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NFV evolution: Towards the Telco Cloud

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Contents

Executive Summary

Network Functions Virtualisation (NFV) and its Management and Orchestration (MANO) framework have transformed radically the way of deploying and operating telecom networks. NFV pioneered many new concepts and approaches such as descriptor-based operations, life-cycle management, scaling and automatic healing, etc., which have become de-facto and are extensively used in multiple commercial network deployments of current network generations like 5G.

In the meantime, the ecosystem around NFV and Cloud has evolved, with many new technologies based on cloud-native principles, automation and artificial intelligence (AI), offering additional paths and opportunities for NFV to grow further. This ecosystem also brings new learnings for improving, and, in some cases, radically evolving NFV. This is a necessary step for supporting the diverse new use cases and services that future network generations, like 6G, will bring. Not only that, but also for the network operator to further make the telecom networks more cost-effective, flexible, resilient and of high-performance.

Use cases such as enabling connectivity for billions of people and devices, providing services beyond connectivity ones, and expanding automation end-to-end, among others, need to be considered for driving the evolution of NFV. The learnings from past and current experience with NFV technologies and the specified frameworks like NFV-MANO, as well as the continuous evolution within the cloud-native ecosystem reinforce existing design principles and bring new ones in steering the future NFV evolution. These can be summarized as: simplification, cloud-nativeness, software portability across diverse infrastructure, stable and sustainable evolution, enhanced automation, flexibility, modularization and scalability.

The white paper introduces a rethought approach for the NFV and its MANO towards the concept of platform-oriented Telco Cloud. Telco Cloud is the result of the NFV evolution while elevating and upgrading the current capabilities of NFV in the areas of virtualization, cloudification, orchestration and automation. The proposed framework aims at simplifying the functionality and integration of necessary infrastructure, platform and its related orchestration and management aspects for network operators wishing to continue or further evolve their approach to digitally transform their telecom networks. By explicitly identifying platform-level capabilities and services at different granularities (e.g., application vs. network level), and scopes (of data, control and management), the proposed framework aims at bridging the intersection between telecom networking and Cloud to enable diverse telecom services.

In addition, the white paper explores some of the key technology enablers that are expected to support the NFV evolution. Enablers such as the use of declarative management APIs, GitOps, resource and service controller-based platforms, "data as the code" approaches, and technologies like big data, digital twins and artificial intelligence are introduced in the white paper highlighting their key advantages and potential usage for NFV. As the driving force for getting more flexibility and enhanced network deployment and operations, these technology enablers are already being considered by network operators and providers alike, which supports the fundamental principles to drive the NFV evolution.

The white paper concludes with a call for action to standards and open-source communities, with the aim that these will help realize the expected NFV evolution for the benefit of the whole telecom industry.

1 NFV: background and evolution needs

1.1 Background

Network Functions Virtualisation (NFV) [1] and its Management and Orchestration (MANO) framework have fundamentally driven the digital transformation of telecommunication networks. NFV and NFV-MANO have achieved remarkable results since their inception, as highlighted in ETSI NFV's white paper *Evolving NFV towards the next decade* [2]. These include, but are not limited to the following ones:

Driving the digital transformation of telecommunications networks: revolutionizing telecom operations by shifting from dedicated hardware and onsite tasks to commercial-off-the-shelf (COTS) server and remote management via NFV-MANO APIs. This transformation has enabled network operators to slash capital expenditure (CAPEX) for hardware and reduce operational expenditure (OPEX) related to network operations and maintenance, such as reducing onsite work, while enhancing network resiliency overall.

Achieving network function virtualization and automation: NFV-MANO pioneered essential elements for descriptor-based automation, lifecycle management and orchestration, network functions virtualization and telco cloud deployment and operations, which have become standard approaches in current telecom networks. NFV made possible the implementation of features like network scaling and automatic healing, enhancing efficiency and reliability, particularly in 5G networks.

Becoming de-facto implementation for future network generations: the industry commonly refers to 5G as an "NFV-native network", supported by multiple and widespread commercial network deployments that leverage virtualized network functions (VNF), cloud-native network functions (CNF) and management and orchestration solutions based on ETSI NFV standards [3].

Considering the current state of new technology offerings, NFV must continuously evolve as a vital industry key driver and enabler for the network transformation and technological advancement. Future use cases will introduce new services by combining telco cloud computing resources with telecom networks, spurred by rapid advancements in the IT and network domains. This continuous evolution is driven by aspects like the following:

Cloud technologies evolution: rapidly evolving advancements in virtualization and cloudification technologies, such as virtual machine and OS container orchestration systems like OpenStack® and Kubernetes® are continuously re-shaping the landscape for NFV. The expansion of the underlying cloud infrastructure in an ultra-distributed setup, along with new kinds of resources like data processing units and acceleration resources, and new automation capabilities will play a crucial role.

Artificial intelligence (AI) trends: AI is expected to become a key component in nurturing the operating supporting systems used to manage and operate telecom networks, as well as a major component in future telco cloud operations and maintenance within NFV-based environments.

Future network demands, including advancements beyond 5G and 6G, emerging deployment scenarios such as virtualized RAN and the broader digital transformation of networks.

