EUCNC - The 6G workshop series by Hexa-X

Design of service management and orchestration functionalities

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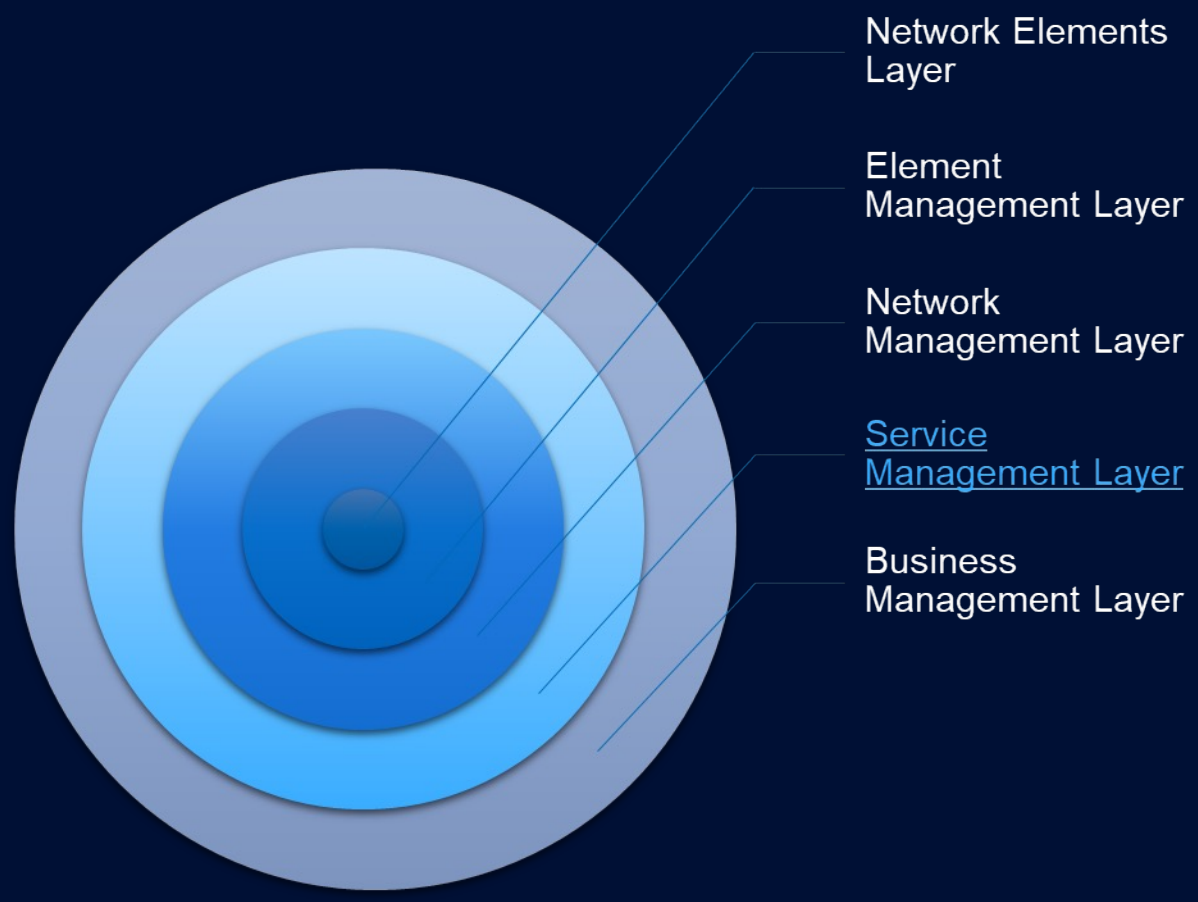
Services Management and Orchestration Fundamentals

Services M&O Fundamentals



WP6 D6.2 targets the Service Management layer which, as described in ITU TMN reference model, consumes orchestration resources from the Network Layer, and provides additional orchestration capabilities to allow the management of services running atop, in an E2E manner, across domains.

The services M&O system is responsible for keeping communication services, digital services, and network slice services, including operations associated to their constituent network services. This would be done by exploiting all the available infrastructure resources envisaged for future 6G networks i.e., Usual core or edge network resources within the MNO administrative domain will be considered, but also resources at the extreme-edge network and resources from 3rd party facilities.

Hexa-X M&O Architecture Insights

Requirements

D6.2 Section "*5.2 Requirements*" provides an exhaustive view on the main requirements for the Hexa-X M&O Architectural design, split into functional and non-functional requirements.

REQUIREMENTS

Functional

- The M&O system shall provide *continuum* orchestration functions to orchestrate services including infrastructure resources from the extreme-edge and third-party networks.
- The system shall provide functions to support enhanced network abstractions/models and service description models.
- The system shall support a wide variety of service definitions and decompositions based on modern lightweight microservice-based functions.
- The system shall provide multi-stakeholder M&O functions.
- The system shall provide with AI/ML-driven orchestration functions to:
  - Enhance service M&O operations.
  - Automating network tasks.
  - Provide cross-layer predictive orchestration.
  - Support proactive and dynamic self-optimisation of network slices.
  - Support the management of collaborative AI components across the network.
  - Support intent-based management.
  - Interpret and enforce sustainability policies.

