



eSAAM 2023

on Cloud to Edge Continuum

NEMO: Building the Next Generation Meta-Operating System

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Oct. 17, 2023

Ludwigsburg, Germany

NEMO: Building the Next Generation Meta-Operating System

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NEMO Identity Card

- 📄 **Title: Next Generation Meta Operating System**
- 📄 **Grant Agreement No.: 101070118**
- 📄 **H2020 Call: Horizon-CL4-2021-DATA-01-05**
- 📄 **Funding Instrument: RIA (Research and Innovation Action)**
- 📄 **Coordinator: ATOS – Technical Coordinator: Synelixis**
- 📄 **Duration: 36 months – Starting Date: September 01, 2022**
- 📄 **EU Contribution: 10.5 M€ – Cascading Funding: 1.8 M€**
- **26 Partners – 9 Countries (ES, FR, IT, RO, LU, GR, DE, FI, CH)**
- **8 Use Cases – 5+1 Living Labs/Pilots**

26 Partners

Next Generation Meta Operating System

~ 11 M€



1 September 2022

36 months

Large Industries

Atos
THALES

INTRASOFT
INTERNATIONAL
ENGINEERING
SPACE
HELLAS

Living Labs

Maggioli

Continental

SIMAVI

Telecoms

Telefonica

OTE **WINDTRE**

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SYNELIXIS
ENTERSOFT
Cumucore
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Introduction



Introduction – General Framework

Challenges:

- The **rapid expansion of the Internet of Things (IoT)** in parallel with the **deployment of 5G/B5G infrastructures**, strongly “influences” the way “*how modern digital technology/facilities interacts with human life*”.
- The **extended growth and deployment of interconnected “things”** supports the **rise of an immense variety of vertical applications** (*i.e., ranging from urban mobility to smart agriculture and energy management*) covering a **multiplicity of market sectors**.
- The global technical evolution promotes the **introduction of the Artificial Intelligence of Things (AIoT) within a fully converged environment**, supporting AI integration with our connected world.
- However, **this transformation poses distinct and critical challenges**, *specifically with regards to the provision of real-time, secure and trusted support from edge cloud systems, coupled with AI.*

Introduction – Responses from NEMO

The NEMO platform:

- **Acknowledges the need for on-device intelligence** to enable AIoT to act as semi-autonomous entities, and;
 - **recognizes that this “intelligence” should be an integral part of the AIoT meta-Operating System (mOS).**
- **By focusing on a transparent IoT-to-Edge-to-Cloud continuum**, NEMO aims to optimize task migration securely, **providing timely orchestration of micro-services.**
- **NEMO recognizes the importance of providing efficient development tools:**
- **By offering intent-based DevZeroOps tools and plugin mechanisms**, it **facilitates faster development and wider deployment of related AIoT services.**
 - A **“key” part of NEMO’s strategy is to support provision of an open and modular mOS**, ensuring easy deployment to any AIoT device while maintaining stringent cybersecurity and privacy standards.
- **NEMO acknowledges the necessity for high penetration of AIoT applications**, **implicating for fostering relationships with open-source communities and incentivizing third parties** (especially SMEs and AIoT developers), to adopt and use this technology.
- **NEMO capitalizes on existing ecosystems (such as GAIA-X and Eclipse IoT)**, **leveraging their strengths to “enhance” its own capabilities**, paving the way towards the forthcoming AIoT era.



NEMO's Conceptual Approach- Overview



NEMO's Conceptual Approach

View:

- ◆ **AIoT is among the future big concepts to support social change and economic growth via “inclusion” of ICT, also focusing upon the development of solutions with high market values.**

Context:

- ◆ Fully distributed **computing and federation** between heterogeneous IoT, edge and cloud nodes **introduce cybersecurity concerns.**
- ◆ There is **no standard method** to describe a cybersecurity, Intrusion Detection System (IDS), policy or privacy enforcement system; **thus, provision of end-to-end (E2E) cybersecurity over an ad-hoc IoT fog/cloud becomes quite complicated...**
- ◆ Applied survivability and self-healing methods consider various factors:
 - *securing cyber assets;*
 - *modelling, simulation & analysis to understand/enable fundamentally robust & fault-tolerant systems,*
 - *dedicated systems architecture that can overcome vital limitations.*

However, the diversity of equipment and protocols used in the communication and control of IoT together with the lack of interoperability create significant obstacles for establishing secure communications.