All these additional capabilities and enhancements from various initiatives, and more, are being integrated into NFV. By maintaining and enriching the abstraction layers provided by VNF (which covers CNF as well) and Network Service (NS) modeling, NFV and NFV-MANO have managed to retain compatibility without significant impacts on Operations Support Systems/Business Support Systems (OSS/BSS) and other management systems, regardless of the underlying deployment technologies.

The evolution of NFV so far has brought to the industry many new learnings about how to efficiently perform the management and orchestration of software and virtualized-based networks. Nonetheless, some challenges still remain. For instance, the standardized solutions might have been perceived as rather complex in nature and, as a result, difficult to be easily developed in and integrated into production networks. Furthermore, in recent years, there has been a prevailing misconception in the industry that orchestration only encompasses the resource orchestration lifecycle steps, such as instantiation, termination, scaling, and upgrading, on which NFV has mostly focused. However, the true goal of orchestration is to achieve comprehensive end-to-end management of telecom networks, including pre-deployment, deployment, and post-deployment configuration automation, along with the long-term support of the VNFs and network lifecycle.

The ongoing advancement of telecom networks, such as beyond 5G and 6G, along with new deployment use cases, such as virtualized RAN, and the demands of digital network transformation necessitate, in some instances, some changes compared to legacy networks and, in others, solutions that provide clear benefits to network operators for embracing this transformation. Consequently, further evolution of NFV should be pursued.

In light of this, this white paper presents the trends, principles and framework guiding the evolution of NFV towards supporting future telecom network generations within an ever-expanding cloud-native ecosystem.

1.2 Evolution needs: support for future network generations

1.2.1 Use cases and trends

NFV concepts and technologies have shaped the design and implementation of recent network generations, like 4G advanced and 5G. In light of this, any future evolution of NFV must consequently consider how to support future network generations, such as 6G. Use cases and key trends for 6G are being extensively studied and referenced in numerous industry initiatives such as in [4], [5], [6] and [7], including numerous references to leveraging and evolving further NFV-based network deployments.

Some relevant use cases to be considered in the evolution of NFV are introduced as follows:

Use case #1: connectivity of billions of people and devices

Future networks need to consider providing connectivity to billions of people and devices. This can translate into the need for provisioning and managing a growing number of networks. Thus, two factors are key to being addressed:

- how to extend communication coverage, and
- how to scale and manage the growing number of devices, terminals and networks efficiently.

Considering this scenario, it is expected that the scale of the network will explode (in number and coverage), and for this, it is crucial to have a common telco cloud framework that can support as many kinds of networks as possible, perform optimal infrastructure allocation to lower the cost per bit and offer the required levels of automation to manage the un-foreseen underlying network complexity. All this needs to be considered for the evolution of NFV, in an environment where the infrastructure is extremely distributed, cost-effective and easier to integrate.

Use case #2: industrial networks and societal automation

Industrial networks and societal automation will propel future network generations to become a fundamental social infrastructure. Some important requirements to consider are:

- Robust and resilient networking across all infrastructures,
- guaranteed maximum latency and time-sensitive communications, and
- diverse local breakpoints to support multiple industries and services.

Additionally, a potential hybrid environment combining users' private facilities and the telecom cloud will necessitate, within the scope of the NFV evolution, an advanced cloud management system able to provide flexible connectivity and computing services, while ensuring resource isolation and data privacy.

Use case #3: beyond connectivity services

Future generations of networks are anticipated to evolve beyond merely connecting devices (both end user and network devices). As the networks transition into becoming a "Cloud" themselves, they will offer additional services beyond connectivity, such as compute and data services. Consequently, applications deployed on these networks will need to encompass not only regular networks, but also light-weight general purpose, or even specialized applications, including those related to AI. Therefore, the NFV evolution needs to support new forms of tailored application virtualization to facilitate the network and services evolution beyond connectivity.

Use case #4: end-to-end automated management

To effectively handle the diverse characteristics of the network, infrastructures, ultra-distributed clouds, and applications, there is an increasing expectation for more automated operations and management supported by AI or AI-assisted tools and technologies. This encompasses aspects like:

- fault and error monitoring and recovery,
- performance monitoring, including energy-saving,
- capacity planning and its management,
- configuration design and its management,
- devices and system-wide upgrades, and
- post-change testing.

Therefore, leveraging AI/ML technologies to achieve true zero-touch management is also a promising avenue for the evolution of NFV.

Use case #5: migration scenarios of interworking between 6G and earlier generations

Finally, an essential use case to consider is the migration and interworking scenarios between existing and future network generations. Network operators are likely to gradually integrate new generations of network support assets into their existing networks. The coexistence of various network generations will increasingly become a reality that network operators will have to cope with, especially considering the adherence to comply with telecom-related regulations. In this context, NFV technologies and software-based network deployment approaches must play a key role.