Non-Functional

- The M&O architectural design shall be aligned with the more general Hexa-X E2E Architectural Design defined in WP1 and the 6G architectural enablers in WP5.
- It shall be flexible and abstract enough to make possible implementations based on multiple SDOs or other standards.
- The M&O architecture shall be aligned with the cloud-native principles.
- The M&O system shall be enabled with data-driven AI/ML capabilities and eXplainable AI (XAI) resources.
- The M&O system shall be enabled with an advanced monitoring system, able to integrate application and infrastructure-based data to leverage AI/ML based decisions.
- The system shall be enabled with means for automation and network programmability.
- The M&O system shall be enabled with security functions by design.
- The system shall be enabled with intent-based mechanisms.
- The M&O system shall be able to contribute to reduce energy consumption and CO_2 emissions.
- ...

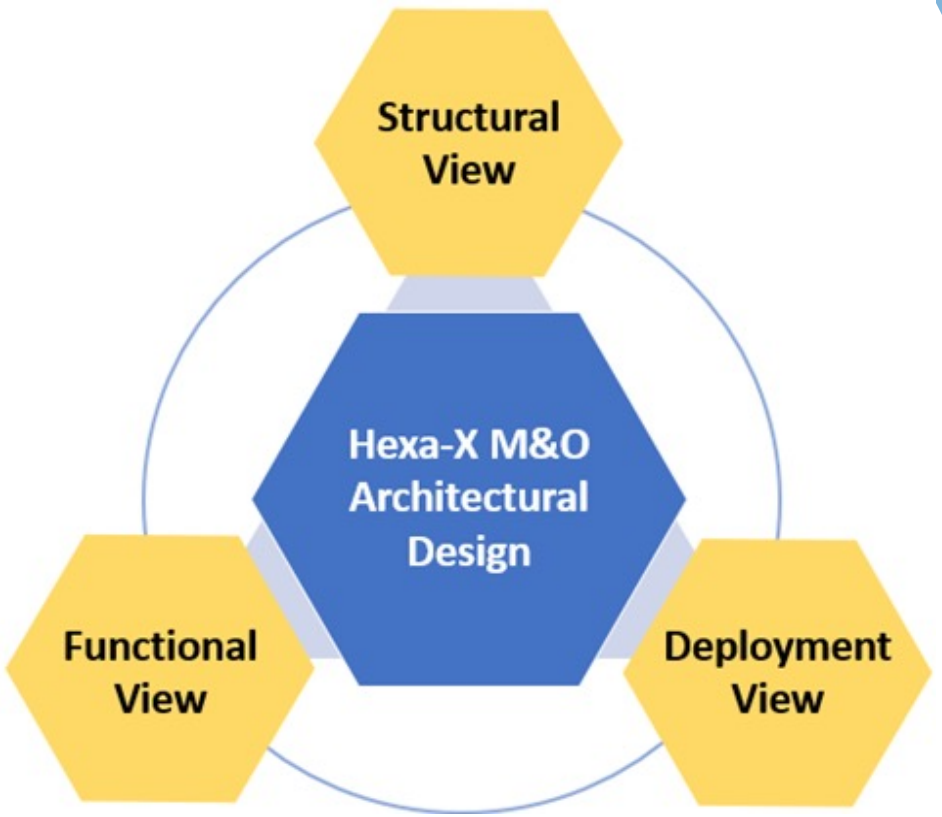
(just a summary here)

Novel M&O Capabilities

Based on the previous 5G Architectural View from the 5G-PPP Architecture Working Group, that has been used as benchmark for the Hexa-X M&O architectural design, Section 5.3 identifies the main novel capabilities regarding M&O for the future 6G networks:

- Unified orchestration across the "extreme-edge, edge, core" *continuum*
- Unified M&O across multiple domains, owned and administered by different stakeholders
- Increased levels of automation
- Intent-based approaches for service planning and definition
- Adoption of data-driven and AI/ML techniques in the M&O system
- Adoption of the cloud-native principles in the telco-grade environment

