ETSI GR NFV-IFA 054 V6.1.1 (2025-02)

GROUP REPORT

Network Functions Virtualisation (NFV) Release 6; Architecture; Report on architectural support for NFV evolution

Reference
DGR/NFV-IFA054

Keywords
architecture, NFV evolution

ETSI

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Sous-Préfecture de Grasse (06) N° w061004871

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Network Functions Virtualisation (NFV).

Modal verbs terminology

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1 Scope

The present document studies and describes the architectural changes related to the NFV architectural framework, to support new trends in NFV-based Telco Cloud evolution, such as new types of virtualisation technologies, heterogenous infrastructure or hyper-distributed edge deployment, computing and network convergence.

Starting with a study on future trends related to NFV-based Telco Cloud evolution and their respective architectural targets applied to the NFV architectural framework, key architectural principles are identified for deriving potential architectural changes to the current NFV architectural framework. Resolutions to fulfil the architectural targets of future trends by the proposed NFV architectural changes are also analysed. At the end, recommendations for the normative work of architectural framework for Telco Cloud are delivered considering the future trends.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI GR NFV 003 (V1.9.1): "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".

[i.2] ETSI GS NFV 006 (V5.2.1): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Architectural Framework Specification".

[i.3] ETSI White Paper No. 54, 2023: "Evolving NFV towards the next decade".

[i.4] ETSI White Paper No.53, 2023: "In the Light of Ten Years from the NFV Introductory Whitepaper".

[i.5] ETSI GR NFV-EVE 018 (V5.1.1): "Network Functions Virtualisation (NFV) Release 5; Evolution and Ecosystem; Report on Multi-tenancy in NFV".

[i.6] ETSI GS NFV-IFA 053 (V5.2.1): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Requirements and interface specification for Physical Infrastructure Management".

[i.7] ETSI GS NFV-IFA 049 (V5.2.1) "Network Functions Virtualisation (NFV) Release 5; Architectural Framework; VNF generic OAM functions specification".

[i.8] "Backward compatibility" from Wikipedia®.

[i.9] ETSI GS NFV 002 (V1.2.1): "Network Functions Virtualisation (NFV); Architectural Framework".

[i.10] ETSI GS NFV-IFA 007 (V5.2.1): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Or-Vnfm reference point - Interface and Information Model Specification".

[i.11] ETSI GS NFV-IFA 050 (V5.2.1): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Intent Management Service Interface and Information Model Specification".

[i.12] ETSI GR NFV-EVE 023 (V0.7.0): "Network Functions Virtualisation (NFV) Release 6; Evolution and Ecosystem; Report on new infrastructure resources for NFV".

[i.13] ETSI GR NFV-EVE 025 (V0.0.5): "Network Functions Virtualisation (NFV); Release 6; Evolution and Ecosystem; Report on Serverless and other application virtualisation forms in NFV".

[i.14] ETSI GR NFV-EVE 026 (V0.0.1): "Network Functions Virtualisation (NFV) Release 6; Evolution and Ecosystem; Report on NFV support for computing and network convergence".

[i.15] ETSI GR NFV-EVE 027 (V0.0.1): "Network Functions Virtualisation (NFV) Release 6; Evolution and Ecosystem; Report on Model-as-a-Service (MaaS) in NFV".

[i.16] ETSI GR NFV-IFA 039 (V5.1.1): "Network Functions Virtualisation (NFV) Release 5; Architectural Framework; Report on Service Based Architecture (SBA) design".

[i.17] ETSI GS NFV-IFA 030 (V5.1.1): "Network Functions Virtualisation (NFV) Release 5; Management and Orchestration; Multiple Administrative Domain Aspect Interfaces Specification".

[i.18] ETSI GR NFV-EVE 021 (V5.1.1): "Network Functions Virtualisation (NFV) Release 5; Evolution and Ecosystem; Report on energy efficiency aspects for NFV".

[i.19] ETSI GS NFV-SOL 003: "Network Functions Virtualisation (NFV) Release 5; Protocols and Data Models; RESTful protocols specification for the Or-Vnfm Reference Point".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GR NFV 003 [i.1] apply.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GR NFV 003 [i.1] and the following apply:

AI Artificial Intelligence
AIOps Artificial Intelligence Operations
ASIC Application Specific Integrated Circuit
CI/CD Continuous Integration/Continuous Delivery
CRD Custom Resource Definition
CSP Communications Service Provider
DevOps Development & Operations
DPU Data Processing Unit
FPGA Field Programmable Gate Array
GPU Graphics Processing Unit
MaaS Model as a Service
ML Machine Learning
MLOps Machine Learning Operations
NPU Neural Processing Unit
RDMA Remote Direct Memory Access

RoCE	RDMA over Converged Ethernet
TCAM	Telco Cloud Application Management
TCAS	Telco Cloud Automation Support
TCIM	Telco Cloud Infrastructure Management
TCOP	Telco Cloud & Orchestration Platform
TC-MANO	Telco Cloud MANagement and Orchestration
TC-MDAF	Telco Cloud Management Data Analytics Function
WASM	WebAssembly

4 Background and overview

4.1 History recapping

The current NFV reference architecture has experienced a decade of evolution. From the very beginning of NFV, an NFV architecture was specified for a virtualised network environment, with the target to de-couple software implementations of network functions from the computing, storage and networking resources that they use. The management and orchestration part of NFV architecture, NFV-MANO was composed of 3 functional blocks (i.e. the NFVO, VNFM and VIM), which managed different levels of abstraction used, namely abstraction of network services, virtualised network functions and virtualised infrastructure respectively. The initial NFV-MANO architecture established a management and orchestration framework for VM-based virtualisation. In Release 3, to support the extended operational scenario of managing network services across multiple NFVI-PoPs or across multiple administrative domains, the WIM functional block and the reference point between two NFVOs were introduced. In Release 4, several functions related to OS container management and orchestration were incorporated, such as the CISM, CIR and CCM, for the management of container based VNFs or network functions, in alignment with "cloud-native" design principles.

This constituted the functional view of the NFV architecture evolution as illustrated in figure 4.1-1 (derived from ETSI GS NFV 006 [i.2]). In Release 5, PIM was specified as a logical function within the NFV-MANO framework. For simplicity PIM is not shown in figure 4.1-1.

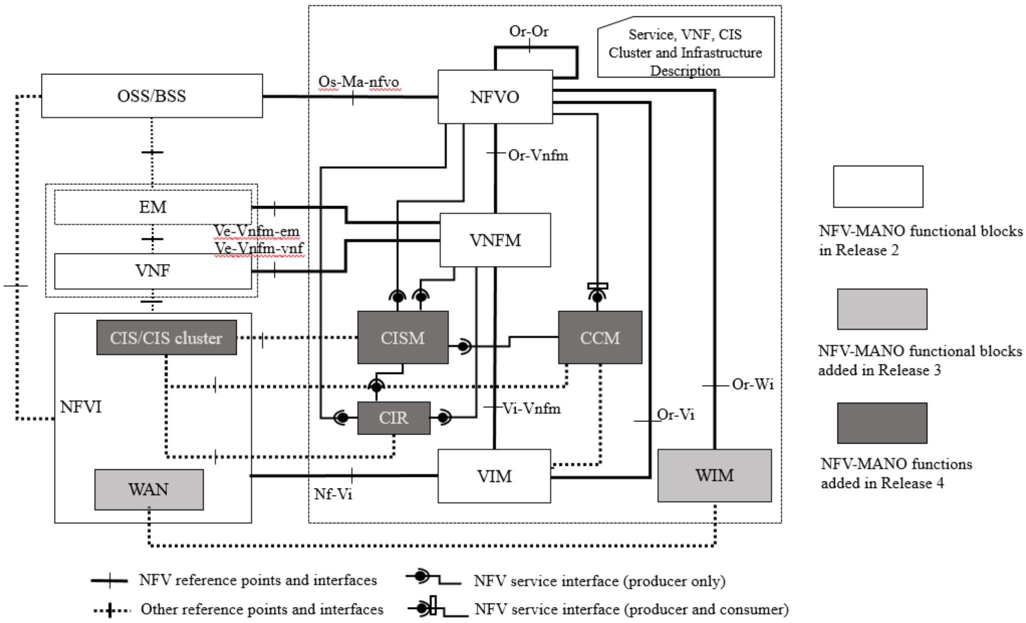

Figure 4.1-1: NFV reference architecture with support for containerized deployments

4.2 Future trends

The ETSI ISG NFV community has engaged in extensive exploration and discussion regarding the future evolution of NFV since 2022, targeting for enhancing the visions and blueprints for the development of NFV-based telecom cloud infrastructure over the next decade Telco Cloud. The outcome of the above work was reflected in the publication of two ETSI whitepapers in the first half of 2023: "Evolving NFV towards the next decade" [i.3] (focusing on future technology scenario trends from the ISG NFV community perspective) and "In the Light of Ten Years from the NFV Introductory Whitepaper" [i.4] (focusing on future business challenges and recommendations from the ISG operators' perspective). The future trends expected to happen in the NFV architectural framework are summarized as follows:

- Evolution of the NFVI. Driven by new Telco Cloud application scenarios, new requirements have been raised, for deploying diversified heterogeneous hardware in NFV system. Multiple innovative technologies related to heterogenous hardware, e.g. DPU, GPU, NPU, FPGA, AI ASIC, encrypted memory space or hypervisor partitioning are expected to be introduced in the NFVI framework. These technologies will enhance the current hypervisor-based or OS-based NFVI, and fulfil diversified telco-grade application requirements (regarding performance, security, reliability or integration) of new Telco Cloud applications, such as AI training, digital twin, high-speed video processing or network security. This is a technical trend of horizontally extending the NFVI physical resource (or hardware) layer by introducing new types of resources and is analysed in more details in ETSI GR NFV-EVE 023 [i.12].

- Evolution of the application virtualisation forms. The ETSI ISG NFV community believes that OS container virtualisation will not mark the end of the evolution of NFV technology. Other types of virtualisation technologies such as micro VMs, Kata containers and unikernels can complement VM-based and OS container-based solutions by combining the advantages of respective virtualisation technologies. Other virtualisation technologies such as WebAssembly (WASM) can be more portable and flexible than OS containers for edge device deployment. This technical trend is about horizontally or vertically extending the NFV virtualisation layer and is analysed in more details in ETSI GR NFV-EVE 025 [i.13].

- Evolution of the Telco Cloud applications. With the wide application of NFV technology in 4G and 5G networks, it is foreseen that the scale of NFV systems will gradually expanding, and more and more telco services or applications will be deployed on top of NFV systems. By adopting new types of infrastructure, virtualisation technologies, NFV systems will be increasingly attractive for emerging types of telco networks evolving towards evolved 5G. In the past releases, ISG NFV has studied the enhancements to NFV-MANO for supporting different types of networks (e.g. 5G, RAN, MEC) or new capabilities (e.g. network slicing). In the future, other new types of applications or services running on top of Telco Cloud are expected to be introduced in the framework, such as AI/ML applications, and other Telco Cloud services (learnt from widely used public cloud services). These changes will significantly increase the diversity of the NFV application ecosystem over the next decade. Some of these new scenarios are further studied in ETSI GR NFV-EVE 026 [i.14] which focuses on computing and network convergence and ETSI GR NFV-EVE 027 [i.15] which studies Model-as-a-Service (MaaS) in NFV.

- Evolution of automation and intelligence for NFV-MANO. Although NFV-MANO has been initially equipped with essential automation mechanisms, such as auto-scaling, auto-healing, or policy management, starting from Release 4, ETSI ISG NFV has consistently explored new mechanisms or technologies within the scope of autonomous networks. The goal is to gradually achieve higher levels of automation and intelligence for the entire NFV framework. Such efforts include but not are limited to, the study of DevOps, and the use of existing interfaces like for Intent driven Management/declarative interfaces or interfaces exposed by the MDAF. In the future, with the holistic enhancement of NFV end-to-end automation framework, Closed Loop Automation (CLA), Artificial Intelligence Operations (AIOps) and Machine Learning Operations (MLOps) technologies are expected to be also introduced to NFV-based Telco Cloud, to support automatic decision-making and optimization.

- Evolution of Telco Cloud deployment and coordination. NFV framework is designed to manage and control network functions. As service providers are getting more experienced with NFV practices, it becomes clear that NFV is rapidly being extended to support more use cases covering edge clouds. Edge clouds move down from the edge network to the access edge, ultra-edge or even terminal edge to ensure real-time applications performance such as industrial control applications and metaverse applications. Correspondingly, infrastructure resources expand from centralized deployment to a full and ubiquitous distributed network functions deployment considering various cloud locations such as central, regional and edge, while in some cases to extreme and far reach locations such as air and space. This will bring new requirements regarding the distribution of infrastructure, network connectivity, telecom networking and coordinated management and orchestration to achieve such a highly distributed infrastructure.