Use cases summary

In summary, the introduction of these use cases suggests that the NFV evolution will have to gravitate around two key general use case-driven requirements:

- **Expanding the scope of virtualization and cloudification:** enabling NFV to offer virtualization/cloudification, not only for network functions (NF), but also for various other types of telecom (and potentially non-telco) applications; and
- **Easier development and integration to cope with the inherent network disaggregation complexities:** making NFV easier to integrate and use in the context of the continuous evolution of network generations, while providing clear and simple "integration points" for other management frameworks or network operators' operating systems to leverage NFV technologies.

1.2.2 Principles for NFV evolution

The basis for a future NFV needs to step upon some fundamental principles, which will provide qualitative and quantitative indicators aimed at guiding the evolutionary path of NFV and assessing its execution.

In the following, some key principles for the evolution of NFV are introduced.

Principle #1: simplification

The current NFV framework is considered to have evolved into a rather complex system, both in terms of a number of management functions and the possible interactions among them. This complexity arises from the necessity to incorporate more technologies and new virtualization deployment mechanisms for VNFs and CNFs such as support for container-based VNFs. Additional functionalities related to automation and intent have also been integrated into the framework. Therefore, to overcome this situation the evolution of NFV and its management and orchestration framework must prioritize simplification as a key objective.

Additionally, the disaggregation of telecom networks, both vertically (by decoupling software and hardware) and horizontally (more granular network functions and services), is regarded as increasing system complexity. This is because more elements and components need to be deployed and managed.

NFV must reduce this complexity by simplifying the integration and operation of all necessary parts. For NFV to achieve this, it needs to be simpler at its core, facilitating more efficient integration into the existing network assets, or as a new asset where applicable. However, simplifying NFV should not compromise its functionality, as the systems need to remain feature-rich to handle the complex use case of telecom networks. Likewise, NFV needs to also be highly scalable, ensuring that it can provide necessary functions and services through on-demand expansion without adding unnecessary complexity.

A more streamlined and user-friendly NFV system will significantly benefit the network operators and the telecommunications industry at large. By simplifying the implementation and management processes, it will lower the barriers to entry and facilitate the widespread adoption of NFV technologies. This transformation is crucial for driving the digital evolution of networks, improving operational efficiency, increasing service agility, and enabling innovative services and applications that enhance the quality and capabilities of telecom infrastructure.

Principle #2: Cloud-nativeness

The evolution of the NFV and NFV-MANO frameworks must consider how to enhance and complement NFV, driven by the rapidly expanding cloud-native ecosystem and its associated technologies.

In this context, NFV should bridge the technology gap that telecom network operators face to integrate more DevOps, CI/CD, GitOps and automated management features into their networks. Declarative management approaches contribute to more automated deployment and operation, and potentially replace or complement the imperative management mode of networks, where appropriate. Network operators are considering these approaches to simplify the deployment and operations of telco workloads. The evolution of NFV must play a key role in adopting the cloud-native approach not only for infrastructure and workloads but also for the entire network, which is the primary business concern and responsibility of network operators.

Principle #3: software portability across infrastructure

Infrastructure is continually expanding, incorporating diverse features such as:

- different types of clouds, e.g., public cloud or edge cloud,
- different physical devices, e.g., diverse processing units (xPUs), hardware accelerators and micro-servers,
- new network protocols, e.g., time-sensitive networking, and
- unified and common interface protocols for a wider range of exposed services and capabilities.

It is conceivable that future network generations might leverage cloud infrastructure and physical equipment located beyond traditional data centers, including platforms in the sky and at sea.

Despite such continuous expansion of the infrastructure in terms of location and resources, an evolution of NFV should adhere to the fundamental principle of decoupling hardware and software, ensuring application portability across various infrastructures. Emerging virtualization and cloudification technologies are already enabling application designers and developers to concentrate more on application (or network function) logic rather than infrastructure concerns, while simultaneously offering portability across different infrastructure deployments. By embracing these approaches in the evolution of NFV, network operators will be empowered to deploy diverse telecom applications anywhere with increased flexibility and portability.

Principle #4: stable and sustainable evolution

Although the rapid advancement of solutions, open source, and cutting-edge cloud technologies is constant and will remain so, the telecommunications industry requires a stable and sustainable evolution. In this context, new system solutions must:

- support the coexistence of existing systems,
- provide upgrade paths between different systems/components, and
- provide robust version management capabilities.

Standards play a vital role in ensuring the interoperability of products through their lifecycle, giving operators and vendors the confidence to adopt and leverage them.

Therefore, the future NFV must also consider how to transition from the current NFV framework, ensuring functional and interface backward compatibility where needed.

Principle #5: enhanced automation

NFV-MANO offers significant automation features compared to legacy network operations. It facilitates the deployment automation and configuration of network functions while optimizing the allocation and use of network resources through intelligent analysis and prediction, thereby improving the overall network operation efficiency.

In the future, NFV needs to further enhance the current state of the art in the automation and intelligence domains. More concrete aspects include:

- Standardized interfaces and protocols: feature enrich and evolve the interfaces to advance on rapid deployment and flexible operation of any NF deployment type (referred to as xNFs) and any kind of other applications of potential use in telecom networks.
- Real-time monitoring: NFV should swiftly adjust resources configuration based on network requirements to meet new service demands, monitor the network status in real-time, issue early warnings, detect and address potential network faults promptly, and ensure stable network operation.