Architecture Description

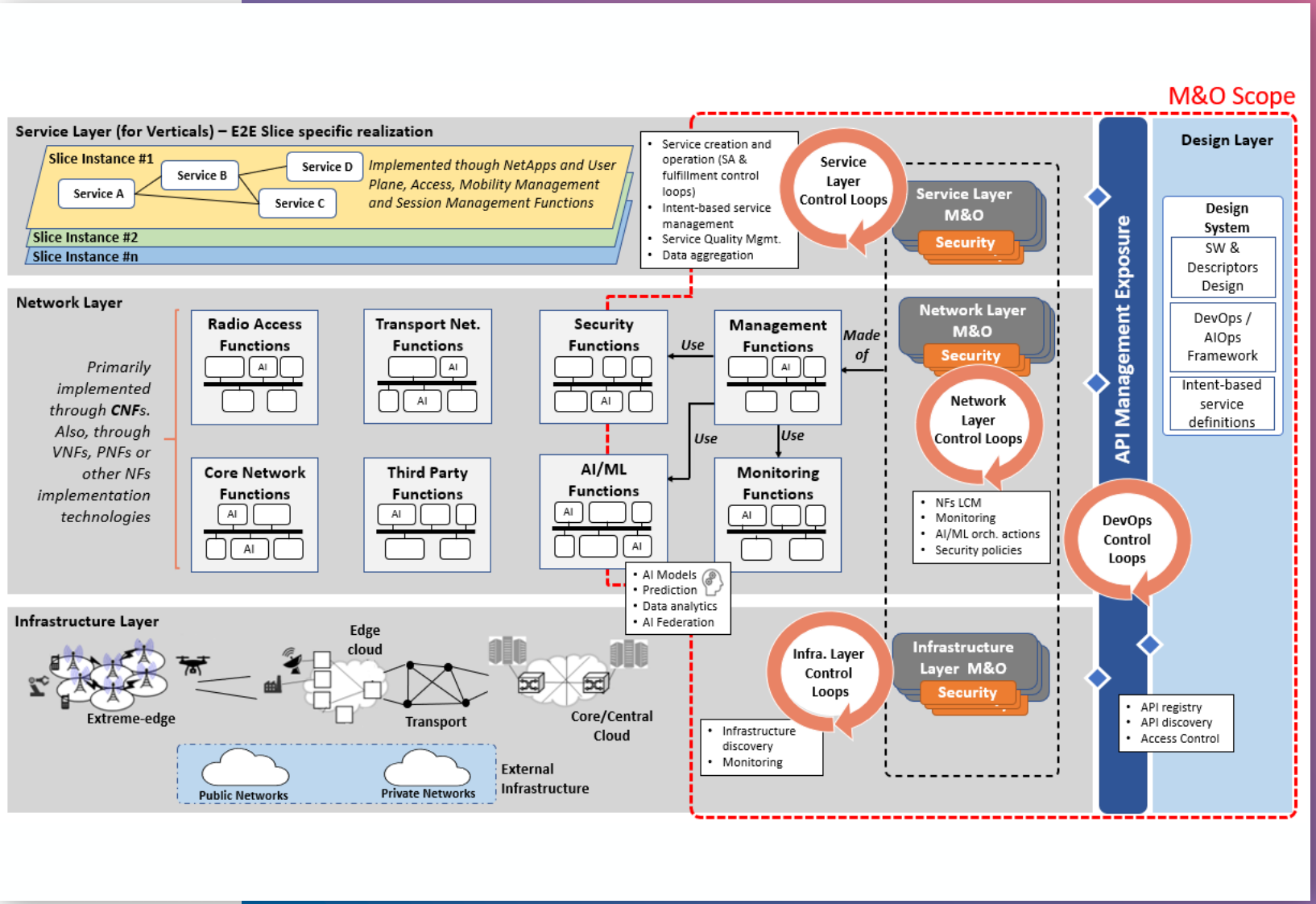


Three different views are used in order to provide a coherent and complete description of the system's architecture:

- **Structural View:** Presents the main building blocks required to make up the system and the interfaces that make communication among them possible.
- **Functional View:** Describes system behaviours, focusing on what are considered the most relevant functionalities that could emerge from this architecture, illustrating how the different functional blocks presented in the Structural View can interact each other to provide the different functions.
- **Deployment View:** Describes how the components in the Structural View could be deployed in practice, considering infrastructure resources and topological aspects.

