the most appropriate, sustainable and future proof. Currently, the mix of cloud solutions on the management plane can only be achieved by realizing a unified translator for interfacing with various orchestrators. However, it is of paramount importance for the Telco industry to have both the ability to "speak the same language", and the same set of features available.

Whether the customer services are powered by Hyperscalers or Telcos, or potentially through a hybrid model, customers will expect a fully digital experience. This experience embraces the service set-up, payment, and the delivery on a managed platform. The overall management of their products is a key factor. Customers expect Cloud Native characteristics of reliability, elasticity, openness, and manageability. Historically, these are Hyperscaler platform strengths. Nowadays Telcos that manage to achieve Cloud Native competence and levels of service, are well placed to secure a leading role in providing 5G services and application support especially leveraging on their distinctive Edge resources.

The future of mobile networks is being re-shaped by the rise of Cloud architectures that extends levels of efficiency and scale from the datacentre to the mobile network and Edge. With Software-Defined Networking (SDN) and Network Function Virtualization (NFV), General Purpose Processors (GPP)-powered cloud servers have the flexibility to change workloads based on demand. This allows Telcos to exploit the flexible infrastructure, with different kinds of NFs or applications. The infrastructure guarantees long term stability for NFs and dynamicity for applications.

To make a smooth and successful evolution to Cloud Native, technical, organizational and operational aspects must be considered. Global standards, including open interfaces, need to be in place for a smooth adoption on technical side. Service development, network operation and maintenance, and security teams must all be aligned with the same mindset for a smooth transition at organizational and operational level. Those teams must augment their skills in Cloud Native architecture, technologies, and processes. Telcos must collaborate with one another creating synergy with HCPs. All the stakeholders are enabled by the Cloud Native technology to embrace a collaborative approach to business towards developers and customers. Cloud network providers and application developers shall take a collaborative approach across the value chain to accelerate the pace of innovation and to establish a robust ecosystem. The current evolution process is indeed not just technical, it is also driven by economical drivers that are related to internal Telco factors (e.g., savings) and to new business opportunities. A favorable future for a Telco will demand transformation to Cloud Native and a change in skills, knowledge, governance, funding, leadership, and culture. In return, a Cloud Native skillset and organization will drive cost efficiency, innovation, agility, automation, customer engagement and data-driven decision making. For a traditional Telco, the transition may be challenging, but Telcos that fail to make the transition to Cloud Native will likely see competition erode existing revenue and lose much of the 5G opportunity.

In summary, the Telco being part of wider ecosystem together with the developers and HCPs is a scenario well supported by the current Telco network cloudification process, by the work of the standardization bodies and international fora, and by the software developed inside the Open Source communities. This is a challenge for the

Telcos to embrace, to enhance the value of the network cloudification investments, to catch a unique opportunity that, driven by new service opportunities, adopts a common technology platform among the stakeholders with a solid base to succeed.

ABBREVIATIONS

5GC	5G-Core
AF	Application Function
AMF	Access and Mobility Management Function
API	Application Programmable Interface
BBU	BaseBand Unit
BSS	Business Support Systems
CAPEX	Capital Expenditure
CI/CD	continuous integration continuous deployment
CM	Configuration Management
CNF	Cloud-native Network Function OR Containerised Network Function
COTS	Common of the shelf
CU	Central Unit
CU-C	CU Control Plane (or CU-CP)
CU-U	CU User Plane (or CU-UP)
cVNF	Cloudified Virtualized Network Function
DDoS	Distributed Denial of Service
DMZ	Demilitarized Zone
DN	Data Network
DoS	Denial of Service
DPDK	Data Plane Development Kit
DU	Distribution Unit
eMBB	enhanced Mobile BroadBand
E-UTRA	Evolved Universal Terrestrial Radio Access
EVPN	Ethernet Virtual Private Network
FM	Fault Management
gNB	Next Generation NodeB
GNBCUCPF	Next Generation NodeB Central Unit Control Plane Function
GNBCUUPF	Next Generation NodeB Central Unit User Plane Function
GNBDUF	Next Generation NodeB Central Distribution Unit Function
GSMA	GSM Association

HCP	Hyperscale Cloud Providers
ICT	Information and Communications Technology
ISP	Internet Service Provider
LBO	Local Breakout
LCM	Lifecycle Management
MAC	Medium Access Control
MANO	Management and Orchestration
MEC	Multi-Access edge Compute
mMCT	massive Machine Type Communication
MNO	Mobile Network Operator
NbR	Name-based Routing
NF	Network Function
NFMF	Network Function Management Function
NFV	Network Function Virtualisation
NRF	Network Repository Function
ng-eNB	Next Generation evolved NodeB
NG-RAN	Next Generation RAN
Non-RT RIC	None Realtime RIC
n-RT RIC	Near-Realtime RIC
NSA	Non-Stand-Alone
NSMF	Network Slice Management Function
NSSMF	Network Slice Subnet Management Function
O-Cloud	Open Cloud SW
O-CU	Open Central Unit
O-DU	Open Distribution Unit
OPEX	Operational Expenditure
OSS	Operational Support Systems
OTT	Over-the-Top
PaaS	Platform-as-a-Service
PDCP	Packet Data Convergence Protocol
PHY-H	Physical Layer - Higher
PHY-L	Physical Layer - Lower
PM	Performance Management
PNF	Physical Network Function
QoS	Quality of Service

RAN	Radio Access Network
RDMA	Remote Direct Memory Access
RF	Radio Frequency
RIC	RAN Intelligent Controller
RLC	Radio Link Control
RRH	Remote Radio Head
RU	Radio Unit
SBA	Service Based Architecture
SCP	Service Communication Proxy
SDN	Software-defined Networking
SEN	Service Edge Node
SMO	Service Management and Orchestration
SMOF	Service Management and Orchestration Function
SR-IOV	Single-Route Input/Output Virtualization
TCO	Total Cost of Ownership
TEN	Telco Edge Node
UE	User Equipment
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communication
VNF	Virtualized Network Function
vRAN	Virtualized RAN

DEFINITIONS

Service Edge Node	Edge location in the network where Application Server are deployed. SEN hosts the application level services, maybe by 3rd party. These Application Server offers services generally to end users.
Telco	Telecommunications service provider
Telco Edge Node	Edge location in the network where Network Functions are located (e.g. component of the Core Network such as UPF)

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