In summary, the future NFV system must integrate more automation and intelligence, driving the development of the network functions virtualization technology towards more efficient, flexible, and intelligent network operations. This evolution will not only improve the overall network performance and user experience, but also provide greater commercial value and competitive advantages to network operators and solution providers.

Principle #6: flexibility, modularization and scalability

While network disaggregation can bring more complexity, it also opens up new opportunities for network operators and suppliers to make telecom networks more flexible and adaptable. At its core, an evolution of NFV needs to consider how to provide and support more flexibility to network operators in building their networks. Such an evolution stands on three key pillars:

- NFV as a stimulus for building telecom networks in a more flexible and efficient way: the management and orchestration elements, together with a unified end-to-end cloud infrastructure, enable the network operator to deploy and operate network functions and other applications to cope with the specific network demands in terms of capacity and location,
- NFV as a catalyst for "gluing" the modular and multi-level disaggregated networks (at an application level, such as more granular application services, and at resource level like OS-container Pods) at both, deployment and monitoring level (ensure QoS level, like latency, jitter, etc.), and
- NFV’s management and orchestration framework flexibility: an improved modular design, which is a common practice in software and complex systems design, can bring more flexibility to fine-tune the necessary management and orchestration system capabilities exposure.

A more flexible and modular NFV will provide additional benefits to network operators, like future forward compatibility, easier maintenance, modules reusability, and overall greater scalability of the system. Furthermore, a highly scalable NFV will be able to flexibly adapt to the ever-changing business demands and further promote the widespread application and adoption of NFV technologies.

2 Rethinking NFV: a new approach for Telco Cloud

2.1 "Elevating" NFV towards Telco Cloud

To ensure a sustainable transition from legacy NFV to an evolved NFV, and address the challenges faced by network operators in procuring, deploying and maintaining NFV-based commercial networks, NFV is expected to be enhanced by "elevating" its current capabilities and functional scope in two areas, as illustrated in figure 2.1-1: a) framework (depicted by the blue-dotted box in the figure), and b) technology and components (reflected by the red-dotted box in the figure).

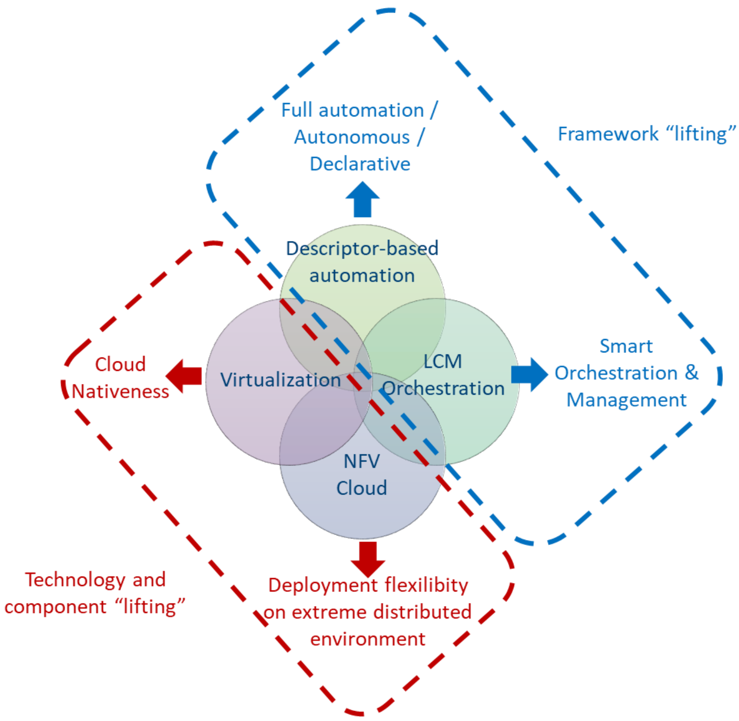

Figure 2.1-1: "Elevating" NFV technology aspects

The primary areas of improvement in the evolution of NFV towards Telco Cloud include:

- The tooling, systems, and frameworks used by network operators for operations, administration and maintenance (OAM) purposes, and
- The adoption of cloud-native principles, practices and relevant technologies.

Network operators see these elements as areas that can be modified (up to some scale) and continuously improved. Meanwhile, the underlying infrastructure, such as hardware, network device resources, buildings and facilities, is expected to be preserved and utilized across both current and future networks as a unified infrastructure able to continuously integrate new technologies thereby enriching its capabilities and performance.

From a framework perspective, it is essential to introduce or enhance declarative management functionalities to move towards full automation and smarter orchestration (also supported by AI) enabling more flexible and streamlined network operations. This evolution will expand beyond the basic lifecycle management (LCM) orchestration and descriptor-based automation that NFV currently supports.

From a technology and component perspective, virtualization needs to expand further and fully realize its true potential by incorporating more cloud-nativeness capabilities to overcome legacy technology challenges such as partial automation and limited support for upstream infrastructure and connectivity technologies.

All these aspects are crucial in propelling the evolution of NFV towards a new Telco Cloud framework.