4.3 Problem statement

The current NFV architecture faces new challenges as NFV evolves to satisfy demanding and complex requirements from innovative scenarios driven by future trends. The future NFV architecture will no longer be designed as an architecture to support a single primary scenario (e.g. as NFV initially supported the virtualisation of network functions), but will instead serve as a unified architectural framework to manage an extensive and diverse set of Telco Cloud applications running on top of heterogenous cloud infrastructures. To adapt to this change, the present document focuses on key architectural aspects and provides corresponding standardization recommendations for a future-proof architecture:

- The gap between a complicated architecture due to addition of new functional blocks/functions, interfaces, and the operators' needs to reduce the complexity of system integration. Main concerns include but not be limited to: Facilitate the interaction between interface consumer and producer, avoid duplicated interface or descriptor information specification across multiple layers, identify interfaces where the NFV framework can bring additional value compared to other available de-facto standard solutions.
- A unified NFV architectural framework that is user friendly and adaptable to various future trends while supporting multi-vendor interoperability in an efficient and flexible manner. In this context, it is essential to consider the diversity of future NFVI, application virtualisation forms as well as Telco Cloud applications.
- Architectural elements of an NFV autonomous domain which supports advanced automation and intelligence, and capability of continuous improvement on automated decision-making and optimization.
- Trade-off factors to maintain backward compatibility of the architecture as NFV evolves, such as incorporating legacy NFV-supported functionalities within a unified framework.

5 NFV architectural targets related to future trends

5.1 Introduction

Clause 5 analyses several future trends as described in ETSI whitepaper "Evolving NFV towards the next decade" [i.3]. It studies their impacts on the current NFV architecture and identifies related architectural targets of NFV architecture to support the trends. Future trends to be studied with regard to their architectural aspects include:

- Diversified and heterogenous infrastructure

NOTE 1: Various types of new NFV infrastructure are studied in ETSI GR NFV-EVE 023 [i.12].

- Cloud technologies accommodating different types of virtualisation forms

NOTE 2: Various types of new virtualisation forms are studied in ETSI GR NFV-EVE 025 [i.13].

- New telco applications/services (rather than network functions) running on Telco Cloud infrastructure

NOTE 3: New types of Telco Cloud applications/services are studied in ETSI GR NFV-EVE 026 [i.14].

- Automation and intelligence in NFV-MANO

NOTE 4: Aspects of enabling Model-as-a-Service in NFV are studied in ETSI GR NFV-EVE 027 [i.15].

- Telco PaaS

NOTE 5: PaaS service management aspects and PaaS Services realizing VNF generic OAM functions are described in ETSI GS NFV-IFA 049 [i.7].

- Energy efficiency and carbon efficiency

NOTE 6: Scenarios for energy efficiency in NFV are studied in ETSI GR NFV-EVE 021 [i.18].

- Multi-tenancy

NOTE 7: Aspects regarding NFV elements consumed by different tenants are studied in ETSI GR NFV-EVE 018 [i.5].

5.2 Trends and respective architectural targets

5.2.1 Trend #1: Diversified and heterogeneous infrastructure

5.2.1.1 Description

The trend of diversified and heterogeneous infrastructure is described in clause 3.2 of ETSI whitepaper 2023 "Evolving NFV towards the next decade" [i.3]. Accordingly, ETSI GR NFV-EVE 023 [i.12] studies relevant NFVI use cases and targets to delineate a set of possible design options and potential solutions. The present document focuses on how potential functionality related to this trend can be integrated in the evolved architecture following the design principles described in the present document.

General background and features of this trend are summarized as follows, based on the descriptions in the ETSI whitepaper "Evolving NFV towards the next decade" [i.3]:

- Driven by new Telco Cloud applications with high-performance and low-cost deployment requirements, such as AI training, video processing and network security.
- In edge deployment scenarios, heterogeneous hardware resources allocated for edge node deployments, can be used to assemble lightweight NFVI edge nodes, and meet the requirements of different industries.
- Multi-level system architecture (NFV-MANO) covering hyper-distributed infrastructure resource pools, spanning from regional/central nodes to edge nodes.
- Heterogeneous hardware (mainly on compute resources) is used to flexibly process basic service and application workloads, such as big data analytics, network, storage and security data processing.
- Miscellaneous dataset types such as video, image, and audio bring requirements for diverse storage formats such as blocks, files, objects.
- Heterogeneous hardware (mainly on network resources) is used to offload virtual switch flow tables and support lossless network. For example, Infiniband (IB) and RDMA over Converged Ethernet (RoCE), are used to meet requirements of zero packet loss, high throughput, high bandwidth, stable low latency, and ultra-large-scale networking.
- Security related infrastructure elements, such as security monitor, encrypted memory space, trust status verification, hypervisor partitioning become additional key building blocks for addressing new challenging security requirements in NFV.

While several types of infrastructure are analysed in ETSI GR NFV-EVE 023 [i.12], the present document studies how a diversified infrastructure can lead to changes in the NFV architecture.

5.2.1.2 Targets from the trend

Physical Infrastructure Management (PIM) function specified in ETSI GS NFV-IFA 053 [i.6] is foreseen to have direct correlation with this trend. According to the ETSI whitepaper "Evolving NFV towards the next decade" [i.3], the NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- The PIM functionality needs to be extended to support heterogeneous hardware management.
- Unified management for heterogeneous hardware is achieved by establishing an abstract model of heterogeneous hardware, unifying infrastructure resource orchestration through standard APIs.

5.2.2 Trend #2: Cloud technologies accommodating different types of virtualisation forms

5.2.2.1 Description

The trend on cloud technologies accommodating different types of virtualisation forms is described in clauses 3.2 and 4.3 of ETSI whitepaper 2023 "Evolving NFV towards the next decade" [i.3]. Accordingly, ETSI GR NFV-EVE 025 [i.13] studies relevant use cases for new types of virtualisation forms and targets to delineate a set of possible design options and potential solutions. Referring to the whitepaper [i.3], general background and features of this trend are summarized as follows:

- With the evolution of virtualisation technology, additional virtualisation forms (e.g. micro VM, Kata Container, unikernel and WebAssembly) besides the current VM-based virtualisation and OS container virtualisation are introduced in NFV architecture.
- Different types of virtualisation forms have their own characteristics and degree of satisfaction of requirements for isolation, security, performance as well as flexibility, rapid deployment and efficient resource utilization.

While several types of new virtualisation forms are analysed in ETSI GR NFV-EVE 025 [i.13], the present document studies how the use of multiple new virtualisation forms can lead to changes in the NFV architecture.

5.2.2.2 Targets from the trend

Referring to ETSI whitepaper "Evolving NFV towards the next decade" [i.3], the NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- The current VNF modelling (e.g. VNFD) and NFV-MANO interfaces for supporting OS container and VM virtualisation (virtualisation technology independent) are expected to be extended to support new types of virtualisation forms. If possible a unified management model to support various types of virtualisation forms can be specified.

NOTE: Diverse and rapidly evolving open-source solutions might pose a risk to the ETSI NFV community in maintaining a unified management model for various forms of virtualisation.

5.2.3 Trend #3: New telco applications or services running on Telco Cloud infrastructure

5.2.3.1 Description

While the ETSI whitepaper "Evolving NFV towards the next decade" [i.3] briefly mentions new application scenarios as a driving factor for deploying diversified heterogeneous hardware in NFV systems, it provides limited details on new telco applications or services running on Telco Cloud infrastructure.

It is anticipated that at least two types of telco applications or services will evolve as mainstream applications, driven by the growing capabilities of Telco Cloud infrastructure:

- Compute-intensive or data-intensive applications, such as AI/ML model training and video processing;
- Cloud services, which learn best practices from public cloud services like IaaS, and provide the infrastructure service capability of Telco Cloud to the tenants. Infrastructure services provided by Telco Cloud includes not only the management of infrastructure resources (e.g. individual virtual machines or bare metal servers), but also the management of various infrastructure resource pools or groups (e.g. physical resource pools) composing the Telco Cloud. The management of infrastructure services can be based on multi-tenancy requirements (e.g. enterprise customers in business-to-business scenario), or for specific management purpose (e.g. supporting network slicing, or isolation among different vendors). Examples of infrastructure services include container as a service, IaaS, etc.

5.2.3.2 Targets from the trend

The NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- The hierarchy of abstracted NFV objects (NS and VNF) can be complemented by a flat structure of NFV objects (generalized) for managing new applications;

- For cloud services, besides the Lifecycle Management (LCM) and Operations, Administration and Management (OAM) related functionality, operations/business supporting functionality (e.g. billing, ordering) of cloud services are also addressed.

5.2.4 Trend #4: Automation and intelligence in NFV-MANO

5.2.4.1 Description

The trend of automation and intelligence in NFV-MANO is described in clause 4.5 of the ETSI whitepaper 2023 "Evolving NFV towards the next decade" [i.3]. According to the whitepaper, general background and features of this trend are summarized as follows:

- New automation methodologies like DevOps can be used to extend the support for automation in the NFV-MANO system, spanning from lifecycle management to service design, testing, fault management, and integration (also known as end-to-end automation).
- AIOps and MLOps can be applied to implement automatic decision making and optimization in end-to-end NFV automation scenarios. Automatic decision making is important for the following four areas:
  a) Intent-based network management can be used to facilitate how NFV-MANO understands service providers' requirements for the network, and translates them into network polices and actions.
  b) NFV will evolve to be capable to perform more proactive infrastructure fault management.
  c) AI-driven capacity planning and optimization will enable NFV-MANO to perform a more accurate orchestration and efficient use of the NFV infrastructure.
  d) AI technology will be used to assist in realizing the NFV unified management framework and optimize resource utilization through intelligent service scheduling.
- Digital twin technology can be used in conjunction with the NFV-MANO system, e.g. to simulate and verify network deployment scenarios.

5.2.4.2 Targets from the trend

The NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- Determine the logical relationship between AI functions and the current NFV-MANO functionality, such as NS or VNF management. The relationship might include, on the one hand, AI support for cloud applications, such as AI functions providing intelligent analytics outputs to NFV-MANO for guiding more efficient NS lifecycle management. On the other hand, cloud support for AI, such as NFV-MANO providing high-precision, fine-semantics and cross-level correlated datasets to AI functions for training models.
- Determine how to integrate AI functions as well as other automation functions (e.g. intent management, or policy management) into the NFV architectural framework in a consistent way, and guarantee the smooth evolution of the architecture.
- Determine how to use new technologies like the digital twin technology to support enhanced automation and intelligence in the NFV architectural framework.

5.2.5 Trend #5: Telco PaaS

5.2.5.1 Description

Telco Platform as a Service (PaaS) is about the cloud computing service model that provides a platform enabling telecommunication service providers to support the management of applications without having to consider the complexity of the underlying infrastructure. Telco PaaS Services can be related to networking, communications APIs, OAM applications development, or other functionalities tailored to the telco industry.

Examples of Telco PaaS capabilities are about support for multiple IaaS platforms, integration with CI/CD tools, application development and deployment facilitating close interaction with Kubernetes® for workload management, application testing and build of container images.

In the context of ETSI NFV, PaaS service management aspects and PaaS Services realizing VNF generic OAM functions are described in ETSI GS NFV-IFA 049 [i.7].

5.2.5.2 Targets from the trend

The NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- Determine the relationship between NFV management and orchestration functionality and PaaS:
  a) from the perspective of NFV-MANO functionality, NFV-MANO can potentially be realized as one or more PaaS Services; and
  b) from a management perspective, NFV-MANO can orchestrate and manage PaaS Services that are closely related to the VNF/NS being deployed and operated.
- Determine the best practices and benefits of using PaaS for enhancing the capabilities and functionality of NFV-MANO.
- Determine how PaaS can contribute to an improved design of VNFs.

5.2.6 Trend #6: Energy efficiency and carbon efficiency

5.2.6.1 Description

The trend on energy efficiency is described in ETSI whitepaper 2023 "In the Light of Ten Years from the NFV Introductory Whitepaper" [i.4]. Accordingly, ETSI GR NFV-EVE 021 [i.18] studies relevant NFV framework use cases and targets to delineate a set of possible design options and potential solutions. The present document focuses on how potential functionality related to this trend can be integrated in a target architecture following the design principles of the present document.

Another important concept related to energy efficiency trend is carbon efficiency. Generally speaking, carbon efficiency refers to the measure of how effectively and efficiently carbon emissions are managed and reduced in relation to a specific activity, process or system. The goal of carbon efficiency is to minimize the carbon footprint, with the measures to empower green compute, storage and network infrastructure, and ultimately maximizing resource utilization and leading to a more sustainable and environmentally friendly operation. In the context of NFV evolution, the carbon efficiency measurements, evaluation, and empowerment of energy saving technologies related to carbon footprint in the lifecycle of a Telco Cloud platform or infrastructure system are future directions of research.

General background and features of this trend are summarized as follows:

- The discovery, collection and use of power consumption information from physical resources in the NFVI.
- The discovery, collection and use of information about the power state of physical resources zones and pools in the NFVI.
- The collection of measurements related to energy metrics associated to all the NFV managed objects.
- Processing power mode switching based on the actual traffic and capacity demands.
- The discovery, collection and use of carbon efficiency characteristic information in the NFV architectural framework, such as physical resources, VNFs and MANO components.
- Measurements of the correlation and transformation of carbon efficiency and energy efficiency brought by new energy-saving technologies.
- A collection of measurements related to carbon efficiency in respect to NFV managed objects, evaluation and empowerment of energy saving technologies.
- Precise resource allocation that effectively reduce the carbon footprint of the NFV architecture.

5.2.6.2 Targets from the trend

ETSI GR NFV-EVE 021 [i.18] is anticipated to have direct correlation with this trend. The NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- Extending the support for power management and energy efficiency for NFV managed objects.
- Support smart energy usage and decision making in NFV considering NFV capabilities such as advanced orchestration and automation.
- Extending the support for carbon footprint management of NFV managed objects, to enable service providers to evaluate and improve carbon efficiency.
- Improving NFV orchestration and automation functionality, to achieve automatic measurement and assessment decisions of carbon footprints in NFV, by using energy-saving policies, new energy-saving technologies and renewable energy.