NEMO's Conceptual Approach

Expectations:

- ➔ **NEMO aims to establish itself as the “game changer” of the AIoT-Edge-Cloud continuum by:**
 - *introducing* an open source, modular and cybersecure meta-operating system;
 - *leveraging* on existing technologies, and;
 - *introducing* novel concepts, methods, tools, testing and engagement campaigns.
- ➔ **NEMO will bring intelligence “closer to the data” and will make *AI-as-a-Service* an integral part of *network self-organization and micro-services execution orchestration*.**
- ➔ **NEMO's penetration and massive acceptance *will be achieved via:***
 - *new technologies;*
 - *pre-commercial exploitation components, and;*
 - *effective liaison with open-source communities.*



NEMO's Architecture and Essential Technologies



NEMO mOS Architecture

Fundamental concerns/principles for structuring NEMO architecture:

- **NEMO pursues a close collaboration among various functional architectural “modules” including:**
 - *semi-autonomous IoT nodes;*
 - *IoT fog clusters;*
 - *far-edge and near-edge cloud, and;*
 - *national and federated cloud infrastructures.*
- **NEMO follows a flexible collaboration model with new generation AIoT nodes “equipped with intelligence” to:**
 - *function in a semi-autonomous mode;*
 - *reduce latency; and*
 - *perform a number of complex operations locally, without transporting raw data.*
- **Federated on-device learning and data sovereignty and trusted/explicitly attested (edge) cloud nodes aim to bring AI especially to environments with limited network coverage, to improve performance and operations.**
- **The use of Local AI models (FML (Federated Machine Learning), DRL (Deep Reinforcement Learning) and TL (Transfer Learning)) will result in reduced latency.**



NEMO mOS Architecture

Fundamental concerns/principles for structuring NEMO architecture (continued):

◆ IoT devices may get support from

- other IoT nodes in vicinity or
- a trusted edge cloud node, or
- the cloud

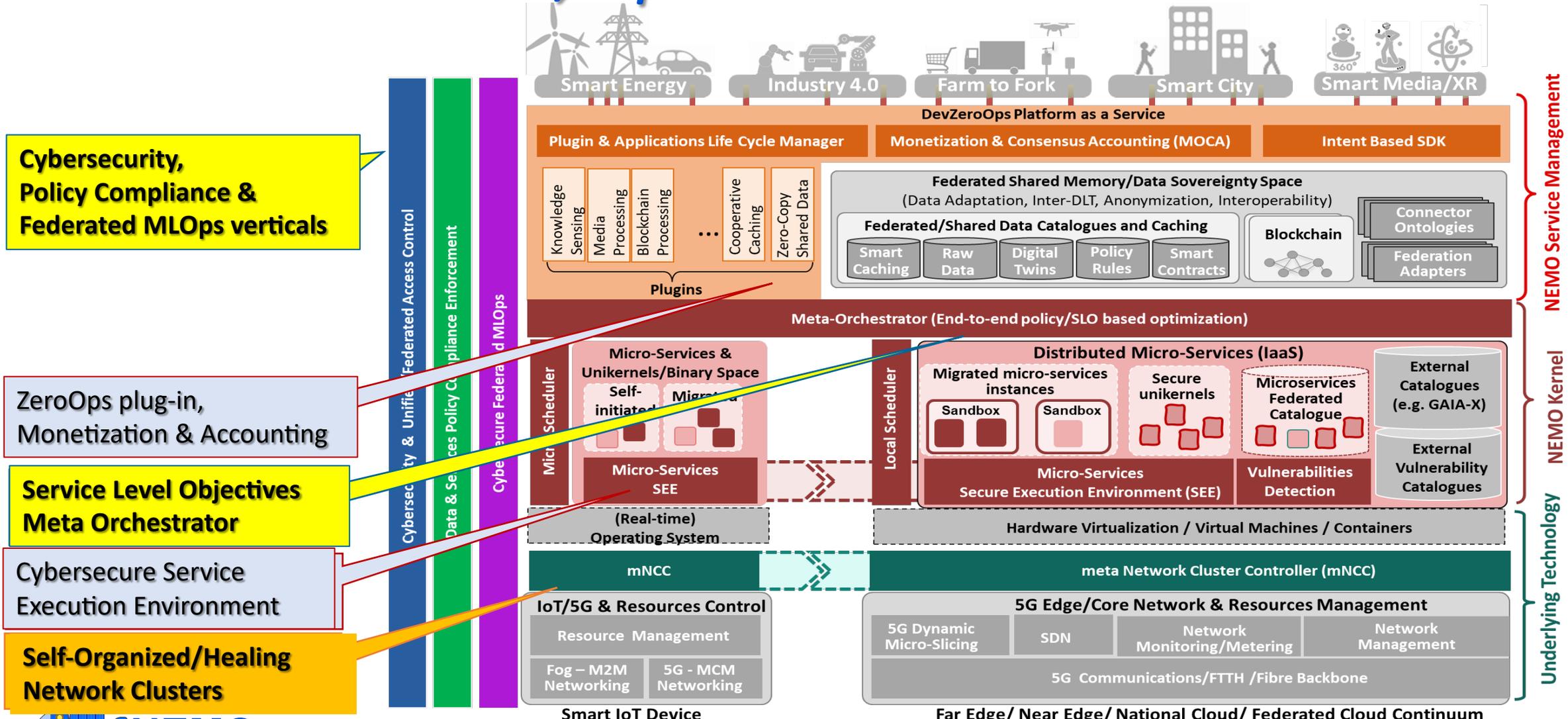
with the aim of realizing a transparent AIoT-Edge-Cloud continuum.