2.2 High-level telco cloud framework

The evolution of NFV and its MANO focuses on developing **a platform that can bridge the intersection between the cloud infrastructure and the deployment and network orchestration of network functions and many other kinds of applications.** This gap needs to be closed for network operators to effectively leverage Cloud and software technologies for building current and future generation networks while making their integration more cost-effective, as well as providing new service opportunities.

The following two assumptions are considered:

- A Cloud infrastructure that is continuously evolving based not only on telecom network related requirements/use cases but also driven by other industries like cloud computing, IT and finance. In this context, there are many tools and systems in place, prominently based on open-source solutions.
- The existence of technological, deployment and operational gaps between deploying and operating IT workloads versus telecom workloads, which need to be resolved to ensure that cloud-native technologies can be effectively leveraged for telecom networking.

The high-level framework concept for the evolution of NFV is illustrated in figure 2.2-1, and it is hereafter referred to as Telco Cloud. This term does not aim at departing from current key concepts of NFV and NFV-MANO, but rather aims at making it easier to differentiate the evolutionary aspects of NFV introduced in this white paper. Furthermore, the different kinds of network applications and other applications that can be deployed on the infrastructure and operated by the orchestration and management services of Telco Cloud are represented as Telco Cloud Applications, moving beyond the concept of VNF/CNF. The Telco Cloud Applications are represented at the top-most layer in figure 2.2-1.

Even though the figure illustrates different layers, Telco Cloud does not intend to define a strict layering, but instead to identify groupings of related functionality. Such a more simplified layout aims at avoiding complex interactions and dependencies between components at different layers to fulfill end-to-end operational procedures, hence providing more flexibility and scalability to support various applications, infrastructure and ways of operation and management.

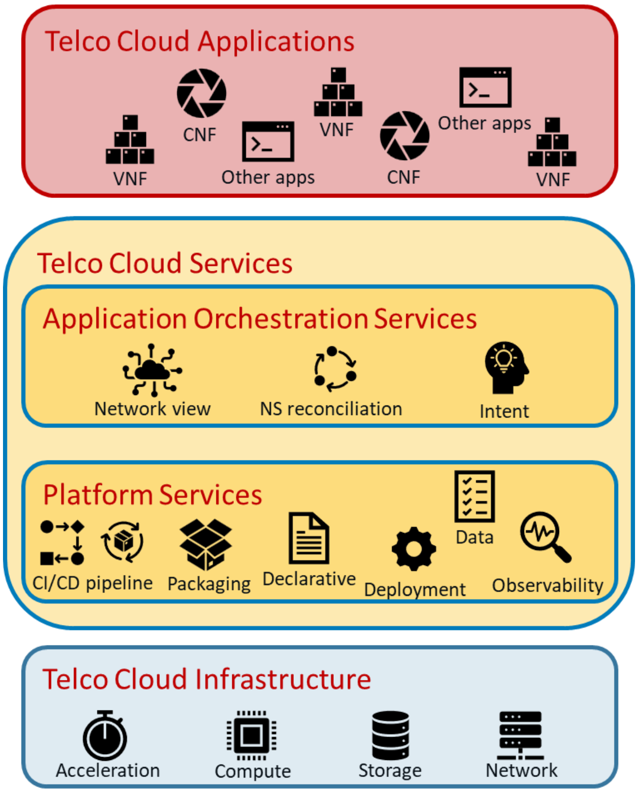

Figure 2.2-1: Telco Cloud concept for Telco Cloud Applications

From bottom to top, the Telco Cloud layout is comprised of:

- Telco Cloud Infrastructure,
- Telco Cloud Services, further comprising of Platform Services and Application Orchestration Services, and
- Telco Cloud Applications.

Telco Cloud Infrastructure represents the foundation over which various network functions and applications can be deployed and operated. Such an infrastructure is highly distributed, covering from access, through edge to central cloud regions. It is comprised not only of computing, storage and network resources, but also of data processing units and acceleration resources to boost the performance of all kinds of workloads. In this domain, Telco Cloud aims at leveraging the industry ecosystem around infrastructure-as-a-service (IaaS), container-as-a-service (CaaS) and software defined networking (SDN), while the focus resides on enabling the means to integrate such kind of infrastructure-related service models and associated resources with the rest of the Telco Cloud stack.

Telco Cloud Platform Services: at its core, the Telco Cloud Services provides platform services (like a platform-as-a-service (PaaS)) for network functions and other telecom applications. This platform is rich and modular, providing all the necessary capabilities (or services) to enable the deployment and management of many kinds of applications, not only network functions, but also other applications, such as for edge, intelligence, coding, etc., as deployable workloads. Services can be integrated and reused in a flexible manner, covering the three main functional planes:

- data and control plane services: they comprise services dedicated to data and control plane aspects, which can be very diverse depending on the needs of applications and networks to deploy, like service mesh connectivity, data repositories, load balancing, etc.
- management plane services: examples of management services include packaging, deployment lifecycle, observability, configuration repositories, and the necessary tools to support continuous integration/continuous delivery (CI/CD) pipelines.