5.2.7 Trend #7: Multi-tenancy

5.2.7.1 Description

Future networks will host services from different consumers in parallel, such as by vertical industries. This trend is about capabilities to manage and run those services in a way where they do not interfere with each other. One of the main capabilities supporting this trend is related to multi-tenancy. Accordingly, ETSI GR NFV-EVE 018 [i.5] studies in detail requirements regarding NFV elements consumed by different tenants and delineates a set of possible design options and potential solutions. The present document focuses on how potential functionality related to this trend can be integrated in a target architecture following the design principles of the present document.

General background and features of this trend are summarized as follows:

- Tenant-aware load balancing.
- Tenant-aware traffic handling.
- Tenant isolation.

ETSI GR NFV-EVE 018 [i.5] provides an analysis of multi-tenancy support in NFV architecture and related recommendations to address the gaps identified.

5.2.7.2 Targets from the trend

ETSI GR NFV-EVE 018 [i.5] investigates topics related to this trend. The NFV architectural framework needs to accomplish the following architectural targets in fulfilling this trend:

- Tenant-aware LCM.
- Tenant-aware resource management.
- Traffic separation.
- Management isolation.
- Tenant quota.

6 Key architectural principles in NFV evolution

6.1 Introduction

Architectural principles to support NFV evolution are elaborated in clause 6, and associated architectural goals to apply respective principle are also analysed.

6.2 Simplification

6.2.1 Description

The current NFV architecture as specified in ETSI GS NFV 006 [i.2] has evolved through multiple Releases, each introducing new functionality and new NFV-MANO functional blocks and functions and associated interactions. These changes have also been reflected in updates to the architectural framework diagram, and overtime, the diagram has become increasingly complex and difficult to follow.

As NFV evolves to support new trends such as diversified and heterogeneous infrastructure, multi-cloud or hybrid cloud accommodating different types of virtualisation forms, or new telco applications running on Telco Cloud infrastructure, it is foreseen that the functionality of NFV-MANO will expand further. This expansion might result in increased NFV-MANO architectural complexity. When implementing the NFV-MANO architectural framework (e.g. as a software system), complexity can be reflected in two key aspects:

- The number of functional components to construct an NFV-MANO system is large.
- The interactions among these functional components are more complex.

Architectural complexity results in the following critical issues for the target system implemented based on the architecture:

- Modifications to a single functional component might affect all of its associated components.
- Root cause analysis in a complex system usually is more challenging than in a simpler system.

For a future NFV-MANO design to be implemented as a software system, its architectural complexity extends beyond it is in the design phase, and becomes more pronounced after it is deployed and put into use. Architectural complexity has a great impact on the entire lifecycle of the system, since new requirements are continuously introduced, and the software system might need to be constantly modified. Therefore, it is a natural principle for an NFV-MANO system to adopt a simplified architecture to meet the growing future demands.

6.2.2 Associated architectural goals to apply the principle

6.2.2.1 Future NFV-MANO, a more declarative system

With regards to applying "simplification" principle to a target architecture, an NFV-MANO system (i.e. a system's implementation is correspondent to NFV-MANO architecture) for fulfilling the future trends of NFV evolution, is foreseen to be a more declarative system. "Declarative" or "imperative" is mainly the goal of a management system following certain architectural principles. A declarative system focuses on "what to do" while an imperative system focuses on "how to do". Accordingly, the APIs a management system exposes are declarative or imperative in nature.

The current APIs exposed by NFV-MANO functional entities are more imperative, except that the CISM exposes declarative interfaces when profiling Kubernetes Declarative Management APIs (e.g. using Kubernetes method kubectl apply). For example, for NS or VNF lifecycle management operations, each API has its specific endpoints for granular operations like instantiation, scaling or healing. For policy management, the APIs exhibit the actions of transfer, delete, activate and deactivate, which need to be further combined by the API consumer for fulfilling a certain objective.

For declarative APIs, on the contrary, the API consumer provides the desired state of a system or object that it wants the API producer to achieve, and leaves the implementation on how to achieve the desired state to the API producer. Declarative APIs help to move the complexity of an interface operation implementation from the API consumer to the API producer, and can be regarded as an effective way to simplify the interactions between the API consumer and API producer. Following a more declarative management paradigm, the current NFV-MANO APIs can become simpler in design, potentially not needing some of the granular imperative operations supported by additional API endpoints.

The future NFV-MANO system can be envisioned to perform management of NFV objects in a more declarative way, e.g. by adopting more declarative APIs in fulfilling the future trends. However, imperative APIs still play their unique role of effectiveness in certain scenarios, such as only creating new objects and not keeping these objects in synchronization after the creation (seldom update), or just updating a single attribute of an object. A good target NFV architecture during its evolution needs to take the strength of declarative APIs and imperative APIs into account, and adopt API solutions to fit in with their appropriate scenarios.

6.2.2.2 Architectural view hierarchy

One aspect of the current NFV architecture's complexity is related to the fact that a single NFV-MANO architectural diagram is used to fulfil all the use cases addressed when NFV-MANO solutions are considered. The detailed and complex functional structure of NFV-MANO could cause an actor to lose his focus when developing a solution for a certain use case by referencing NFV-MANO architecture. When more functional entities are accommodated in NFV-MANO considering the future trends, this phenomenon will be more evident.

Although a simplified architectural diagram might be advantageous for certain stakeholders, it could present a challenge for others. For example, an OSS developer only needs an abstract view of NFV-MANO and which external interfaces are supported by NFV-MANO, but a developer of a function within NFV-MANO will need to know which interfaces are provided and consumed by each NFV-MANO function. Therefore, multiple architectural diagrams might be needed to satisfy the needs of different actors.

A goal to apply "simplification" principle in this context, is to provide a hierarchical set of NFV architecture diagrams:

- The top level NFV architectural view can provide architectural elements with the highest abstraction level in NFV architecture, e.g. NFVI, MANO and network elements or applications deployed on top of certain virtualisation technology.
- In the lower level of architectural view, specific architectural elements are introduced and specified as the unfolding elements of the element in the top-level view. These are used to fulfil the functionality required for a certain use case, e.g. using the NFVO, VNFM and VIM as unfolding elements of MANO for managing VM based VNFs, and using the NFVO, VNFM and CISM as unfolding elements of MANO for managing containerized VNFs.

6.2.2.3 Simplifying open-source integration complexity

NFV standards are developed considering open-source solutions but also beyond them. To apply simplification principle for the future NFV architecture, it is necessary to handle in an efficient way the relationship between NFV and open source in respect to functionalities which are integrated in the framework that are able to fulfil new trends in a unified architectural framework.

In the current NFV architecture, the NFVO or VNFM communicates with other management functional entities (e.g. the CISM or VIM) by adopting the open-source de-facto standard solutions. From Release 4 and beyond, for the CISM and CCM interfaces specification, ETSI NFV has adopted a new service interface specification approach, which aims at profiling ETSI specified service interface requirements to respective de-facto APIs such as Kubernetes, Helm Chart.

For the new functionality that is able to fulfil future trends in NFV-MANO, continuing to use this profiling approach in handling the relationship between ETSI specified NFV standards and open-source de-facto standards remains a valid goal in respect to applying simplification principle. From the viewpoint of ETSI specified management interfaces on abstracted NFV objects, profiling open-source de-facto APIs provides a feasible method for open-source de-facto solutions to be integrated into NFV-MANO, in respect of domain-specific requirements for the Telco Cloud.

6.2.2.4 Improved modular design

Modular design is a software design pattern that involves breaking a complex software system into smaller and independent parts, called modules. Each module is designed to perform a specific task and can be used as a building block for creating larger systems. Modular design brings some benefits for software development, including future forward compatibility, improved maintainability, reusability and scalability.

- Future forward compatibility: As technology changes, modules can be replaced to implement new technologies without impacts on the rest of the system.
- Reusability: Modules can be reused by different consumer functions, making the development process faster and more efficient.
- Easy maintenance: Modules are independent, making it easier to maintain and update the code. If an error is found in one module, it can be fixed without affecting the rest of the system.
- Scalability: Modules are added or removed as needed, making it easier to scale the system as requirements change.

NFV-MANO initially targeted a component design approach, by decomposing the functionality of NFV-MANO into independent components. Each component is responsible for specific functionality with defined interfaces between components, making NFV-MANO easier to understand, maintain and expand. However, the current NFV-MANO component-based approach specified in ETSI NFV standards, components have strong dependencies to each other. For example, if containerized VNF deployment is to be deployed, both the VNFM and NFVO need to be synchronously upgraded. The VNFM is enhanced with the lifecycle management of containerized VNF, and the NFVO needs to grant resources and control capacity for the containerized VNF. Synchronous upgrade reflects some extent of dependencies between the NFVO and VNFM. Another example is, when the NFVO communicates with the NFV infrastructure, it exchanges messages with different infrastructure management functional entities (e.g. the CISM, VIM or PIM) by using different set of interface operations. This is because the CISM, VIM and PIM were designed as independent modules in NFVI management. Considering this, there are opportunities for endorsing modular design principles in the NFV-MANO design.

6.2.2.5 Services-driven architecture

Simplification of the architecture can also be achieved by focusing on the actual capabilities that the architecture is expected to produce both internally (among components comprising the management and orchestration system) and externally (to external consumers). Services can be of different granularity depending on the level of dependency to system capabilities. The less a capability depends on other capabilities, the more such capability can be regarded as an independent service.

Service-based architectures are an industry trend in the telco domain; however, implementation assumptions tend to drive the specification of the architecture by assuming specific service bus technologies, resulting to an architecture design which is implementation depended. That is, services are defined in a way that mimic the actual possible implementation of the system, based on the industry trend around the concept of micro-services while in parallel additional goals are to improve the Continuous Integration/Continuous Delivery (CI/CD) and maintenance procedures.

A goal to apply "simplification" principle is to understand the management and orchestration architecture from a service-based perspective from consumers point of view. By applying this principle:

- Independent services are used to "build" the architecture, following a loosely coupled relationship between components exposing the services and avoiding complex interactions among the components composing the management and orchestration system.
- The architecture defines clear responsibilities and management scopes, of the specified services. Services do not duplicate capabilities/responsibilities.
- Clear boundaries between operating support systems for network functions, cloud platform and the network can be determined.

NOTE: This principle does not make any assumption on how the services or consumers and services might interact, either based on message buses or by other means mimicking more point-to-point interactions, as these are regarded to be more an implementation matter.

6.3 Evolution

6.3.1 Description

NFV architecture supporting the management of Telco Clouds needs to follow the architectural principle of evolution. No matter what new advanced trends are to be supported by the NFV architecture, the objectives related to additional functionality to be supported could be achieved "step by step" instead of "in one step", by inheriting legacy functionality (e.g. preserving the outstanding design ideas, functional logic of the existing functions in the architecture, as well as identifying lessons learnt from best practices). Based on this, the NFV architecture can be iteratively improved to better adapt to the ongoing changes and developments to support future Telco Cloud management requirements.

The following procedures can be followed for the design of the architecture of a software system following the evolution principle:

- Firstly, the designed architecture should meet the business requirements at that time.

- Secondly, the architecture is continuously refined during the actual application process, preserving effective designs, addressing flaws, correcting design errors, and deprecating outdated functionalities, so that the architecture improves over time.
- Thirdly, when the business logic changes or develops, the architecture needs to be extended or redesigned. From an implementation perspective, the code might be updated, but valuable experience, lessons, logic, design can be reused in the new architecture.

6.3.2 Associated architectural goals to apply the principle

6.3.2.1 Backward compatibility

Backward compatibility is a basic and important architectural goal to achieve when telco networks evolve. According to Wikipedia® definition in [i.8], backward compatibility is a property of an operating system, software, real-world product, or technology that allows for interoperability with an older legacy system, or with input designed for such a system, especially in telecommunications and computing.

In the context of NFV evolution, backward compatibility has two levels of semantics:

- Architectural level, which focuses on how does a future-proof NFV architecture consistently include and work with older legacy functions, such as keeping VM based VNF management in case that OS container-based virtualisation is introduced in NFV-MANO, or keeping virtualised resource management in case that the NFVI management is extended to include more physical resources or bare-metal servers. In some other words, the legacy VNFs or legacy OSS/BSS can interact with NFV-MANO during NFV evolution.
- Interface level, which focuses on how a new format of APIs works with a legacy format of APIs in the architecture, such as connecting the NFVO produced intent-based APIs (northbound) with the NFVO invoked imperative APIs (southbound) in an end-to-end NS lifecycle management scenario.

6.3.2.2 High extensibility

Extensibility includes several characteristics related to the maintainability of a software system. The level of extensibility (e.g. from low extensibility to high extensibility) indicates how easy it is to extend or enhance the software system. Software systems that are designed to be extensible take future growth into account by anticipating the need to incorporate new functionality.

A future-proof NFV-MANO system is expected to support high extensibility, with accommodating new management functionality to fulfil the future NFV trends in a smooth and flexible way. This might include the targets to refine the functional layout in NFV-MANO, distribute functions into multiple functional categories, and evolve the functionality in each category independently from each other. The design of high extensibility for the NFV architecture also needs to ensure that the integration complexity of the NFV-MANO system remains in a reasonable range.