Structural View

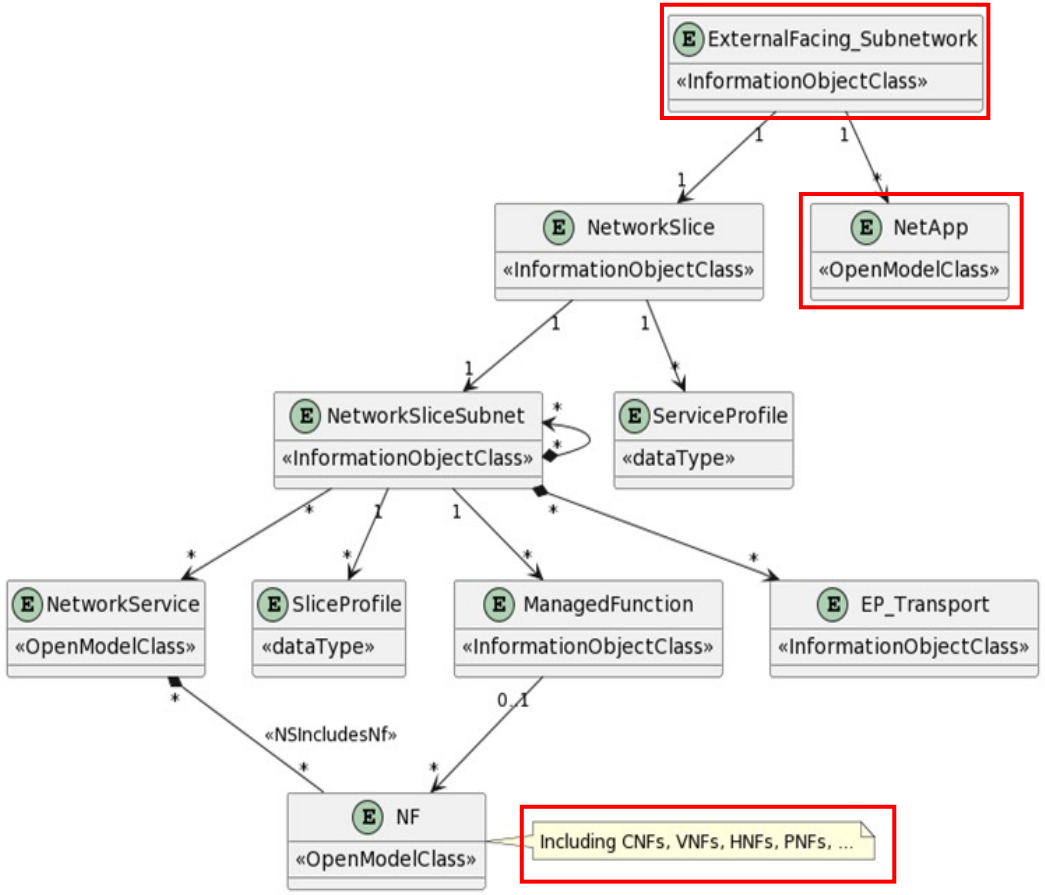
Structural View Design Principles



- Evolution based on the former 5G architecture.
- Aligned with the Service Based Management Architecture (SBMA) model, which is still considered a paradigm shift on the telco stack design.
- NFs primarily implemented through CNFs.
- Clear split between Managing Objects and Managed Objects, aligned with the OSI management protocols.
- Design Layer added to represent 3rd party SW providers.
- Extreme-edge and public/private networks included as part of the Infrastructure Layer.
- Four controls loops included, for Infrastructure, DevOps, Network Layer, and Service Layer.
- Functions are associated in different groups at the Network Layer, and they are generic. The M&O Scope includes AI/ML Functions and Security Functions.
- AI collaborative components are distributed across the network.
- Communication among layers (and with external resources) is carried out through the API Management Exposure block, following a cloud-native approach.

Managed Objects (MOs)

An extension to the 3GPP Slicing Model is proposed with the following innovations regarding MOs:



- **External Facing Subnetwork Object:** Builds upon the classical definition of the subnetwork concept, extending it for the "network of networks" support. It represents the view of a subnetwork that a MNO, when becoming a CSP, provides to external administrative domains.
- **NetApps Construction:** Assets where NFs may be chained across several domains to create applications tailored to the requirements of specific tenants. They can be deployed as stand-alone entities or interacting with other NetApps to deliver more complex services. It inherits from the *External Facing Subnetwork* object for providing "network of networks" capabilities
- **Up-scoping NF constructions to CNFs:** Increase the scope of the NF by considering the representation of NF generic objects. Using CNFs will be the preferred implementation, but maintaining compatibility with other NFs implementations.

M&O Functions

D6.2 presents, on the one hand, the *Primary M&O Functions* which represent the collection of Management Functions (applicable to all managed resources, including Infrastructure Layer, Network Layer and Service Sayer resources) offering what are considered the basic management capabilities: *fulfilment capabilities, assurance capabilities and artifact management capabilities*.

On the other hand, it presents a thoroughly description of *Complementary M&O Functions.* In this category, three M&O Functions types are considered:

- **AI/ML Functions:** Intended to provide the mechanisms to build out the knowledge and the intelligence for controlling, managing and optimising the services deployed on the network.
- **Security Functions:** Their main objective is to protect the confidentiality and integrity of operations and data, and to ensure the continuity of the provided services.
- **Monitoring Functions:** Intended to provide information regarding the operational processes, in the form of trace files, alarms, KPI values, or usage parameters, among others.