While the Telco Cloud Applications are deployed on the cloud infrastructure in various forms (e.g., as containerized workloads), the Telco Cloud Platform Services further facilitate the decoupling of the applications from the infrastructure thanks to its data, control and management capabilities. The Telco Cloud Platform Services, as a whole, define the platform that can be expanded all across the infrastructure facilitating in turn the true portability of the applications on a hyper distributed infrastructure.

Telco Cloud Application Orchestration Services: the upper layer within the Telco Cloud Services encompasses the network-wide application orchestration and automation. It is responsible for the application service end-to-end orchestration and automation, as well as the orchestration of the hyper-distributed infrastructure. Application orchestration services aim at expanding the orchestration beyond pure network applications, thus its more generic name. In this layer, the focus is twofold:

- enabling the interworking of Telco Cloud and its management and orchestration functionality to other OSS that the network operator already uses, and
- enabling the interworking with the modular Telco Cloud Platform Services and the underlying Telco Cloud Infrastructure for flexibility.

The purpose is to primarily focus on providing network-level and diverse application reconciliation between the intents of network orchestration and management and the individual management actions towards the Telco Cloud Platform Services and the Telco Cloud Infrastructure for end-to-end automated network operation.

Telco Cloud Applications: they represent the top-most layer of the Telco Cloud. Networks in the future will not only comprise network functions, such as 3GPP-defined NFs for 4G (e.g., MME, S/PGW-C, S/PGW-U, etc.) and 5G (e.g., AMF, SMF, UPF, etc.), but also many different applications, e.g., for AI/ML, application acceleration, etc. Having this in mind, Telco Cloud considers introducing more modularity in the templates/descriptors of the various NFs and applications to deploy as declarative targets, providing a clear separation between the declarative target expression and the management of the data to reconcile into an actual managed object. Current NFV already provides the VNFD and VNF LCM/FM/PM APIs, and such abstraction is very useful for managing xNFs.

However, Telco Cloud envisions that application's LCM and other OAM services of the Telco Cloud Platform Services should be defined in a way facilitating network operators to leverage more declarative management, while facilitating the coexistence of existing NFV specifications and new architecture LCM management functions.

Overall, the envisioned framework can enable a richer multi-vendor platform-oriented ecosystem. This can be achieved by helping network operators maximize the outcomes from the already established current infrastructure investments, as well as planned ones for future network generations. It could also be doneby leveraging existing cloud infrastructure solutions, and bringing telecom network deployments closer to achieving cloud-nativeness principles for a more reliable and sustainable telecom network vision.

2.3 Evolution of NFV-MANO

Conceptually, the Telco Cloud is based on functionality and management scopes already provided by NFV-MANO. However, as depicted in figure 2.3-1, Telco Cloud redistributes the functionality into different layers aiming at further simplification.

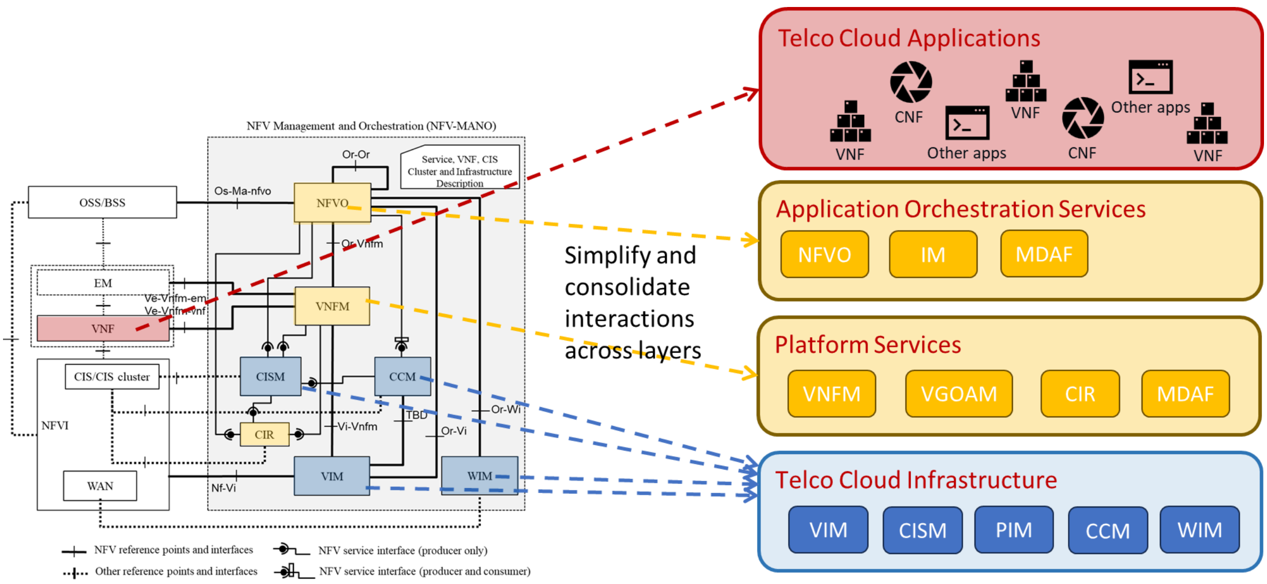

Figure 2.3-1: Evolution of NFV-MANO towards Telco Cloud

One of the key ideas with a simplified management and orchestration framework for NFV is to strive for complexity to be spun within a layer, as needed by the interoperability among components, while simplifying the interaction and consolidating functionality views across layers, e.g., by adopting more declarative management, with the end goal of providing more flexibility and easy integration.