6.4 Federation

6.4.1 Description

Scalability in large deployments usually leads to a performance bottleneck when one function is responsible for a global view of the whole network. In difference to that, the Internet for example has no central authority but applies a decentralized way following the federation principle where each component interacts with its peers to make decisions. NFV-MANO when acting according to federation principles can interact with a peer NFV-MANO to find the best deployment options for the workloads running on the distributed Telco Cloud.

Following the principle of federation, an NFV-MANO can share information with peer NFV-MANO instances instead of obeying hierarchical invocations. In case it is part of a large, distributed infrastructure resource management environment, e.g. in multi-clouds or hybrid cloud, using a central instance or the OSS can easily become a bottleneck and/or a single point of failure.

The current concept of administrative domains (see ETSI GS NFV-IFA 030 [i.17]) defines the Or-Or reference point and LCM operations to manage nested NSs as specified in the NSD of a nesting NS. It is however not specified, how peer NFVOs (e.g. an NFVO-N that manages a nested NS instance) are identified. Following a federation architectural principle, an NFVO can discover capabilities of peer NFVOs. The selection of a peer NFVO, that can act as NFVO-N can be moved from the OSS to NFV-MANO.

EXAMPLE: An edge network can span many different NFVI-PoPs, hosting many VNF and NS instances managed by different NFVOs. Thus, the network is structured as multiple administrative domains, each with its NFVO. Each NFVO can interface with peer NFVOs of neighbouring (and possibly overlapping) geographical areas. When NSs and VNFs are deployed in a defined geographical area, or during scaling, the NFVOs serving the area can select the best way to deploy the service instances for example based on acceptable latency criteria.

6.4.2 Associated architectural goals to apply the principle

The "federation" principle might impact on the interactions between peer NFV-MANO components (e.g. the NFVOs) in a distributed Telco Cloud environment, in which NFV-MANO components perform autonomous decision making. This principle does not derive any architectural goal at the functional level, which is the main focus of the present document.

7 Architectural solutions and potential enhancements

7.1 Introduction

Clause 7 proposes specific architectural solutions addressing one or more future trends of NFV evolution as introduced in the previous clauses, while applying appropriate architectural principles and their respective goals in formulating the architectural solutions. A target architectural solution for NFV evolution is therefore derived from the analysis of specific architectural solutions. The solutions focus principally on the architectural changes or improvements for NFV-MANO, but not only. Functional requirements (or recommendations) to interfaces or NFV descriptors to fulfil these architectural changes are out of the scope of the present document.

Architectural goals related to simplification (reducing the interoperability complexity) and evolution (increasing new trends and functionality that an architectural framework supports) might lead to different conflicting requirements on the target architecture. Architectural solutions to achieve these architectural goals can take necessary trade-offs points into account to accommodate the above-mentioned contradictions.

7.2 Specific architectural solutions

7.2.1 Solution #1: Expanding NFV-MANO's scope to Telco Cloud management

7.2.1.1 Description

Following the architectural goal of "architectural view hierarchy", as described in clauses 6.2.2.2 and 7.2.1, proposes an architectural solution for future Telco Cloud management, which considers unfolding different architectural views, namely referred as Level 0, Level 1 and Level 2, to fulfil the future trends described in clause 5.

7.2.1.2 Level 0 abstracted conceptual view

Learnt from the high-level NFV architectural framework as depicted in clause 5.2 of ETSI GS NFV 002 [i.9], an abstracted NFV conceptual view consists of three architectural elements: NFVI, VNF and NFV-MANO, as shown in figure 7.2.1.2-1.

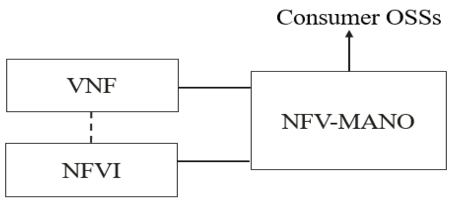

Figure 7.2.1.2-1: High-level architectural elements in NFV architectural framework

With the NFV evolution to fulfil increasing future trends as described in clause 5 of the present document, the depicted high-level architectural elements and their interoperability in NFV architectural framework could be kept unchanged, and be further filled in with new or enhanced functionality. To more accurately reflect the scope that the future NFV architectural framework targets to support, the Level 0 abstracted conceptual view for NFV based Telco Cloud management might be adapted as in figure 7.2.1.2-2. The northbound Telco Cloud MANO (TC-MANO) consumers include not only the OSSs which consume the management of NSs and VNFs, but also the BSSs and enterprise portals of self-services which consume the Telco Cloud management services provided by Telco Cloud MANO.

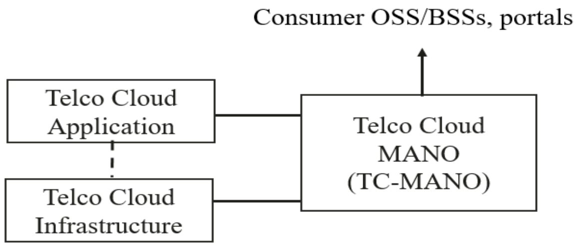

Figure 7.2.1.2-2: Level 0 abstracted conceptual view for Telco Cloud framework

The composition of the Telco Cloud framework is as follows:

- Telco Cloud Infrastructure, which represents a set of infrastructure resources and services, including the diversity of physical resources, virtualisation-specific infrastructure services such as virtual machines or OS containers, and Telco PaaS services in the Telco Cloud environment, fulfilling telco-grade requirements on networking, performance, reliability, security and O&M. Telco Cloud Infrastructure supports the execution of Telco Cloud Applications.

- Telco Cloud Application, which covers diverse applications (e.g. network functions/services as telco network applications, 3rd party applications, or Telco Cloud services) running over Telco Cloud Infrastructure.

- Telco Cloud MANO (TC-MANO), which is responsible for the orchestration, lifecycle management as well as FCAPS management (also known as Operations, Administration and Management, OAM) of infrastructure resources/services and Telco Cloud applications. TC-MANO focuses on all virtualisation-specific management tasks for Telco Cloud applications.

7.2.1.3 Level 1 unfolded-MANO architectural view

Derived from Level 0 abstracted conceptual view in clause 7.2.1.2, the architectural element Telco Cloud MANO can be further unfolded to formulate Level 1 architectural view for Telco Cloud management, as depicted in figure 7.2.1.3-1.

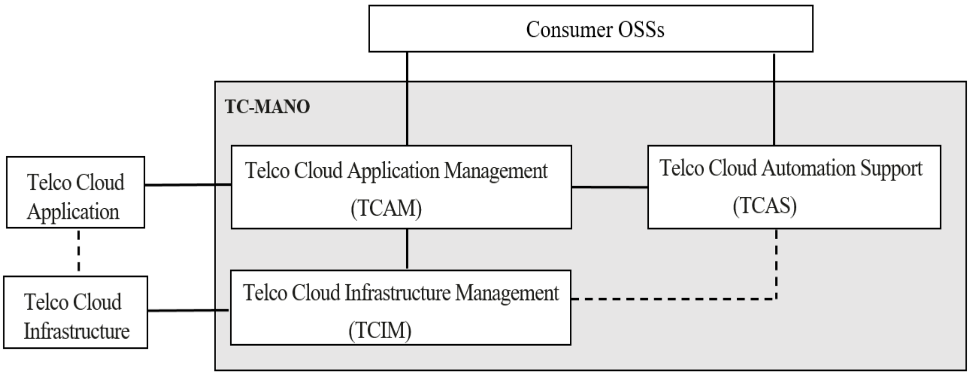

Figure 7.2.1.3-1: Level 1 unfolded-MANO architectural view for Telco Cloud management

In Level 1 architectural view, TC-MANO is unfolded to the following logical functions: Telco Cloud Application Management (TCAM), Telco Cloud Infrastructure Management (TCIM) and Telco Cloud Automation Support (TCAS):

- Telco Cloud Application Management (TCAM) is responsible for the lifecycle management and FCAPS management of Telco Cloud applications.
- Telco Cloud Infrastructure Management (TCIM) is responsible for the lifecycle management and FCAPS management of Telco Cloud infrastructure resources or services.
- Telco Cloud Automation Support (TCAS) is responsible for autonomous management related functionality to improve the automation of management processes in the scope of TC-MANO.

Within the scope of TC-MANO, both the TCAM and TCAS produce their management services to the external Consumer OSSs. The TCAS consumes the services produced by the TCAM, and the TCAM consumes the services produced by the TCIM. The TCAS can interact with the TCIM directly (by consuming the services produced by the TCIM), or interact with the TCIM indirectly (in which the TCAM serves as a proxy function to transmit the messages between the TCAS and TCIM). Which specific scenario regarding the TCAS interaction with the TCIM applies is expected to be defined through operational and network operator deployment policies.

7.2.1.4 Level 2 architectural solutions

7.2.1.4.1 Introduction

Each of the Level 2 architectural solutions introduced in clause 7.2.1.4 expands upon Level 1 architectural elements with more details, to illustrate how a dedicated Level 2 architectural solution fulfils one or more future trends in clause 5. Evolution architectural principles are also considered in describing Level 2 architectural solutions, which evolve the future architectural changes from the current NFV architecture specified in ETSI GS NFV 006 [i.2].

7.2.1.4.2 Level 2 baseline: Mapping current NFV architecture to Level 1 architectural view

As a starting point to expand Level 1 architectural view to fine-grained Level 2 scenario-specific architectural solutions, it is helpful to firstly study how the current NFV architecture supporting container-based VNF management (as depicted in figure 5.2-3 of ETSI GS NFV 006 [i.2]) can be embedded in Level 1 architectural view, as shown in figure 7.2.1.4.2-1.

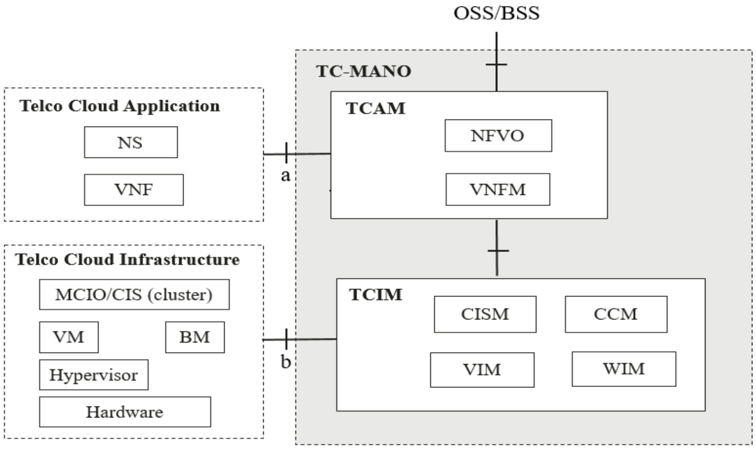

Figure 7.2.1.4.2-1: Mapping container-based VNF management NFV-MANO to Level 1 architectural view

In figure 7.2.1.4.2-1, Telco Cloud Application includes two hierarchical NFV managed objects: NS, VNF. On the right side of the same figure, concerning to the management plane (TC-MANO), respective layering TC-MANO functions (or functional blocks) are equipped to manage the hierarchical NFV managed objects, in a similar way as the NFVO manages NSs, and the VNFM manages VNFs with regards to the present NFV-MANO architecture. Interfaces tagged by "a" in a horizontal direction represents collective functionalities in the TCAM related to its managed application-related entities. In the underlying Telco Cloud Infrastructure element, the infrastructure functional components (e.g. Hypervisor, CIS) or objects (e.g. MCIO, VM) are also organized in a hierarchical way, and management functions (or functional blocks) in the TCIM produce collective functionality to communicate with their respective infrastructure components, or manage their respective infrastructure resource objects. Interfaces tagged by "b" in a horizontal direction represents the functionalities in the TCIM related to its managed infrastructure-related entities.

In the vertical direction, the two logical functions TCAM and TCIM within TC-MANO, both expose interfaces to their northbound consumers. Inside the TCAM and TCIM, respective NFV-MANO functional blocks or functions are included, e.g. the TCAM consists of the NFVO and VNFM.

A mapping of existing automation functions in the NFV-MANO with TC-MANO Level 2 solutions is provided in clause 7.2.1.4.4.

Another example of Level 2 architectural solution, is to map VM based VNF management NFV-MANO to Level 1 architectural view, as shown in figure 7.2.1.4.2-2.

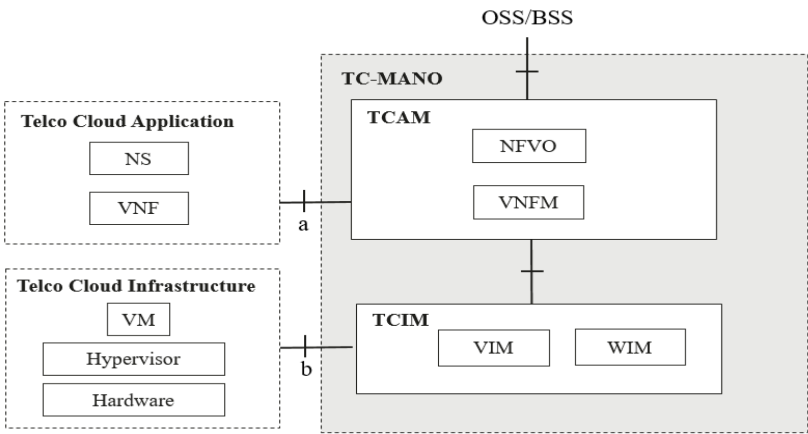

Figure 7.2.1.4.2-2: Mapping VM based VNF management NFV-MANO to Level 1 architectural view

NOTE: Although the PIM is not shown in figures 7.2.1.4.2-1 and 7.2.1.4.2-2, the PIM is one functional component in the TCIM. Both figures refer only to functional components specified in the referred ETSI GS NFV 006 [i.2] of Release 5 to create the baseline Level 2 architectural views of Telco Cloud management to further accommodate functionality brought by new trends in clause 5.