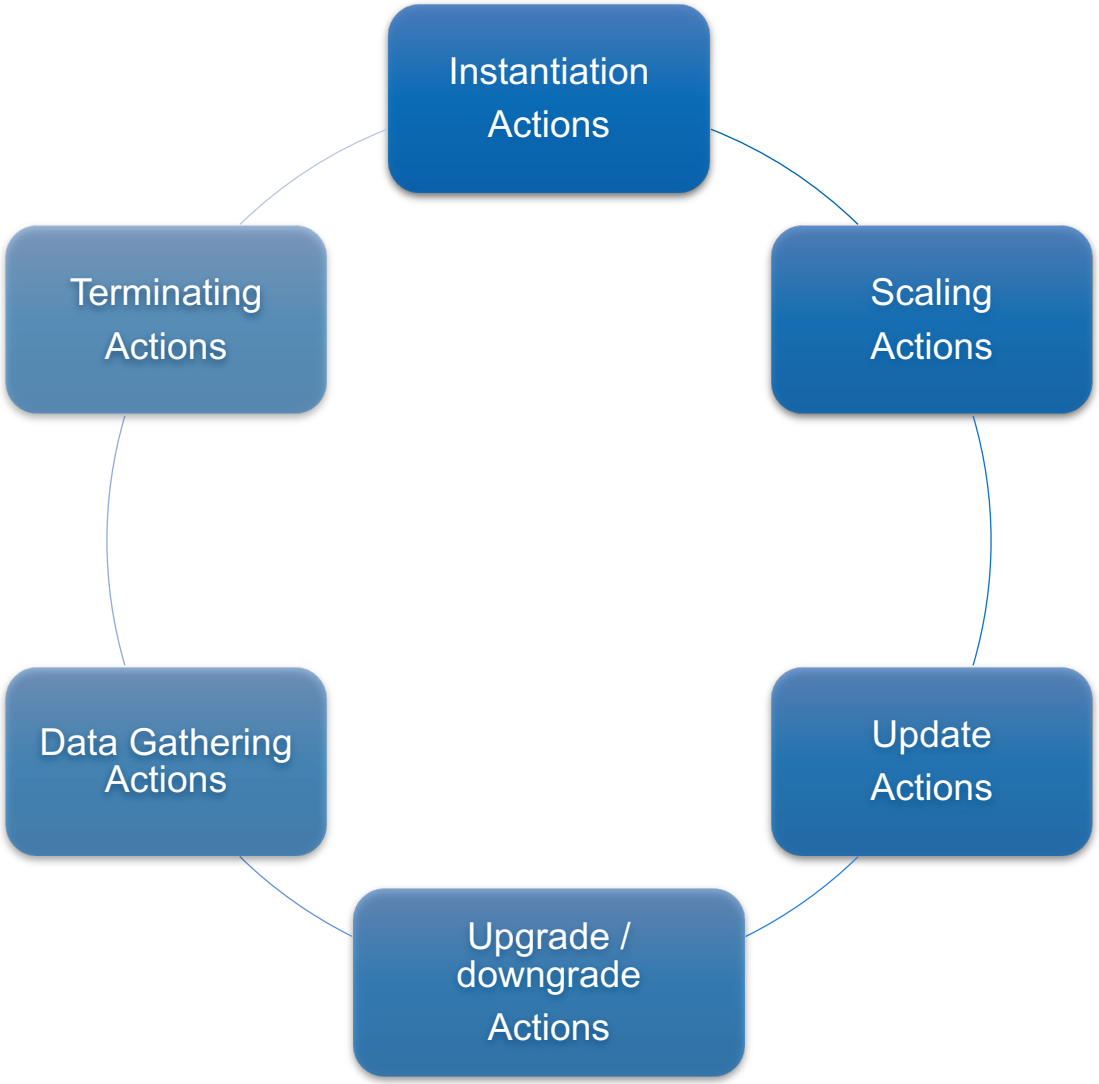
All these *Complementary M&O Functions* may be used the Management Functions Block in order to extent its M&O capabilities.

Functional View

Basic Orchestration Actions

The Functional View is intended to describe the "dynamic" aspects of the M&O system from a high-level perspective, describing relevant behaviours or mechanisms that would be implemented through the interactions among the basic building blocks described in the Structural View.

Basic orchestration actions can be understood as those M&O actions that could be used as the main Building Blocks that would be used to compose more complex M&O processes. They are considered as the most basic M&O operations, D6.2 Section "*7.1 Basic Orchestration Actions*" contemplates the following:



Orchestration Processes

Orchestration processes are considered to be those more complex processes that could be arranged using *Basic Orchestration Actions.* HEXA-X considers the following categories as the most relevant for future 6G networks:

E2E seamless integration processes

vailable infrastructure as a common pool of resources.

a) Device-edge-cloud continuum M&O processes.

Hexa-X proposes to evolve the Network Slicing concept for future B5G/6G networks by introducing the "Device-Edge-Cloud continuum M&O" concept, which considers expanding network slices beyond core and edge resources by integrating other network domains, from the extreme-edge (those end-user resources beyond the edge) up to the cloud, considering all the network resources in between.

b) Network Slices Orchestration processes.

In 6G networks the slice orchestration needs to achieve higher levels of dynamicity and automation than in the previous generations, with provisioning customised on-demand on the basis of service intents and slice operation at runtime enabling a continuous service assurance.

c) Processes for the integration with other Networks.

6G networks will be able to cope with different access and backbone networks to provide E2E solutions. Typically, the integration concerns different technological or administrative domains in that context. Such integration can be dynamic, and it concerns the user plane primarily but, in some cases, has to be supported by control plane services for the E2E integration.

d) Optimised placement processes.

One of the problems typically associated to M&O services is the placement problem. This is an optimisation problem consisting in finding the best (most optimal) way to deploy the atomic SW components (e.g., NFs) that typically conform other more complex structures (e.g., NSs or Network Slices). This section describes how to address this issue aligned with the Hexa-X M&O architectural design.

Automation processes

ined set of tasks with minor or no-human intervention.

a) Zero-touch Automation.

Zero touch network is a term used to describe autonomous networks that can heal and adjust themselves, based on the data they collect and analyse across all network elements/functions and activity. This section describes how the Hexa-X M&O architecture can be used to implement th type of automation processes.

b) Autonomic Computing processes.

Autonomic Computing refers systems able to change their behaviour with a high automation degree, being driven by environmental awareness ar high-level policies. It makes it possible to process a large number of events, to generate fast and reproductive response activity. This section describes how AC could be implemented through the M&O architectural design.

c) Closed-loop automation.