In figure 2.3-1, currently specified (and in progress) functional blocks/functions of NFV-MANO are represented in the new proposed framework, by allocating them to a corresponding layer of the Telco Cloud. As depicted, Telco Cloud shows a great level of functional compatibility with the existing NFV-MANO. Consequently, a simpler transition towards future implementations of the Telco Cloud can be foreseen, addressing the principle of a sustainable evolution of NFV.

2.4 Technology enablers for NFV evolution

In the evolution of NFV, some technologies are expected to play a key role in driving the transformation of the management and orchestration systems and the deployment/lifecycle of networks and other applications. A few examples of relevant technology enablers are further described as follows:

1) Declarative management APIs

Interactions between the network orchestration and the systems below leverage declarative management approaches, where feasible and meaningful, for simplifying and optimizing the management and orchestration workflows. This mechanism will help realize the "infrastructure as code" and "management as code" approaches and facilitate the operation of the whole network (infrastructure and applications) leveraging DevOps and GitOps methodologies, which are also presented as a technology enabler.

One of the key technology enablers for expressing these intents (e.g., applicable to xNF deployment and configuration) is the use of solutions like custom resource definitions (CRD) [10], which are currently employed in many cloud orchestration environments. Leveraging the basic principle of decoupling configuration and state data from application/service logic, CRDs can simplify interoperability between different layers. An NFV evolution for 5G and future generations of containerized applications should develop intelligent, intent-driven application-specific and/or NFV infrastructure-specific custom resource controllers to reconcile the intents expressed in the CRDs. This new orchestration paradigm will also move telecoms closer to network autonomy, enabling multiple event-driven systems, within the Telco Cloud framework, to coordinate and interact in order to accomplish the desired intents, transforming the way VNF management has been performed traditionally by VNF Managers (VNFMs) and enabling simpler and minimal intervention from higher orchestration functions, such as typically done by NFV Orchestrators (NFVOs).

2) GitOps

GitOps is rapidly gaining momentum in the telecom industry as a promising solution for addressing complex legacy network operations. By applying GitOps to telecom networking, best practices of version control and collaborative development are utilized to integrate network declarative targets into actual orchestration and automation pipelines. However, due to the inherent diversity of deployment environments within the telecom networks, direct application of GitOps can be challenging. It is necessary that network orchestration systems can leverage GitOps methodology and pipelines more efficiently, including being able to separately manage templates and configuration for network and telco cloud applications, such as xNFs, while reconciling them as needed for actual deployment and operations.

GitOps plays a vital role in identifying the configuration drifts and maintaining infrastructure consistency, serving as a single source of truth across all network deployments. When integrated with Telco Cloud Platform Services, GitOps enhances the capability to dynamically and on-demand scale the xNF and other Telco Cloud Applications’ topology via the orchestration pipelines, providing as well more flexible and automated operation.

This approach offers significant benefits to telecom providers by improving operational efficiency, reducing manual interventions, and ensuring consistent, replicable and reliable network performance.

3) Resource and service controller-based platforms

As a target for making the Telco Cloud system more flexible to adapt and scale its functionality in a robust manner, modularity becomes critical. Modularity can be introduced by a common and unified telco cloud platform providing more granular level services and capabilities which can be employed just when needed, e.g., by the applications/network services, for OAM purposes by the network operator, etc. Modularity can be achieved by integrating specific controllers into the platform dedicated to managing and operating the various aspects of it.

Controller-based management, like the case of K8s Operators [8][9], can also facilitate the network operator to provision and troubleshoot the network by fostering a clear split between data and its processing, as also described in the following technology enabler. Data repositories/stores and controllers fulfill this clear split, the former by offering the means to manage the desired state data, while the later fulfilling the processing of the data and the reconciliation of the managed objects according to the desired state. This enabler relates to the "declarative management APIs" previously introduced.

4) Data as code and readable/versatile data models

Textual data models are anticipated to play a pivotal role in facilitating the management and orchestration of networks, in conjunction with other key technologies such as GitOps. In effect, "data", as meant for the templating and provisioning of telecom networks, can become the "new code". By using this principle, core tenets like versioning, automated testing and continuous integration pipelines can be realized at their fullness.

To such an extent, a possible way of making NFV simpler is to consolidate interfaces and functions that produce the same or similar output, to organize descriptors separated by purpose or goal and to simplify the minimum required parameters for using the descriptors. This approach will facilitate easier management and deployment of NFV technologies, ultimately driving the efficiency and effectiveness of the telecom network operations.

5) Automation and intelligence

With the rapid advancement of cloud-native technologies, NFV systems are rapidly advancing towards increased automation and intelligence. The core of this trend involves the introduction of advanced automatic management tools and intelligent algorithms to enable dynamic deployment, flexible configuration, and intelligence of/for network functions.