7.2.1.4.3 Telco Cloud management supporting 5G-Advanced and beyond 5G networks

As part of the broader industry's evolution of mobile networks towards 5G-Advanced and beyond 5G networks, the present solution conceives extending the concept of "VNF" to cover additional virtualisation technologies, like the notation "xNF", in which "x" represents one kind of virtualisation technology, such as "C" can be used to represent OS container-based virtualisation, or "W" to represent WASM.

To adapt to the above future trends, one basic Level 2 architectural solution for Telco Cloud is depicted in figure 7.2.1.4.3-1.

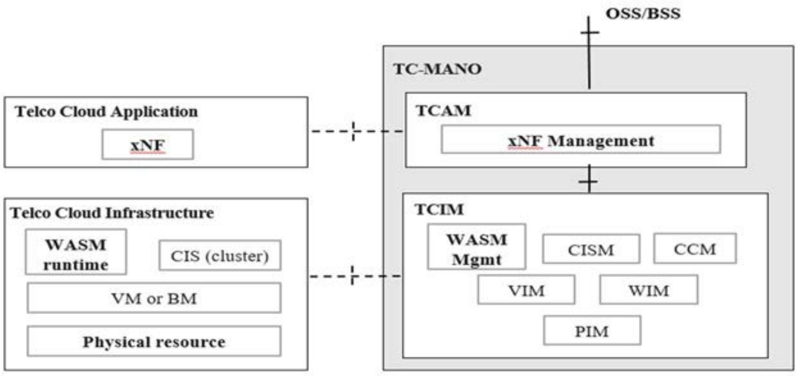

Figure 7.2.1.4.3-1: Basic Level 2 architectural solution for Telco Cloud supporting 5G evolution

In figure 7.2.1.4.3-1, Telco Cloud Application includes one or more kinds of network functions implemented by different virtualisation technologies. For example, "VNF" is a kind of network function deployed in the form of virtual machines, "CNF" (also known as Container-Based VNF according to ETSI NFV specifications) is a kind of network function deployed in the form of OS containers. When a new virtualisation technology is introduced in the Telco Cloud, corresponding "xNF" represents a kind of network function implemented by this virtualisation technology.

NOTE: In the present Level 2 architectural solution, the NFV concepts of "NS" or "PaaS services" are not the focus of the present Level 2 architectural solution, and therefore not represented or further described in the present solution. For further analysis refer to clause 7.4.

Telco Cloud Infrastructure is enhanced with the runtime binary processes of the new virtualisation technologies under consideration. In figure 7.2.1.4.3-1, WASM runtime is explicitly depicted, which is one example that fulfils this purpose. Runtime process from other virtualisation technologies such as CIS is placed in Telco Cloud Infrastructure to maintain backward compatibility. In the physical resource layer, new formats of infrastructure resources such as heterogenous computing resources of GPU or DPU are introduced, which work together with CPU to fulfil customized resource requirements from xNFs.

In the TC-MANO framework, logical functions can be improved or selectively used for providing the solution for a dedicated xNF management scenario. In figure 7.2.1.4.3-1, the TCAM is composed of xNF Management, which is responsible for the management of lifecycle and FCAPS aspects related to xNF. The TCIM is further enhanced with WASM management, in case that WASM runtime is newly introduced to Telco Cloud Infrastructure as a new virtualisation form. In a specific deployment scenario, TCIM functions responsible for managing infrastructure services related to other virtualisation technologies, e.g. the CISM and CCM, might not be considered, if the purpose is to only support the management of WASM applications.

Future trends #1, #2, #3 in clause 5 are expected to be addressed by the Level 2 architectural solution described in the present clause.

7.2.1.4.4 Telco Cloud Operations and Maintenance (O&M) automation

As described in trend #4, the evolution of telco networks and their further disaggregation is likely to extend autonomous management requirements for Telco Cloud Operations and Maintenance (O&M). Based on the functionality of the MDAF and Intent Management (IM) as specified in NFV Release 4 feature work, a Level 2 architectural solution for Telco Cloud O&M automation is depicted in figure 7.2.1.4.4-1.

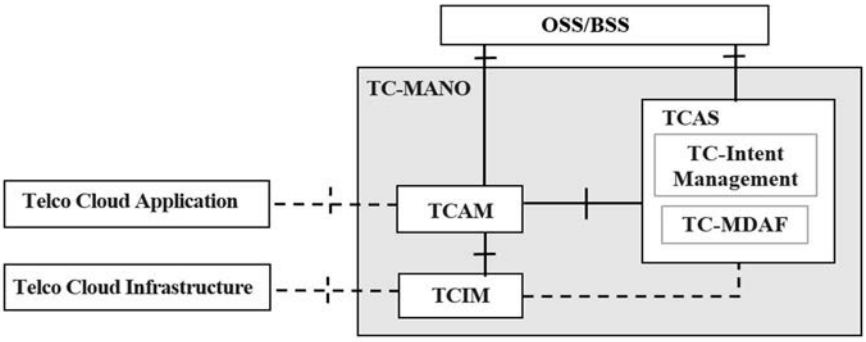

Figure 7.2.1.4.4-1: Level 2 architectural solution for Telco Cloud O&M automation

In figure 7.2.1.4.4-1, Telco Cloud Application, Telco Cloud Infrastructure, as well as the TCAM and TCIM within the TC-MANO are depicted as a whole without exhibiting their internal composition. A new architectural element of Telco Cloud Automation Support (TCAS) is introduced in TC-MANO, which contains the autonomous management functionality in respect to TC-MDAF and TC-Intent Management, considering the so far related specification work in ETSI NFV. The TCAS produces autonomous management and orchestration related services to the OSS/BSS, and it consumes the management services produced by the TCAM. In addition, the TCAS consumes the services produced by the TCIM directly, or interacts with the TCIM indirectly (through the TCAM), which depends on the specific scenarios that the TCAS interacts with the TCIM (see also relevant description in clause 7.2.1.3).

NOTE 1: To distinguish the similar concepts of MDAF/MDAS and Intent Management between 3GPP and ETSI NFV specifications, the MDAF and Intent Management specified in ETSI NFV are renamed (with a prefix of Telco Cloud) to TC-MDAF and TC-Intent Management respectively.

NOTE 2: Within the scope of NFV-MANO functionality specified until Release 5, the functionality of TC-Intent Management and TC-MDAF is accommodated in the TCAS. It does not preclude any new autonomous management related functionality from Release 6 or onwards versions to be added in the TCAS.

Future trends #4 in clause 5 are expected to be addressed by the Level 2 architectural solution described in the present clause.

7.2.1.4.5 Telco Cloud infrastructure service management

Telco Cloud infrastructure service management supports scenarios of Telco Cloud service provisioning and management, based on the infrastructure resource management capabilities produced by the functional entities within the TCIM. A Level 2 architectural solution for Telco Cloud infrastructure service management is depicted in figure 7.2.1.4.5-1.

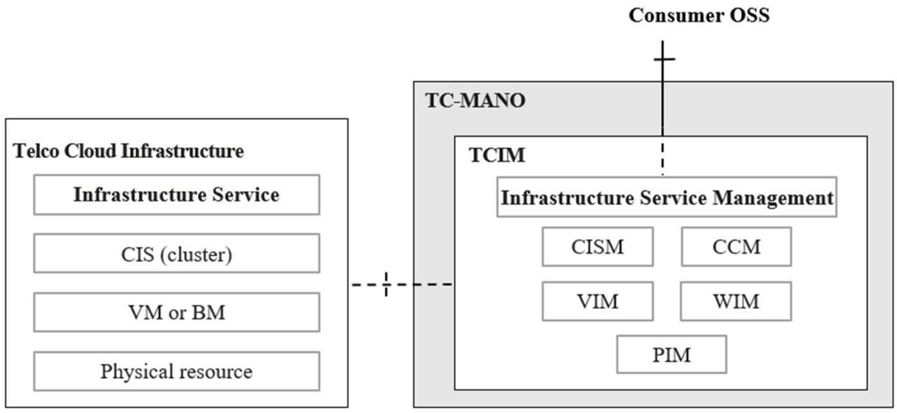

Figure 7.2.1.4.5-1: Level 2 architectural solution for Telco Cloud infrastructure service management

In figure 7.2.1.4.5-1, Telco Cloud Infrastructure and the TCIM in the scope of TC-MANO have the similar functionality composition as in the architectural solution for Telco Cloud 5G-Advanced and beyond 5G networks. Infrastructure service is newly introduced in Telco Cloud Infrastructure and represents the capability of the Telco Cloud Infrastructure to provide additional infrastructure services leveraging the different infrastructure type, like VM, CIS, etc. Examples of additional infrastructure services can include resource composition of various infrastructure types, multi-tenancy. A corresponding management functional entity Infrastructure Service Management is newly added in the TCIM. The TCIM produces Telco Cloud infrastructure service management related services to the Consumer OSS.

NOTE: For simplicity purpose, other architectural elements that consume services of the TCIM (e.g. the TCAM in TC-MANO) are not displayed in this architectural solution.

Future trends #3 in clause 5 are expected to be addressed by the Level 2 architectural solution described in the present clause.

7.2.2 Solution #2: Telco Cloud and Orchestration Platform

7.2.2.1 Description

The "Platform as a Service (PaaS)" concept comes from IT industry and enables consumers to focus on the deployment and management of applications. Tasks of resource management, capacity planning, maintenance of underlying software systems, etc. do not need to be handled by the consumer, thus making more efficient the tasks of the consumer to focus on the design and development of the logic and behaviour of the applications.

If telco network functions can be treated as an application, then it means that NF providers and Communication Service Providers (CSPs) can focus more on the matters of NF's application logic and network operation, rather than on underlying infrastructure and cloud/virtual platform management. In the present solution, it is proposed that the PaaS concept goes beyond the typical PaaS only applied to applications design, and it is further evolved to cover both aspects, NF (as applications) and network operations, thereby becoming a Telco PaaS.

NOTE: Different actors/roles in the CSP ecosystem are still regarded as necessary, like on infrastructure provisioning and operations, but the perspective considered in the solution focus on the "network service" perspective in the context of an CSP.

Figure 7.2.2.1-1 illustrates the proposed solution, the Telco Cloud and Orchestration Platform (TCOP) architectural framework. At its core, the TCOP provides a Telco PaaS for NFs and other applications, as well as Telco Cloud management services exposure to upper-level OSS/BSS. This platform is rich and modular, providing all the necessary capabilities (or services) to enable the deployment and management of many kinds of applications in a generic form, not only NFs, but also other applications such as for edge, intelligence, coding, etc. In effect, the Telco PaaS enriches the baseline stratum Cloud infrastructure and delivers a telco ready platform for CSPs.

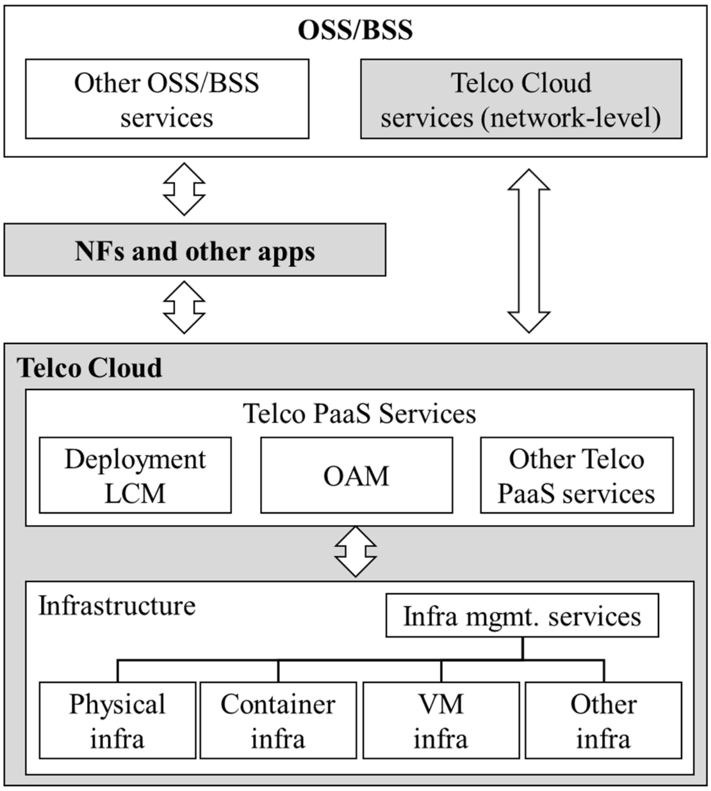

Figure 7.2.2.1-1: Telco Cloud and Orchestration Platform architectural framework

The TCOP architectural framework introduced in the present solution includes the following three main major building blocks (which are shaded in grey in figure 7.2.2.1-1):

- Telco Cloud;
- NFs and other apps; and
- Telco Cloud services at OSS/BSS level.