Closed-loop control systems are those in which a feedback signal is back-propagated from the system output towards the input, so that the syster output is taken into account to perform the control actions. This section describes how control-loop automation can be implemented based on the M&O architectural design abstractions.

d) Automation in multi-stakeholder scenarios.

This section provides considerations regarding the usage of the automation abstractions in the previous sections, considering their implementatio multi-stakeholder scenarios, such as those envisaged for the future 6G networks.

e) Dynamic self-optimisation of network slices.

The future mobile networks are expected to handle a vast number of network slices with divergent requirements in terms of hardware, compute ar connectivity resources. This section considers the mechanisms enabling dynamic optimisation of network slice operations.

Programmable processes

grammability.

a) Intent-based means for expressing application/service requirements.

Processes to describe application or service requirements by using intents, that could be expressed event in natural language using AI/ML approaches.

b) Enhanced service description models and profiling.

In 6G networks, it is expected a variety of information can be used to specify characteristics, dependencies, or resource constraints for the services, that should be contained in the service description models. This section addresses this topic.

c) Diagnostics processes.

In this section the M&O diagnostic processes are presented from a high-level perspective, considering a holistic approach able to bridge the gaps between the service, network, and infrastructure layers in the M&O architecture. The diagnostic processes are presented as an integral part of the Management Functions, and specifically the Assurance Subsystems, being able to handle the diverse needs of future 6G services and provide automated and programmable operation.

d) Programmable network enablers for reasoning.

The programmability of 6G networks can be exploited by the network intelligence to trigger several automated actions following the zero-touch and data-driven patterns. In particular, reasoning techniques combined with extensive network knowledge representations (e.g., based on ontologies) are in the area of AI/ML are considered relevant to build semantic learning strategies applicable to 6G network M&O. ML and reasoning, together with data and knowledge management, are key enablers for cognitive networks that are expected to play a crucial role in E2E 6G architectures. Processes related to this are addressed in this section.

e) SW Integration Processes

SW Integration Processes are those involving the well-known DevOps processes, such as Continuous Integration and Delivery (CI/CD), which are cesses are introduced in this section.

Data-driven processes

ted at multiple network levels (slice, service, infrastructure etc.).

a) Monitoring and handling processes.

In Hexa-X the monitoring and processing of monitoring data is implemented in the Service Layer, the Network Layer and the Infrastructure Layer. In these layers there can be independent management functions instances that can exchange monitoring data via the API Management Exposure. The overall monitoring, in order to handle E2E optimisation, exchange also information between layers and external domains mixing application and infrastructure-based data.

b) AI/ML-driven orchestration processes.

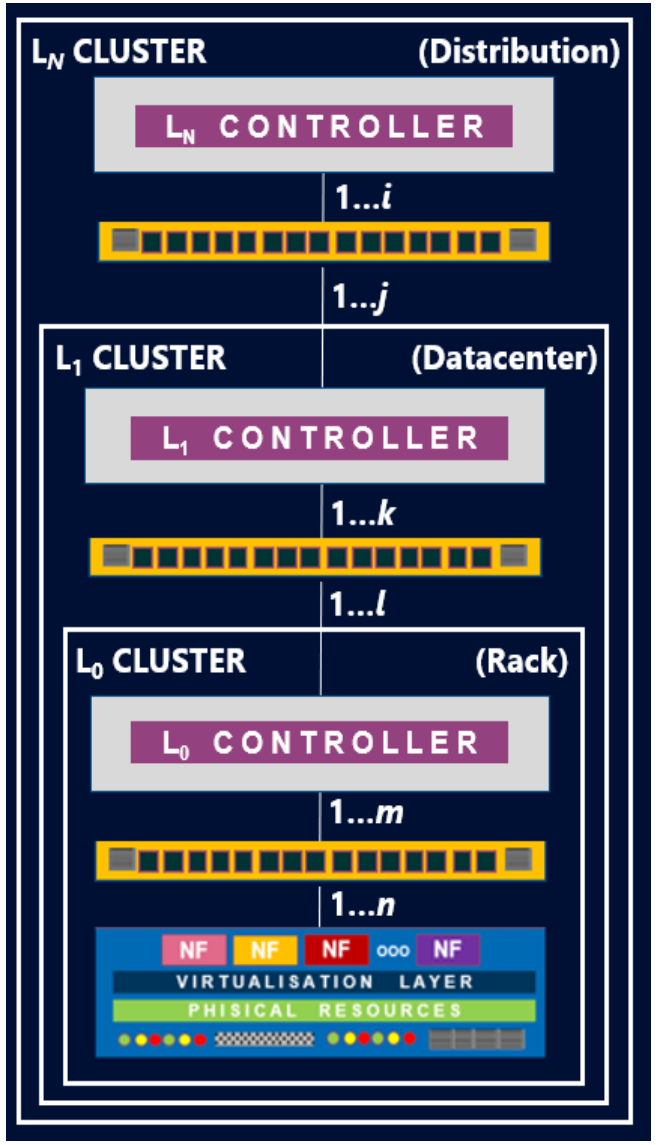
This section considers the integration of some of the most representative AI/ML paradigms into the Hexa-X architecture, i.e., supervised, unsupervised, reinforcement and federated learning paradigms. The objective is twofold: the usage of the AI/ML systems to implement data-driven orchestration strategies, and the deployment of AI/ML systems as one of the M&O actions associated to the Design Layer.

c) Security related processes.