- ◆ *During off-line training, the federated ML models will be aggregated at an edge node, to be processed and combined through TL.*
- ◆ *The inter-DLT (Distributed Ledger Technology) transactions and the smart contracts will be facilitated by trusted edge nodes, allowing resource constrained nodes to acquire a full “ground truth” using novel approaches.*
- ◆ *Complex and potentially malicious functions will be executed at the edge nodes, using a secure micro-services framework and container-based sandboxing techniques.*



NEMO Technological Innovation in a Nutshell

Full Stack, open source meta-OS



Cybersecurity, Policy Compliance & Federated MLOps verticals

ZeroOps plug-in, Monetization & Accounting

Service Level Objectives Meta Orchestrator

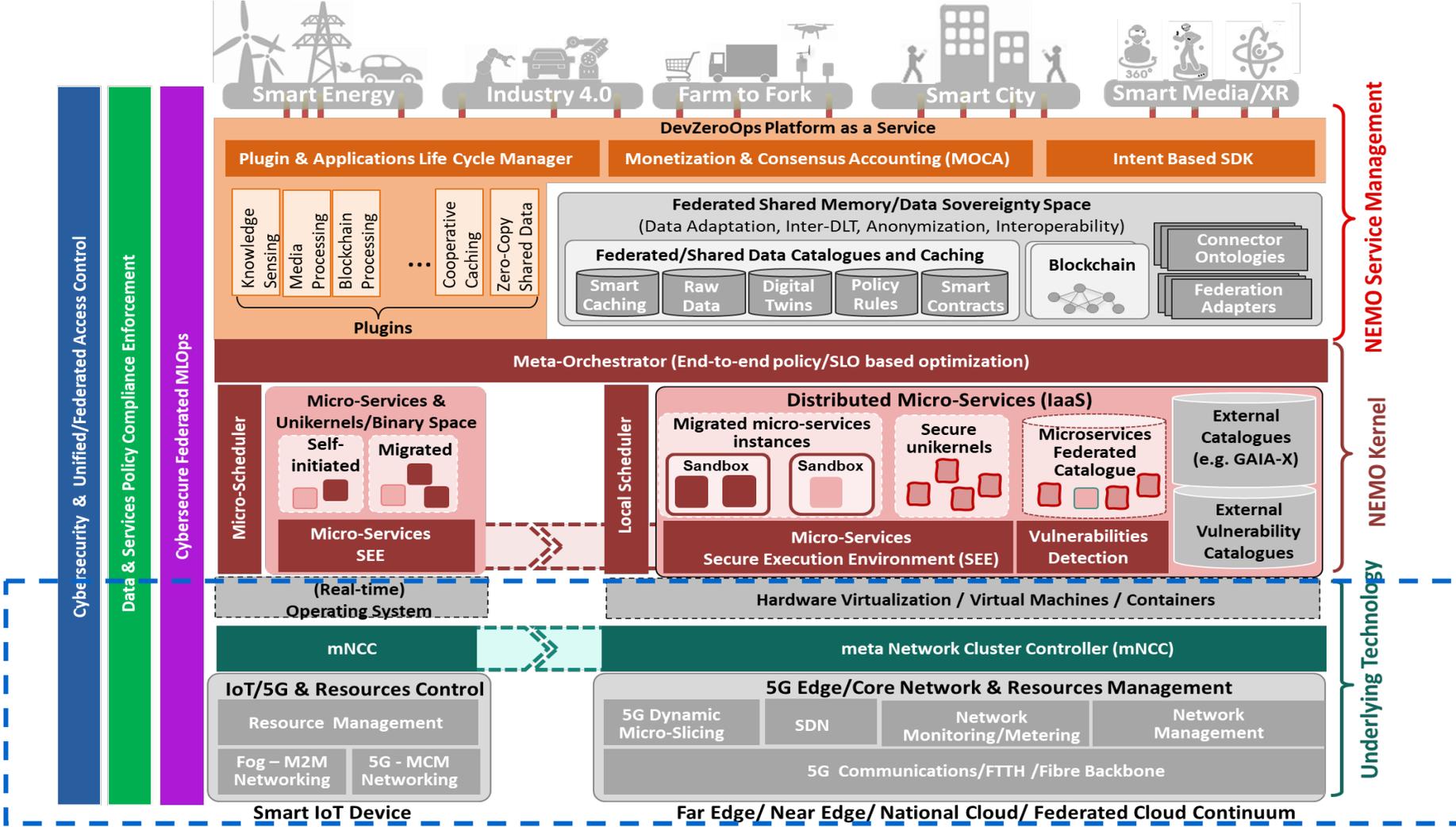
Cybersecure Service Execution Environment