The Telco Cloud is further comprised of:

- Infrastructure stratum; and
- Telco PaaS Services stratum.

The infrastructure stratum represents the foundation over which various NFs and applications can be deployed and operated. The infrastructure includes resources and is comprised not only of compute, storage and network resources, but also of acceleration resources used to boost the performance of any kind of NF/application workload. It includes the necessary services for physical, OS container and virtualised infrastructure services. Other components of infrastructure to support new virtualisation and deployment technologies can also be included in this group as technologies evolve and adoption for telco use cases becomes prominent. The infrastructure also includes the necessary management services associated to the respective infrastructure types, and the services to perform the inventory and reconciliation of the whole cloud infrastructure, which is envisioned to be highly distributed, covering from access, through edge to central cloud regions. The infrastructure stratum considers leveraging the industry ecosystem around Infrastructure-as-a-Service (IaaS) and Container-as-a-Service (CaaS). This stratum includes the potential evolution or reuse of services/capabilities associated to already specified NFV-MANO functions like the VIM, CISM, PIM and CCM.

The Telco PaaS Services stratum, includes services for NF/application deployment lifecycle management, deployments OAM and other Telco PaaS services. Telco PaaS Services are envisioned to be prominently generic, and can be common, applied or used by multiple NF instances, or dedicated, if applied or used by a single NF. The Telco PaaS Services are categorized into two main groups:

a) data and control plane services for the NF, applications and network; and

b) management services for the management and operation of the NF and other applications.

Examples of management services include packaging, deployment lifecycle, observability (including energy related metrics and information), configuration repositories, and all the necessary workflow tools to support Continuous Integration/Continuous Delivery (CI/CD) pipelines. Services dedicated to data and control plane aspects can be very diverse depending on the needs of applications and networks to deploy; some examples include: service mesh connectivity, load balancing, etc. This stratum includes the potential evolution or reuse of services/capabilities associated to already specified NFV-MANO functions like the VNFM, and PaaS Services functional framework like VNF generic OAM functions.

Networks are built with NFs and other applications, and the TCOP provides the means for their deployment and operation. Future network generations will not only comprise NFs, but be also comprised of many different applications, e.g. for AI/ML, application acceleration, etc. The framework envisions that the NFs and other applications leverage the services provided by the Telco Cloud in a generic manner by means of APIs or other mechanisms.

Finally, the top-most block in the architectural framework is the Telco Cloud services (network-level) at the OSS/BSS level, representing the operating supporting systems of the CSP, including the management functions that consume the services offered by the Telco Cloud and that perform the provisioning of the NFs and other applications deployments into actual network service offerings by the CSP. The OSS/BSS is responsible for the network service end-to-end orchestration by means of policy and intent-driven automation mechanisms. The purpose of the Telco Cloud services (network-level) is to primarily focus on providing a network-level reconciliation between the intents of network orchestration and management and the individual management actions towards the underlying Telco Cloud. This part includes the potential evolution or reuse of services/capabilities associated to already specified NFV-MANO functions like the NFVO and Intent Management.

Interactions between the OSS/BSS and the Telco Cloud, and within the Telco Cloud leverage common APIs, e.g. following a declarative management approach, where feasible and meaningful for simplifying and optimizing the management and orchestration workflows. This approach helps realize the "infrastructure as code" and "management as code" approach and facilitate the operation of the whole network (infrastructure and applications) leveraging DevOps and GitOps methodologies. As an example, solutions like Custom Resource Definitions (CRDs), currently in use in prominent cloud orchestration environments, can help simplify the interoperability between the different management systems.

7.2.2.2 Future trends addressed by the solution

The present solution addresses the following trends:

- Trend #1 on "diversified and heterogeneous infrastructure", as it is considered that the Telco Cloud infrastructure is highly distributed and encompasses various infrastructure types.
- Trend #2 on "cloud technologies accommodating different types of virtualisation forms", as it is considered that the Telco Cloud infrastructure will have virtualised infrastructure considering other forms of virtualisation beyond pure VM and OS containers.
- Trend #3 on "new telco applications or services running on Telco Cloud infrastructure", as not only NFs are considered for deployment but also other kinds of applications.
- Trend #4 on "automation and intelligence in NFV-MANO", considering the use of GitOps and DevOps functionality as part of the Telco PaaS services stratum.
- Trend #5 on "Telco PaaS", as one of the key elements of the architectural framework is the Telco PaaS Services stratum.
- Trend #6 on "Energy efficiency and carbon efficiency", as the Telco PaaS Services stratum aims at delivering fine granular and diverse observability services, like energy consumption monitoring.

- Trend #7 on "Multi-tenancy", as it is envisioned that the Telco Cloud will host diverse kind of NF and other applications, and by leveraging state of the art and further enhanced solutions in the IaaS and CaaS ecosystem.

7.2.3 Comparison between the architectural solutions

In the present document, Solution #1 "Expanding NFV-MANO's scope to Telco Cloud management" and Solution #2 "Telco Cloud and Orchestration Platform" are the two main proposed architectural solutions to fulfil the future trends in clause 5. Table 7.2.3-1 summarizes the comparison between the two architectural solutions in respects to functional composition and organization.

Table 7.2.3-1: Comparison between the architectural solutions

	Solution #1	Solution #2	Remarks
Infrastructure Management	One abstracted block named TCIM converges the management of various Telco Cloud infrastructure resource services via their respective management functions (e.g. the CISM, VIM, PIM).	The infrastructure stratum includes various infrastructure management services from physical, virtual machine, OS container or other infrastructure.	The concept of "Infrastructure Management" representing a set of generic functionalities can be aligned.
Management of xNFs or applications	One abstracted block named TCAM manages evolved xNFs, 3rd party apps, AI applications or exposed Telco Cloud services.	The Telco PaaS Services stratum includes deployment LCM, OAM services and other platform services to support the running of xNFs/apps.	Can be aligned between application management in Solution #1 and Telco PaaS Services in Solution #2.
NS Management	Not explicitly mentioned, can be combined in the TCAM block.	Be moved to network-level Telco Cloud services.	No correspondence.
Autonomous Management/ Automation	Grouped in the TCAS block, and the TCAS exposes services to the OSS/BSS.	Not explicitly mentioned, globally considers GitOps concepts, in which any blocks can be in the loop of automation.	No correspondence.
Inter-block interaction	Declarative APIs, descriptors and system.	Declarative APIs, descriptors and system.	Aligned.
Organization of intra-block functionality	Use case driven, group necessary functionality in one block to fulfil the requirements of certain scenarios.	Use case driven, group necessary functionality in one block to fulfil the requirements of certain scenarios.	Aligned.
Architectural layout style	NFV-MANO like, keep the management functionality alone and integrated in MANO stack.	Management services are embedded in the full stack of infrastructure or platform.	Can be aligned.

7.3 Enhancements to achieve architectural goals

7.3.1 Introducing Declarative APIs

As described in clause 6.2.2.1, in order to fulfil the future trends of NFV evolution by simplifying the interworking with external entities, a new declarative API can be introduced and exposed as evolved NFV-MANO NBI. A declarative API can provide a user-friendlier way for the external entities (e.g. the OSS) to manage the objects (e.g. NS, VNF) based on its requirements and desired states.

The internal interfaces within an evolved NFV-MANO might use a declarative style as well. By using a common style of API, the interfaces design and their maintenance can be further simplified. It can also make it easier to incorporate new infrastructure technologies in the future, which are likely to tend towards a declarative style of API.

The concept of a new declarative API reflects the following aspects:

1) Defining NFV managed objects to be exposed to API consumers (e.g. NS, VNF, networking, cluster, etc.), the properties to be defined in the managed object are mainly focused on the desired state of the managed object (e.g. the VNF can be defined based on vnfInfo IE as described in ETSI GS NFV-IFA 007 [i.10]);

   - The granularity of managed objects depends on the management scope to be exposed to API consumers, and mainly focus on the requirements from API consumers.

- A declarative API could be generic enough to enable the support for using the Intent management service interface as described in ETSI GS NFV-IFA 050 [i.11].

2) The main operations for managing the objects are:

   - Submit description of desired state.

   - Apply changes.

3) The existing open-source design pattern (e.g. how Kubernetes Declarative Management pattern is applied to CRDs) can be used as a reference.

Declarative APIs can be particularly suitable for defining and describing the status and configuration of resources for management and deployment. Declarative management can help setting up the managed objects used to retrieve and monitor the status of other managed objects. However, a declarative API does not aim at providing real-time monitoring like performance data exposure and alarm events. Other tools and services for monitoring or logging can be used together with declarative APIs for fulfilling monitoring goals.

NOTE: It is not in the scope of the present document to perform a detailed analysis of which current NFV-MANO or future evolved architecture exposed interfaces can be handled in a declarative approach, but further evaluation should be performed in future work items.

7.3.2 Grouping and consolidating NFV-MANO functionality inside blocks

In the architectural solutions for fulfilling future trends of NFV based Telco Cloud evolution, the functionality in the architecture is grouped into function-aggregated blocks, such as the TCAM, TCIM and TCAS blocks in TC-MANO of Solution #1 in clause 7.2.1, or the Telco PaaS services and Infrastructure blocks in Solution #2 of clause 7.2.2. Each architectural block further contains finer-granular functionality mapped to NFV-MANO functions (or functional blocks) as specified by NFV-MANO interface specifications, or NFV services as reported in ETSI GR NFV-IFA 039 [i.16]. Taking the TCAM in Solution #1 as an example, MANO functionality in this block might be grouped in several options in respect to the TCAM implementation:

Option #1: Grouping the NFVO and VNFM functional blocks directly into the TCAM, and the NFVO communicates with the VNFM via ETSI GS NFV-SOL 003 [i.19] specified interface operations (as the TCAM internal implementation), as depicted in figure 7.3.2-1.

NOTE: When the TCAM functionality evolves, it is possible that the layout of the NFVO and VNFM be replaced by xNF management inside the TCAM.

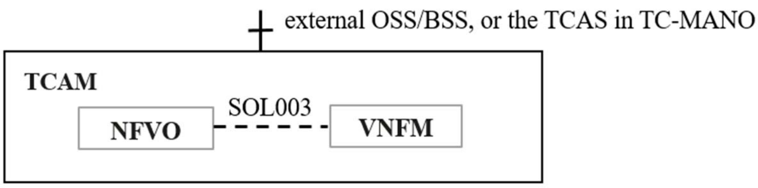

Figure 7.3.2-1: Grouping the NFVO and VNFM into the TCAM

Option #2: Following NFV services categorization alternatives (Target #1) in ETSI GR NFV-IFA 039 [i.16], the NFVO and VNFM provided services (NFV-Ss) are grouped into the TCAM, as depicted in figure 7.3.2-2.

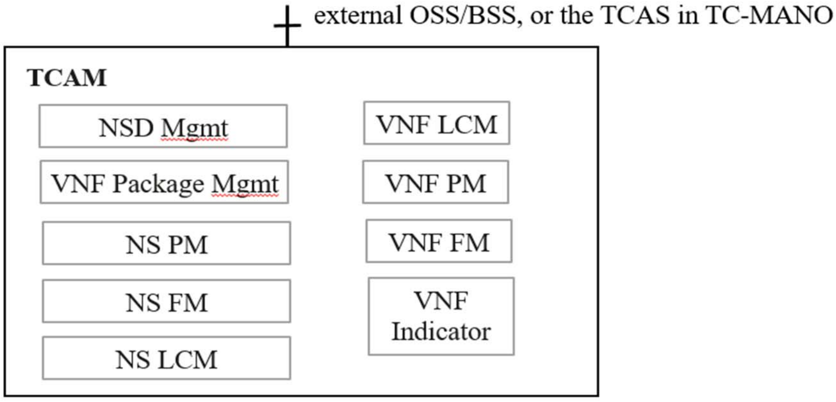

Figure 7.3.2-2: Grouping the NFVO and VNFM provided services into the TCAM

Option #3: Following NFV services categorization alternatives (Target #2) in ETSI GR NFV-IFA 039 [i.16], the NFVO and VNFM provided consolidated services are grouped into the TCAM, as depicted in figure 7.3.2-3.

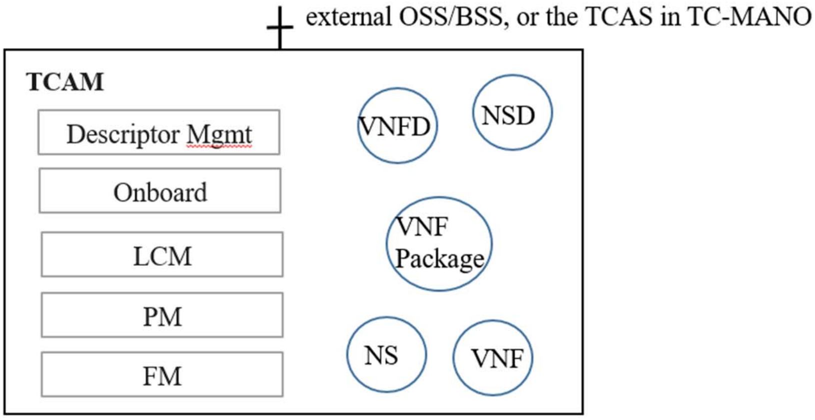

Figure 7.3.2-3: Grouping the NFVO and VNFM provided consolidated services into the TCAM

7.4 Target architectural solution for NFV evolution

7.4.1 Overview

Based on the proposed specific architectural solutions in clause 7.2, clause 7.4 summarizes clause 7 architectural solutions analysis with a consolidated target architectural framework to support NFV evolution.