Security is natively incorporated in the Hexa-X M&O system. Specific security-related M&O functions are incorporated in order to gather information from different sources and take appropriate actions to keep the system safe. This section describes how this is implemented in the Hexa-X M&O architecture.

Deployment View

Building Blocks Grouping



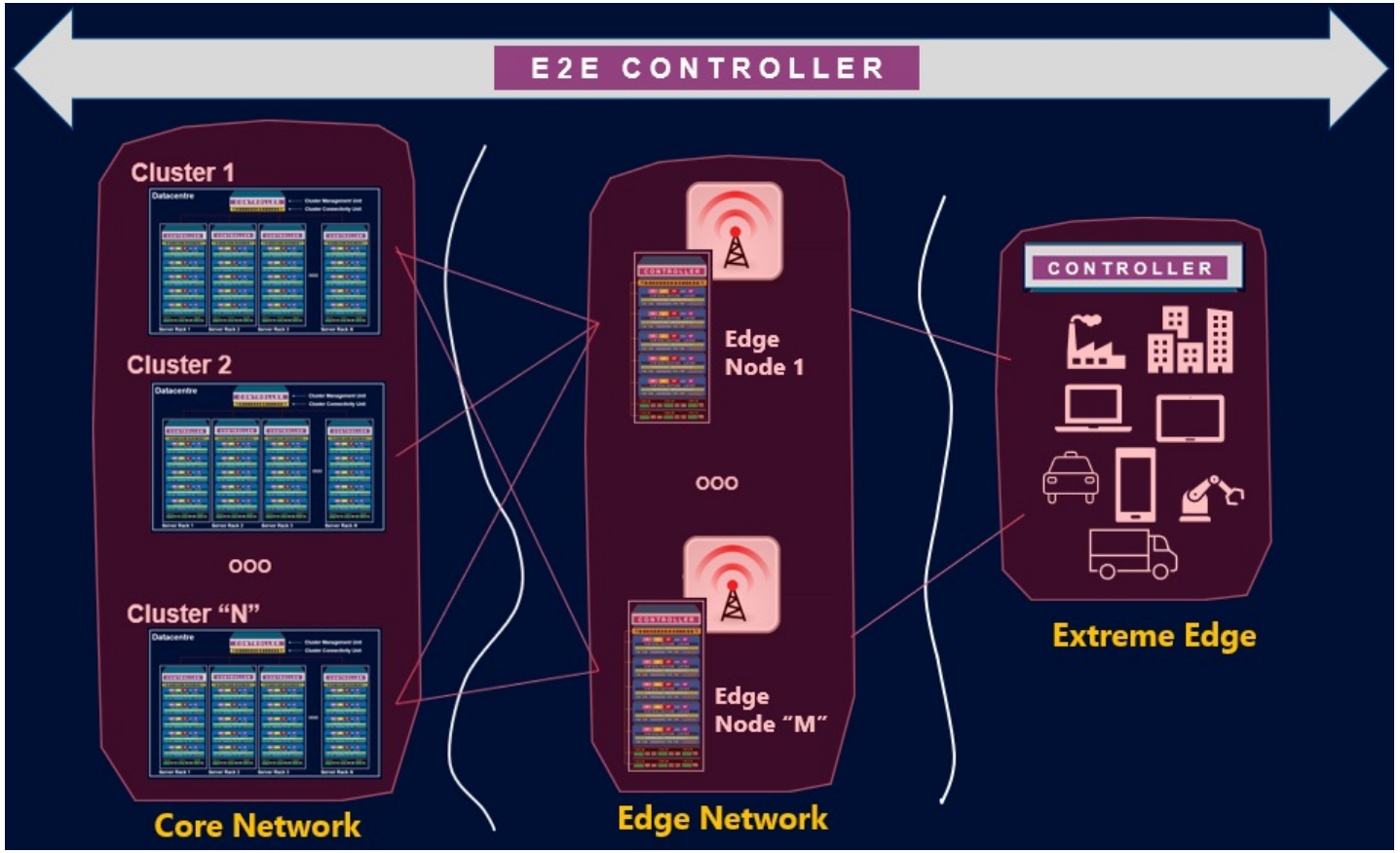
Though deployment aspects can go far beyond the D6.2 scope (e.g., considering HW-related aspects), the deliverable offers a high-level description explaining how the M&O system could be deployed in practice, giving different considerations and possibilities to bring the M&O system towards an actual deployment state.

In the deployment view four main building blocks are defined:

- Computing Units, in charge of executing the Managed Objects.
- Management Units (Controllers), to host and execute the Managing Objects (i.e., the M&O resources).
- Storage Units, that provide the storage capacity by different means, and
- Network Units (network switches), providing the network connectivity among the different units above, and with other network elements.