Technologies such as big data, digital twin and artificial intelligence are anticipated to play a crucial role in the evolution of NFV, providing powerful support for network optimization, decision-making and productivity enhancements. By leveraging intelligent algorithms and large language models, NFV systems will be able to predict network traffic trends, adapt the network configuration, and perform proactive resource scheduling and capacity expansion planning to prevent network congestion and performance bottlenecks.

In addition, intelligence can also implement automatic network security protection and response, thereby enhancing overall network security capabilities.

6) Observability and security

The rapid advancement of cloud-native technologies is driving NFV systems toward greater levels of observability and security. This evolution is underpinned by the integration of innovative enablers such as advanced observability frameworks ensuring more dynamic, efficient and responsive operations and maintenance. These new observability tools also offer the capability to perform in-band network and compute monitoring in consideration of the kinds of resources and deployment models in the cloud-native ecosystem, like is the case of containerized workloads. By leveraging advanced observability tools available in the cloud-native ecosystem and other prominent solutions and protocols like message buses, NFV systems can achieve real-time insights at a greater scale into infrastructure health, performance metrics, and operational anomalies, further enhancing operational reliability.

In the realm of security, the introduction of a Minimum Baseline Security Standard (MBSS) and AI-driven threat detection mechanisms ensures robust protection against emerging threats. These mechanisms enable automatic threat response, vulnerability management, and compliance adherence, fortifying the overall network security posture. Together, these enablers not only address current challenges but also pave the way for NFV systems to evolve into highly autonomous and secure ecosystems, seamlessly integrated within the Telco Cloud paradigm.

3 Conclusion and next steps

The expectation of NFV and MANO is to evolve based on splitting and converging functionality in different layers and offering more declarative management capabilities. This would simplify the overall framework while keeping it rich in terms of functionality and capabilities required in the management and operation of telecom networks.

At its core, NFV is expected to focus more on becoming a framework whereby the Telco Cloud infrastructure can be integrated and used efficiently for not only telecom purposes but also for deploying many other kinds of applications, thanks to a rich Telco Cloud Services platform.

Overall, the proposed platform-oriented framework will help network operators leverage existing cloud infrastructure solutions and make telecom network deployments more reliable and sustainable while adopting best practices and principles from the cloud and network virtualization ecosystem.

To realize this framework and the main principles backing it up, actions should be taken by standardization organizations, like the ETSI ISG NFV, and other fora like open-source communities in the following areas:

- Architecture specification to formalize the Telco Cloud framework for future NFV.
- Specification and guidelines to evolve from NFV/NFV-MANO solutions towards evolved NFV framework, such as the described Telco Cloud.

- Network Service orchestration and reconciliation:
    - Network and service orchestration capabilities consuming Telco Cloud PaaS services.
- Intent management:
    - Exposure of intent management to third party and other management systems.
- PaaS services data models and interfaces:
    - Leverage declarative methodologies used in the cloud-native ecosystem, such as CRD.
    - Package management for CRDs and custom controllers agnostic of CNCF technologies such as Helm, Operator Lifecycle Manager (OLM), Kubernetes Package Tool (KPT), Package Orchestration Server (Porch).
    - Dependency management among the NF services and modular CNF constituents.
- Telco Cloud Applications:
    - Modular descriptors and packaging for any kind of application (network functions such as xNF, AI applications, etc.).
    - Modernize CNF applications to incorporate best practices defined by CNCF standards.
- Observability and monitoring of intra and inter-xNF deployments (e.g., in-band network telemetry).
- Use of Generative AI in orchestration and automation:
    - Leverage GenAI technologies to generate textual data configurations, GitOps orchestration pipelines, and resource and service controllers.

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Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
BSS	Business Supporting System
CaaS	Container-as-a-Service
CCM	CIS Cluster Management
CI/CD	Continuous Integration/Continuous Delivery
CIR	Container Image Registry
CIS	Container Infrastructure Service
CISM	CIS management
CNCF	Cloud Native Computing Foundation
CNF	Cloud-native Network Function
COTS	Commercial-off-the-Shelf
CRD	Custom Resource Definition
IaaS	Infrastructure-as-a-Service
IM	Intent Management
KPT	Kubernetes Package Tool
LCM	Life-Cycle Management
MANO	Management and Orchestration
MBSS	Minimum Baseline Security Standard
MDAF	Management Data Analytics Function
ML	Machine-Learning
NF	Network Function
NFV	Network Functions Virtualisation
NFVO	NFV Orchestrator
NS	Network Service
OAM	Operations, Administration and Maintenance
OLM	Operator Lifecycle Manager
OS	Operating System
OSS	Operations Supporting System
PaaS	Platform-as-a-Service
PIM	Physical Infrastructure Management
Porch	Package Orchestration Server
SDN	Software-Defined Networking
VGOAM	VNF Generic OAM
VIM	Virtualized Infrastructure Manager
VNF	Virtualized Network Function
VNFD	VNF Descriptor
VNFM	VNF Manager
WIM	Wide-area Infrastructure Manager

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