The key aspects for the consolidated target architectural framework are:

- Architectural elements layout style can adopt the approach from Solution #2 of clause 7.2. Management services produced by the Telco Cloud are embedded in respective stacks of functionality corresponding to infrastructure or platform in Telco Cloud, leveraging cloud computing, IT and telco industry practices.

- Block "NFs and other apps" in Solution #2 can be incorporated in the block "Telco Cloud Application" defined in Level 1 architectural view of Solution #1, which accommodates a broad range of future applications (e.g. evolved NFs, AI models/agents, Telco Cloud services) running on Telco Cloud. In the consolidated target architectural framework this block is referred as "Telco Cloud Applications".

- Part of the functionality in block "TCAM" and the "TCAS" in Level 1 architectural view of Solution #1 can be combined to formulate the entire Telco Cloud service orchestration. Similarly, the block "Telco PaaS Services" in Solution #2 can be mapped to Telco Cloud platform in the same direction. In the consolidated target architectural framework these blocks are referred as "Telco Cloud Service Orchestration" and "Telco Cloud Platform", respectively.

- Block "Telco Cloud Infrastructure" and "TCIM" in Level 1 architectural view of Solution #1 can be combined to formulate a unified Telco Cloud infrastructure containing infrastructure management services in the target architectural solution. It aligns with the 1st item in this list. In the consolidated target architectural framework this block is referred as "Telco Cloud Infrastructure".

7.4.2 High-level architectural framework

The present clause provides a high-level description for the target Telco Cloud architectural framework to support NFV evolution, which is derived from specific architectural solutions analysis in clause 7.2.

The consolidated target architectural framework, depicted in figure 7.4.2-1, is described at a functional and logical level.

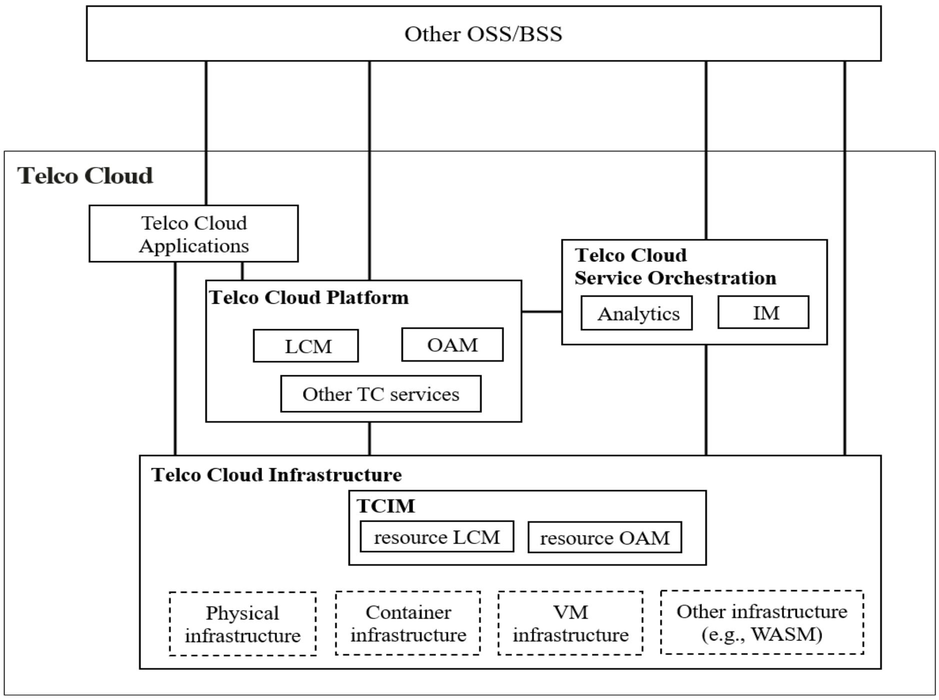

Figure 7.4.2-1: Logical view for the Telco Cloud architecture

NOTE: The solid lines between blocks represent main points of interaction of groups of functionalities. Solid blocks without any connecting lines represent the kind of management functionality and services contained within a logical entity. Blocks with dotted lines represent the kinds of infrastructure resources within the Telco Cloud Infrastructure.

A stack of functionalities exposed by service interfaces are encapsulated in the Telco Cloud. The services of the Telco Cloud are provided to the Other OSS/BSS or Telco Cloud Applications. The Telco Cloud Infrastructure, Telco Cloud Platform and Telco Cloud Service Orchestration produce infrastructure services, platform services and orchestration services respectively. From bottom to top, the functionality in respective architectural blocks is as follows:

- Telco Cloud Infrastructure: represents the infrastructure for the Telco Cloud, which is considered to be hyper-distributed, covering from edge to central cloud regions. The infrastructure is comprised not only of compute, storage and network resources as specified in the current NFV specifications, but also other heterogeneous hardware resources (including acceleration resources, such as DPU and NPU) to boost the performance of Telco Cloud applications and services. Telco Cloud Infrastructure includes various infrastructure management services for physical, container, Virtual Machine (VM) resources, networks within and across sites, data storage and possibly new type of infrastructure (e.g. using new virtualisation technologies like WASM), which are represented collectively as the TCIM. The later might be capable of providing some more abstracted view by means of a common infrastructure service interface on top of underlay infrastructure management services provided by different solutions, to ease interoperability.

- Telco Cloud Platform: represents a modular platform of services, including LifeCycle Management services (LCM) and Operations, Administration and Management (OAM) services. These services are generalized to fulfil any type of workload (e.g. evolved network functions, 3rd party applications) running on the Telco Cloud. Other Telco Cloud services, e.g. integrated infrastructure management services across Telco Cloud sites (as similar concept to NFVI-PoPs) are also included in Telco Cloud Platform.

- Telco Cloud Service Orchestration: encompasses the network-level orchestration, e.g. for network slices, analytics, Intent Management, as well as the orchestration of the hyper-distributed infrastructure. It focuses on providing a network-level reconciliation between the intents of service requirements, and the management service requests towards the Telco Cloud.

- Telco Cloud Application: represents the NF and other applications deployed and operated on the Telco Cloud. The range of applications is broader than the current VNF concept in NFV-MANO. It covers not only network functions, but also many different applications that can be part of the future network services, e.g. AI/ML models, edge computing applications, digital twins, video and audio processing.

On top of the Telco Cloud, the entities which consume the services provided by the Telco Cloud can include:

- Other OSS/BSS: OSS/BSS (e.g. 3GPP management system, business level intent management) other than Telco Cloud Service Orchestration, which can consume the services provided by Telco Cloud.

The consolidated target architectural framework addresses the same trends as documented in clause 7.2.2.2, based on the mapping and reference to solutions described in clause 7.4.1.

7.4.3 Simplified view of the target architectural framework

The consolidated target architectural framework can also be represented in a simplified architectural view, to address the requirements of architecture understanding and communication at a more an abstracted level.

The simplified architectural view is depicted in figure 7.4.3-1. A stack of functionalities implementing the Telco Cloud provides Telco Cloud services to Consumers. Telco Cloud is composed of Telco Cloud Infrastructure, Telco Cloud Platform, Telco Cloud Applications and Telco Cloud Service Orchestration.

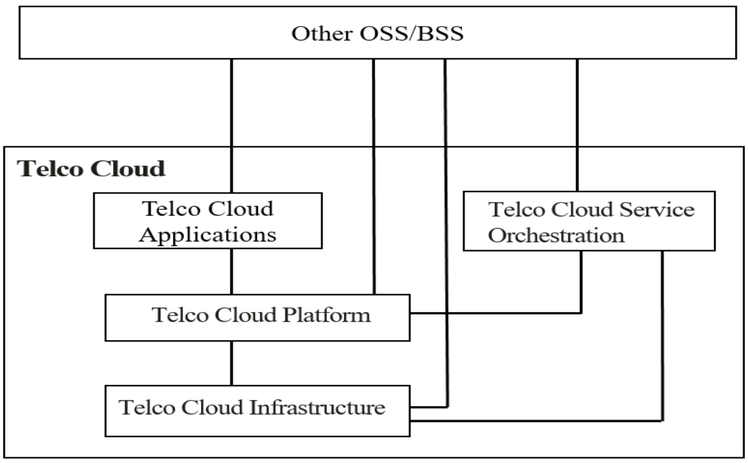

Figure 7.4.3-1: Abstracted architectural view for the Telco Cloud

7.4.4 Architectural blocks and their exposed service interfaces

From an interoperability point of view, architectural blocks and their exposed service interfaces in the consolidated target architectural framework to support NFV evolution are:

- Telco Cloud Infrastructure: produces infrastructure services of the Telco Cloud to Telco Cloud Platform, Telco Cloud Service Orchestration, Telco Cloud Applications or other OSS/BSS. Infrastructure services might act on unified, abstracted infrastructure resources, in respect to their Lifecycle Management (LCM) and Operations, Administration and Management (OAM). Management requirements of abstracted infrastructure resources are further translated to the management of physical resources, virtualised resources, managed CIS cluster objects, or managed container infrastructure objects, which are operated by the respective specialized infrastructure management functions (like the PIM, VIM, CCM or CISM when considering the current NFV-MANO architectural framework respectively.

- Telco Cloud Platform: produces application and management-oriented platform services of the Telco Cloud to Telco Cloud Service Orchestration, Telco Cloud Applications or other OSS/BSS. Platform services might act on network functions or applications of different virtualisation forms, other Telco Cloud services, or other workloads of Telco Cloud including 3rd party applications, etc., in respect to their LCM and OAM procedures.

- Telco Cloud Service Orchestration: produces network-level orchestration services of the Telco Cloud to other OSS/BSS. Orchestration services might act on Telco Cloud services (e.g. platform services, infrastructure services) in respect to their orchestration operations, to construct network-level service reconciliation capabilities in the Telco Cloud, such as network service/network slicing, Telco Cloud related management data analytics or intent management.

A declarative management style is expected to be used for the interfaces, where feasible.

7.4.5 Mapping NFV-MANO functional entities in the target architecture

The current NFV-MANO functional blocks and functions, as specified in ETSI GS NFV 006 [i.2] can be mapped and accommodated in the architectural elements of the target architecture, as depicted in figure 7.4.5-1. This shows that the new target architecture is backward compatible to NFV-MANO from a functional perspective, i.e. the consolidated target architectural framework carries and redistributes existing functionality provided by NFV-MANO.

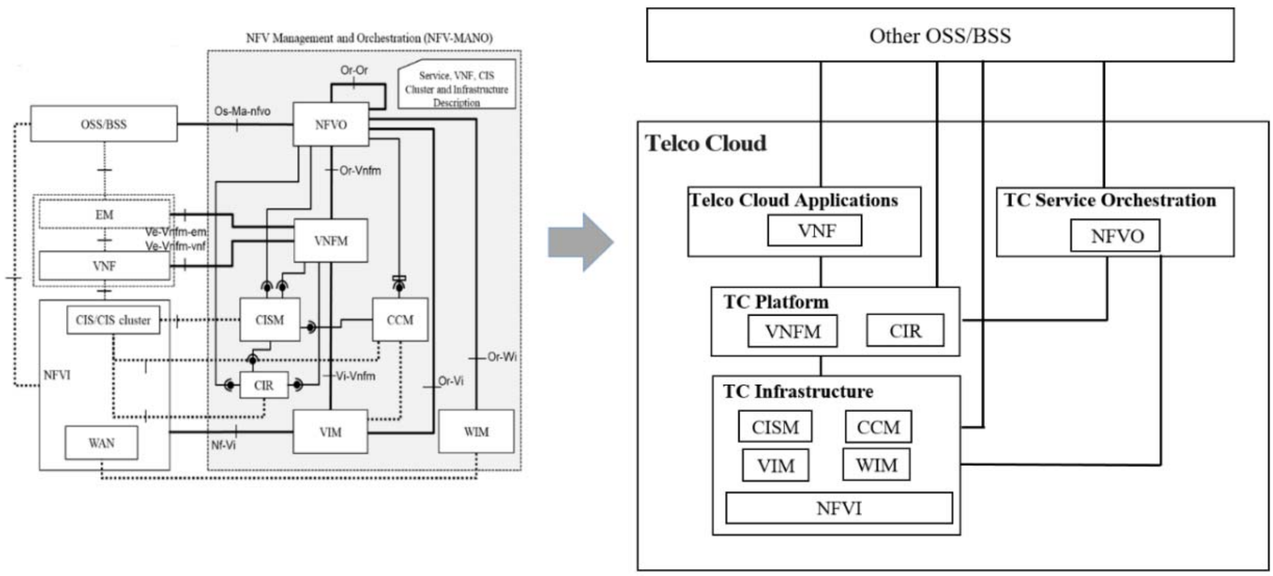

Figure 7.4.5-1: Mapping NFV-MANO functional entities in the target architecture

NOTE 1: Other NFV-MANO functions specified not shown in architectural framework figure 5.2-3 of ETSI GS NFV 006 [i.2] are mapped as follows:

a) the MDAF, IM are mapped in Telco Cloud Service Orchestration;

b) The CMF, PSM, PSR are mapped to the Telco Cloud Platform;

c) The PIM is mapped to the Telco Cloud Infrastructure.