These building blocks can be grouped in L_0 clusters (servers racks – see figure) that can be recursively scaled as required to build up more complex datacentres and distributions that can be geographically distributed to meet large-scale telco operator's requirements (L_1 and L_N in the figure). In D6.2 *Section "8.3 Grouping Racks"* the pooling of these units is thoroughly analysed considering matters such as Management Units allocation (Centralised VS. Federated).

Extreme-Edge Integration



In the specific case of the Extreme-Edge, some points of presence may have very limited resources or even, some of them, might not be suitable to host the necessary software artifacts to enable them as "orchestrable" resources. Therefore, integrating Extreme-Edge devices into the MNO scope is a major challenge due to the potentially diverse and heterogeneous range of end-user devices that will comprise the Extreme-Edge domain. In order to start addressing this issue, microservice-based software components running on lightweight containers orchestration platforms could be deployed on these end-devices.

As it can be seen in the figure, extreme-edge resources are treated as an additional set of infrastructure resources, that can be also associated to a controller for providing the E2E *continuum* M&O functions. D6.2 *Section "8.5 Integration of the extreme-edge"* explores this topic and covers two different options to provide this functionality: federated lightweight controllers, or a set of "trusted" Management Units within the MNO scope.

KPIs, KVIs and Core Capabilities

KPIs (I)

D6.2 identifies a set of KPIs considered relevant regarding M&O, aligned with the Key Value Indicators (KVIs) and Core Capabilities already defined for the Hexa-X project in the previous Deliverable D1.2:

KPI	Brief description	Related KVIs	Core Capabilities
Latency [s]	M&O can impact in latency by moving resources from one domain to another.	Trustworthiness	Flexibility
Storage Capacity [Bytes]	Refers to the space available to allocate managed objects.	Sustainability	Flexibility Embedded Devices
Processing Capacity [Number & Type of processing units]	Refers to the processing units (PUs) available to execute both: managing and managed objects. The number of each different type of PUs should be considered (e.g., CPUs, GPUs, FPGAs, TPUs…).	Sustainability	Flexibility Embedded Devices
Programmability [%]	Indicates the number of devices in the architecture aligned with the SBMA pattern and the different possibilities of the exposed APIs (grade of programmability)	All KVIs	Flexibility
Energy efficiency [W]	Based on the optimised placement of managed objects and exploiting elasticity.	Sustainability	Integrated intelligence Flexibility
Creation time [s]	The time it takes to create the different manged objects.	-	-
Availability [%]	Percentage of time a system is available.	Trustworthiness	Flexibility
Reliability [%]	Measures how long a system can perform its intended function without interruption, i.e., it measures the failure rate of a system.	Trustworthiness	Integrated intelligence Flexibility

KPIs (II)

KPI	Brief Description	Related KVIs	Core Capabilities
AI/ML models training time [s]	Training time could vary from the different AI/ML techniques.	All KVIs	Integrated intelligence
Security by design [Boolean]	Security should be considered from the initial stages of the system design.	Trustworthiness	-
Maintainability [Degree]	Maintainability refers the ability of a system to be retained in, or restored to, a state in which it can perform as required under given conditions of use and maintenance.	Trustworthiness	Flexibility
Scalability [%]	The ability of the system to scale its resources in order to manage the high demand from 6G heterogeneous resource.	Inclusiveness	Flexibility
Elasticity [Degree]	The degree to which a system is able to adapt to workload changes by provisioning and de-provisioning resources in an autonomic manner, such that at each point in time the available resources match the current demand as closely as possible.	Sustainability	Flexibility Integrated intelligence
Resiliency [%]	The ability of the network to continue operating correctly during and after a natural or man-made disturbance, such as the loss of mains power.	Trustworthiness	Flexibility Integrated intelligence
Automation [Degree]	Full network automation is driven by high-level policies and rules without minimal human intervention, with networks being capable of self-configuration, self-monitoring, self-healing, and self-optimisation. Lowest automation degree means no automation.	Trustworthiness Sustainability	Flexibility Integrated intelligence
Intent expressiveness [Degree]	Refers to the M&O system's ability to support orchestration actions expressed by means of high-level intent declarations.	Inclusiveness	Integrated intelligence

Summary & Conclusions

Summary & Conclusions

- Hexa-X WP6 D6.2 considers the main features and enablers identified in D6.1, in order to create the document structure and its methodology.
- Presents the rationale leading to the creation and description of the Hexa-X M&O Architectural design. It has been described by means of three architectural views: Structural, Functional, and Deployment views. Built upon them, a specific section has been included describing how this M&O Architecture may be aligned with actual or future relevant standards.
- Several 6G technological challenges are addressed, such as: AI/ML-driven orchestration, automation and network programmability, intent-based mechanisms, adoption of cloud-native principles maintaining backward-compatibility with traditional virtual appliances…
- Cognitive-based service M&O mechanisms are provided and described through a set of specific AI/ML Functions. Optimised placement (together with resource optimisation and dynamic allocation) are also specifically addressed.
- Data driven mechanisms and Device-edge-cloud continuum orchestration mechanisms are thoroughly described.
- Finally, a set of relevant M&O KPIs are described and related to the main KVIs and Core Capabilities.

Thank you!

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