NOTE 2: The EM in architectural framework depicted in figure 5.2-3 of ETSI GS NFV 006 [i.2], and its functionality, is regarded to be in the category of other operation support systems, and if needed, thus be covered by the "Other OSS/BSS".

7.4.6 Achievement status analysis of architectural goals

Table 7.4.6-1 provides an analysis on achievement status of the architectural goals in clause 6, in the Telco Cloud architectural framework depicted in figure 7.4.2-1.

Table 7.4.6-1: Achievement status analysis of architectural goals

Principles	Architectural goals	Description of achievement status
Simplification	More declarative system	Declarative interfaces and descriptors are expected to be mainstream interaction approach, where feasible, of architectural blocks in the target architecture, succeeded by Phase 1 normative work plan in clause 8.4.
	Architectural view hierarchy	Full architectural view in clause 7.4.2 and simplified architectural view in clause 7.4.3 provide different levels of architectural details to different actors.
	Simplifying open-source integration complexity	Integrate open-source de-facto solutions into the architectural blocks per case-by-case basis, with the advance of cloud-computing and AI technologies.
	Improved modular design	Architectural blocks of Telco Cloud Applications, Telco Cloud Infrastructure, Telco Cloud Platform and Telco Cloud Service Orchestration follow modular goals.
	Service-driven architecture	Internal functionality of each architectural block in the target architecture can be implemented following service-driven architecture principles, and each respective architectural blocks produce service interfaces to both internal and external consumers.
Evolution	Backward compatibility	Backward compatibility is not only from functional perspective (accommodating legacy NFV-MANO functionality in the target architecture), but also from the perspective of reusing models and interfaces from NFV-MANO in best effort way.
	High extensibility	The target architecture sustainably supports future trends of NFV evolution (include but not be limited to the ones in clause 5).
Federation	N/A	Not explicitly reflected in the target architecture, due to the fact that this goal is applied in a distributed Telco Cloud environment and the target architecture focus on the description of logical functionality (no deployment view).

7.5 NFV features migration considerations

It is foreseen that the consolidated target architectural framework for NFV evolution proposed in clause 7.4 will not be directly evolved from the current NFV-MANO architecture as specified in ETSI GS NFV 006 [i.2]. The new architecture restructures the functionality from the viewpoint of Telco Cloud, which enlarges the scope of NFV-MANO, accommodates and re-distributes the current NFV-MANO functionality in the layout of the target framework.

With regards to NFV features planned across releases and from a specification perspective, a potentially feasible migration procedure of NFV-MANO to the consolidated target architectural framework for Telco Cloud might be as follows:

- Step 1, NFV Release 5 as well as its previous Release features development and maintenance are made in the current NFV-MANO architectural framework.

- Step 2, for Release 6 features (targeted to support new trends of NFV evolution), the feature development work includes two aspects: on one hand, use case study in the informative work uses the current NFV-MANO architecture as the baseline architecture, which facilitates to derive key issues and potential solutions to address the issues in the informative study phase. On the other hand, use case study and potential solutions need to be revisited and validated in the new architectural framework for Telco Cloud, in which the proposed solutions are confirmed to take effect in the new architecture. This working procedure for Release 6 features could be applied on per case-by-case basis.

- Step 3, from Release 7 on, new features work could target its specification in the architectural framework for Telco Cloud. The legacy NFV-MANO functionality (from Release 5 and earlier Releases) is also gradually migrated to the new architecture.

8 Recommendations

8.1 Overview

Clause 8 documents recommendations related to the architectural framework for Telco Cloud in the next phase normative work, based on architectural solutions analysis in clause 7. It also delivers recommendations on how the NFV architectural framework specified in ETSI GS NFV 006 [i.2] can evolve towards a Telco Cloud architectural framework.

8.2 Recommendations related to the architectural framework for Telco Cloud

The present clause provides recommendations related to the architectural framework for Telco Cloud, as described in Table 8.2-1.

Table 8.2-1: Recommendations related to the architectural framework for Telco Cloud

Identifier	Recommendation description	Comments
Tca.001	It is recommended that an architectural framework for Telco Cloud be specified to support long-term evolution of NFV-based Telco Cloud.	This recommendation is related to the overall NFV-based Telco Cloud framework which includes, orchestration and management aspects, Telco Cloud applications and Telco Cloud Infrastructure, according to clause 7.4.
Tca.002	It is recommended that the functionality of the target architectural framework for Telco Cloud aligns with emerging innovative trends in Telco Cloud technology.	Telco Cloud trends are described (but not be limited to the ones) in clause 5.
Tca.003	It is recommended that the target architectural framework for Telco Cloud be backward compatible to NFV architectural framework.	The scope of NFV-MANO functionality refers to ETSI GS NFV 006 [i.2]. Backward compatibility is not only considered from a functional perspective, but also from the perspective of reusing models and interfaces to the best extend possible.
Tca.004	It is recommended that the target architectural framework for Telco Cloud comprised of Telco Cloud Applications, Telco Cloud Infrastructure services, Telco Cloud Platform services and Telco Cloud Service Orchestration services.	Refer to clause 7.4.2.
Tca.005	It is recommended that Telco Cloud Infrastructure service producers expose unified infrastructure services to consumers external or internal to the Telco Cloud.	Refer to clause 7.4.2.
Tca.006	It is recommended that Telco Cloud Platform service producers expose application and infrastructure management-oriented platform services to consumers external or internal to the Telco Cloud.	Refer to clause 7.4.2.

Identifier	Recommendation description	Comments
Tca.007	It is recommended that Telco Cloud Service Orchestration service producers expose network-level orchestration services to the consumers external or internal to the Telco Cloud.	Refer to clause 7.4.2. Telco Cloud Service Orchestration exposure of services to internal consumers is not excluded.

8.3 Recommendations related to NFV architectural evolution towards Telco Cloud

The present clause provides recommendations for the NFV architectural evolution towards Telco Cloud, as described in Table 8.3-1.

Table 8.3-1: Recommendations related to NFV architectural evolution towards Telco Cloud

Identifier	Recommendation description	Comments
Tcae.001	It is recommended that guidelines be specified for the migration process to follow (e.g. interface level, descriptor level) towards designing the architectural framework for Telco Cloud.	
Tcae.002	It is recommended that service interfaces in the Telco Cloud architectural framework support management operations following a declarative way.	See clause 7.3.1.
Tcae.003	It is recommended that the functionality of NFV-MANO system can be grouped in architectural elements related to orchestration and management of the architectural framework for Telco Cloud.	See clause 7.3.2.

8.4 Recommendations related to the next steps in normative work

The normative work derived from the analysis of the present document is expected to consider the following aspects:

- Phase 1:
  - Specification of the Telco Cloud architectural framework according to clause 8.2 recommendations.
  - Analysis of endorsing declarative management approaches in NFV specifications aligned with the Telco Cloud architectural framework, including the management considering both declarative interfaces and descriptors. New group specification for declarative interfaces (e.g. infrastructure services, platform services or orchestration services as depicted in figure 7.4.2-1) can be used to support this activity.
- Phase 2:
  - Specification of management interfaces for Telco Cloud Infrastructure services in the new architecture, according to the outcome of Phase 1 analysis on exploiting declarative management approaches.
  - Specification of management interfaces for Telco Cloud Platform services in the new architecture, according to the outcome of Phase 1 analysis on exploiting declarative management approaches.
  - Specification of management interfaces for Telco Cloud Orchestration services in the new architecture, according to the outcome of Phase 1 analysis on exploiting declarative management approaches.
  - Specification of updated declarative descriptors, aligned with the new architecture.

Specification of functional and interface enhancements in the new architecture, accommodating changes introduced by other Release 6 features, e.g. from new infrastructure resources types as studied in ETSI GR NFV-EVE 023 [i.12], computing and network convergence as studied in ETSI GR NFV-EVE 026 [i.14].

9 Conclusion

The present document outlines several future trends related to the evolution of NFV. Based on key architectural principles and their associated targets, two specific architectural solutions are proposed. These solutions are analysed in terms of their respective architectural elements and the functionality they provided. A target architectural framework is then derived by integrating ideas and components from both the architectural solutions proposed. Recommendations are provided to drive the normative work for advancing the NFV evolution towards the new architectural framework for Telco Cloud.

Based on the study in the present document, the normative work activities are expected to be carried out in close collaboration between ETSI ISG NFV and its related surrounding Standards Development Organizations (SDOs) and open-source communities to ensure the successful realization of future architectural framework for Telco Cloud.

Annex A: Change history

Date	Version	Information about changes
August 2023	0.0.1	Initial draft creating the skeleton of the group report in NFVIFA(23)000549r1.
October 2023	0.1.0	Early draft including the following contributions until IFA#350 meeting: NFVIFA(23)000565r1, NFVIFA(23)000620r2, NFVIFA(23)000639r1.
October 2023	0.2.0	Early draft including the following contributions until IFA#355 meeting: NFVIFA(23)000676r1, NFVIFA(23)000677r1, NFVIFA(23)000685.
December 2023	0.3.0	Early draft including the following contributions until IFA#362 F2F meeting: NFVIFA(23)000720r1, NFVIFA(23)000721r1, NFVIFA(23)000722r1, NFVIFA(23)000723r1, NFVIFA(23)000733r2, NFVIFA(23)000806r1, NFVIFA(23)000817r1, NFVIFA(23)000818, NFVIFA(23)000819.
February 2024	0.4.0	Early draft including the following contributions until IFA#369 meeting: NFVIFA(24)000009r1, NFVIFA(24)000014r1, NFVIFA(24)000019r1, NFVIFA(24)000024, NFVIFA(24)000051r2, NFVIFA(24)000084r1, NFVIFA(24)000096r1, NFVIFA(24)000097r2.
March 2024	0.5.0	Early draft including the following contributions until IFA#373 F2F meeting: NFVIFA(24)000149r2, NFVIFA(24)000150r2, NFVIFA(24)000160r1, NFVIFA(24)000161r1.
June 2024	0.6.0	Early draft including the following contributions until IFA#384 F2F meeting: NFVIFA(24)000085r3, NFVIFA(24)000165r2, NFVIFA(24)000285r1, NFVIFA(24)000291r4, NFVIFA(24)000310r3, NFVIFA(24)000331r1, NFVIFA(24)000332r1, NFVIFA(24)000343r1, NFVIFA(24)000344r1, NFVIFA(24)000348r1, NFVIFA(24)000349r2.
July 2024	0.7.0	Early draft including the following contributions until IFA#388 meeting: NFVIFA(24)000162r6, NFVIFA(24)000368r1, NFVIFA(24)000372, NFVIFA(24)000379r2.
July 2024	0.8.0	Early draft including the following contributions until IFA#392 meeting: NFVIFA(24)000345r3, NFVIFA(24)000397r2, NFVIFA(24)000407r1, NFVIFA(24)000408r1.
September 2024	0.9.0	Early draft including the following contributions until IFA#395 interim F2F meeting: NFVIFA(24)000380r1, NFVIFA(24)000381, NFVIFA(24)000442r1, NFVIFA(24)000468, NFVIFA(24)000469r2, NFVIFA(24)000470, NFVIFA(24)000471, NFVIFA(24)000473r1, NFVIFA(24)000483r2, NFVIFA(24)000484r1, NFVIFA(24)000533.
October 2024	0.10.0	Early draft including the following contributions until IFA#400 F2F meeting: NFVIFA(24)000490r4, NFVIFA(24)000580r1, NFVIFA(24)000586, NFVIFA(24)000587, NFVIFA(24)000590r1, NFVIFA(24)000591, NFVIFA(24)000597r1, NFVIFA(24)000598r1, NFVIFA(24)000599r1, NFVIFA(24)000600r3
November 2024	0.11.0	Stable draft including the following contributions until IFA#404 meeting: NFVIFA(24)000623, NFVIFA(24)000624, NFVIFA(24)000625r3, NFVIFA(24)000626, NFVIFA(24)000630r2, NFVIFA(24)000631r2, NFVIFA(24)000632r1, NFVIFA(24)000633, NFVIFA(24)000634r1, NFVIFA(24)000635r1, NFVIFA(24)000636r1
December 2024	0.12.0	Stable draft including the following contributions until IFA#408 meeting: NFVIFA(24)000650r1, NFVIFA(24)000653r2, NFVIFA(24)000655r1, NFVIFA(24)000656r1, NFVIFA(24)000657r1, NFVIFA(24)000658r2, NFVIFA(24)000662, NFVIFA(24)000664, NFVIFA(24)000665r1
December 2024	0.13.0	Final draft including the following contributions until IFA#409 F2F meeting: NFVIFA(24)000640r3, NFVIFA(24)000663r1, NFVIFA(24)000671r1, NFVIFA(24)000672r2, NFVIFA(24)000673r1, NFVIFA(24)000678r1, NFVIFA(24)000679r1, NFVIFA(24)000680r1, NFVIFA(24)000681r1, NFVIFA(24)000682r1, NFVIFA(24)000683r1, NFVIFA(24)000684r1, NFVIFA(24)000685, NFVIFA(24)000687r3, NFVIFA(24)000688r1, NFVIFA(24)000696 Minor rapporteur's editorial changes on term/name alignment when a review text proposal is accepted.

History

Document history		
V6.1.1	February 2025	Publication