Self-Organized/Healing Network Clusters



NEMO Technological Innovation in a Nutshell

Full Stack, open source meta-OS



NEMO mOS Architecture

Realisation of transparent network connectivity consisting of (i) a set of **IoT/5G/6G network optimization functions** and; (ii) **dynamic allocation of self-aware resources**, into **self-constructed/self-healing** and **zero-delay failback network clusters**.

Aim	Response - Actions
Offering ad-hoc/opportunistic clouds and zero delay failback “by design”, in the IoT-to-Edge-to-Cloud continuum.	Introduction of a polymorphic <i>meta Network Cluster Controller (mNCC)</i>: (i) to interface independent and different tools and protocols, and; (ii) to replace one technology with another.

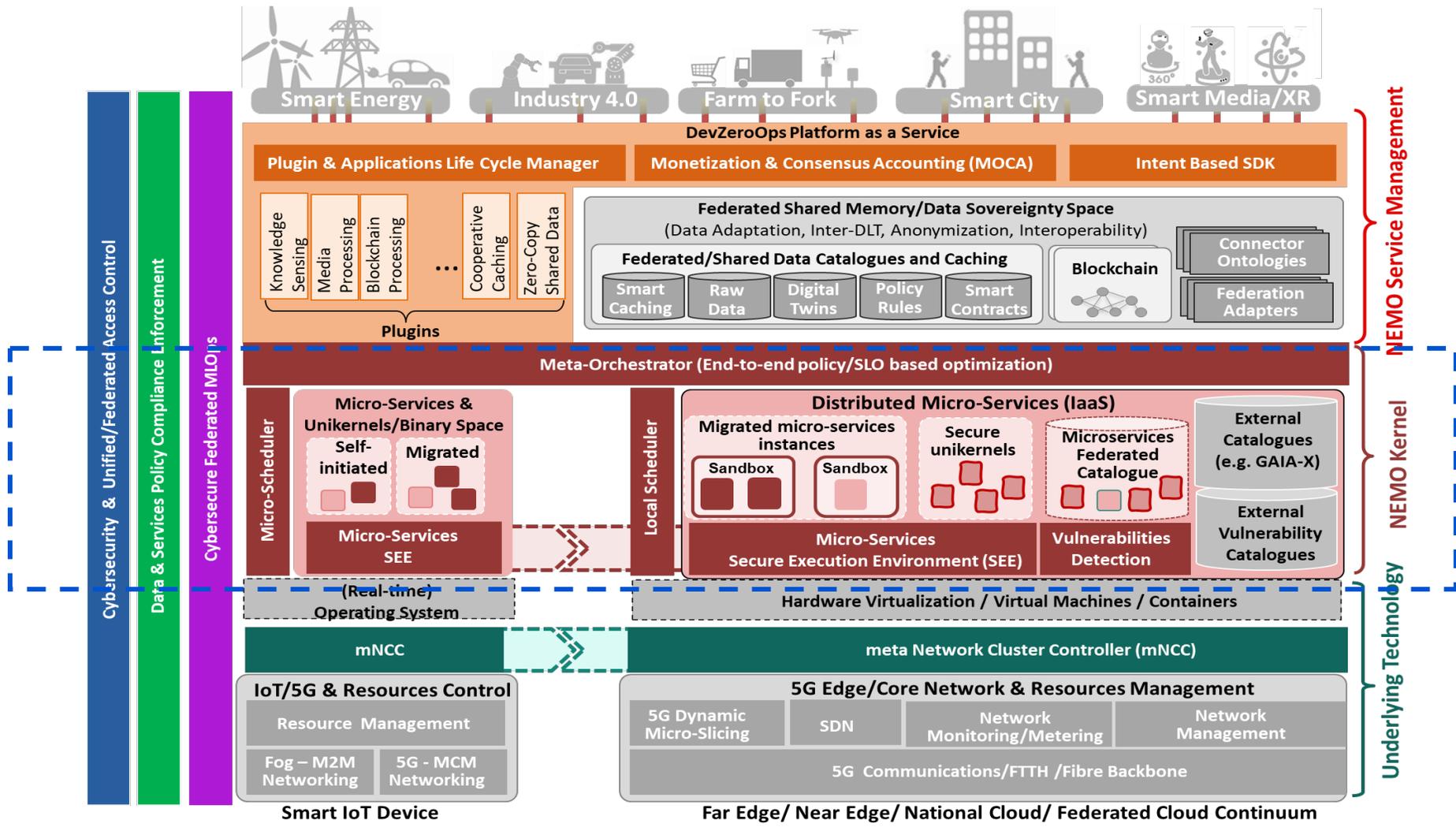
Specific actions:

- **Study and validation of various options** including **Eclipse Zenoh.net** and **ETSI OSM**, along with various **multi-path connectivity approaches** (i.e.: **MPTCP** (Multipath Transmission Control Protocol) / **CMT-SCTP** (Concurrent Multipath Transmission – Stream Control Transmission Protocol) / **AEPS** (Adaptive and Efficient Packet Scheduler)), **dynamically constructed via secure FML models and experimentation with network zone and path-aware protocol stacks** (i.e. **QUIC**) that encapsulate control and/or data plane information.
- **Experimentation with full micro-services isolation.**
- **To gain accurate information from network resources but keep flexibility and openness, NEMO will interface existing Monitoring Tools** (e.g.: **CNCF** (Cloud Native Cloud Foundation), **Prometheus** and **Thanos**) **and Network Management tools** (e.g. **ETSI MANO**) to request dedicated resources.
- **Use of TSN (Time Sensitive Networking) bridge technology and time synchronization aspects to validate service stability, quality and compatibility with IEEE TSN systems.**



NEMO Technological Innovation in a Nutshell

Full Stack, open source meta-OS



NEMO mOS Architecture

<i>Aim</i>	<i>Response - Actions</i>
Offering the NEMO core functionality	Introduction of an AI-based meta-Orchestrator , able to: <i>(i) automatically -and in real-time- reconfigure the mOS setup at each system node</i> <i>(ii) allow E2E federation to operate optimally and;</i> <i>(iii) “match” applications’ SLOs (Service Level Objectives) and policies set by the mOS administrators.</i>

Specific actions:

The meta-Orchestrator will consider:

- **existing solutions such as open source containers’ platforms and orchestrators** (i.e. Docker, Kubernetes, Minikube, K3S, MicroK8s, Kubermatic or OpenShift), together with
- **technological, business and policy priorities** (ranging from high availability and low latency to reduced energy consumption and CO2 footprint to cost and community incentives trade-offs).

It will dynamically (re-)render micro-service and unikernels or even update automatically the hosting clusters.

It will support secure and transparent migration of Virtual Machines (VMs) between federated Data Centers.



NEMO mOS Architecture

Aim	Response - Actions
Offering a “security by design” concept	Introduction of a novel Secure Execution Environment (SEE) , to: <i>(i) implement operational tasks in close cooperation with micro-services.</i> <i>(ii) allow use of the SotA and most advanced programming language in security (e.g. RUST).</i>

Specific actions:

- A version of the SEE for the edge cloud is already under development **in the IoT-NGIN project** and a version for IoT devices will be implemented within NEMO.
- NEMO SEE will manage the complete micro-service life cycle, *from image migration and storage up to hosting, execution and supervision of both fully trusted/digitally signed micro-services instances along with potentially malicious ones.*
- Cyber-secure ML model will be continuously updated, *from external Vulnerability Catalogues.*



NEMO mOS Architecture

<i>Aim</i>	<i>Response - Actions</i>
Support of Data Sovereignty Space at design phase	Introduction of a Federated Data Sovereignty Space, to: <i>(i) follow the GAIA-X approach.</i> <i>(ii) adopt some of the emerging Self-Sovereign Identity (SSI) technologies.</i>

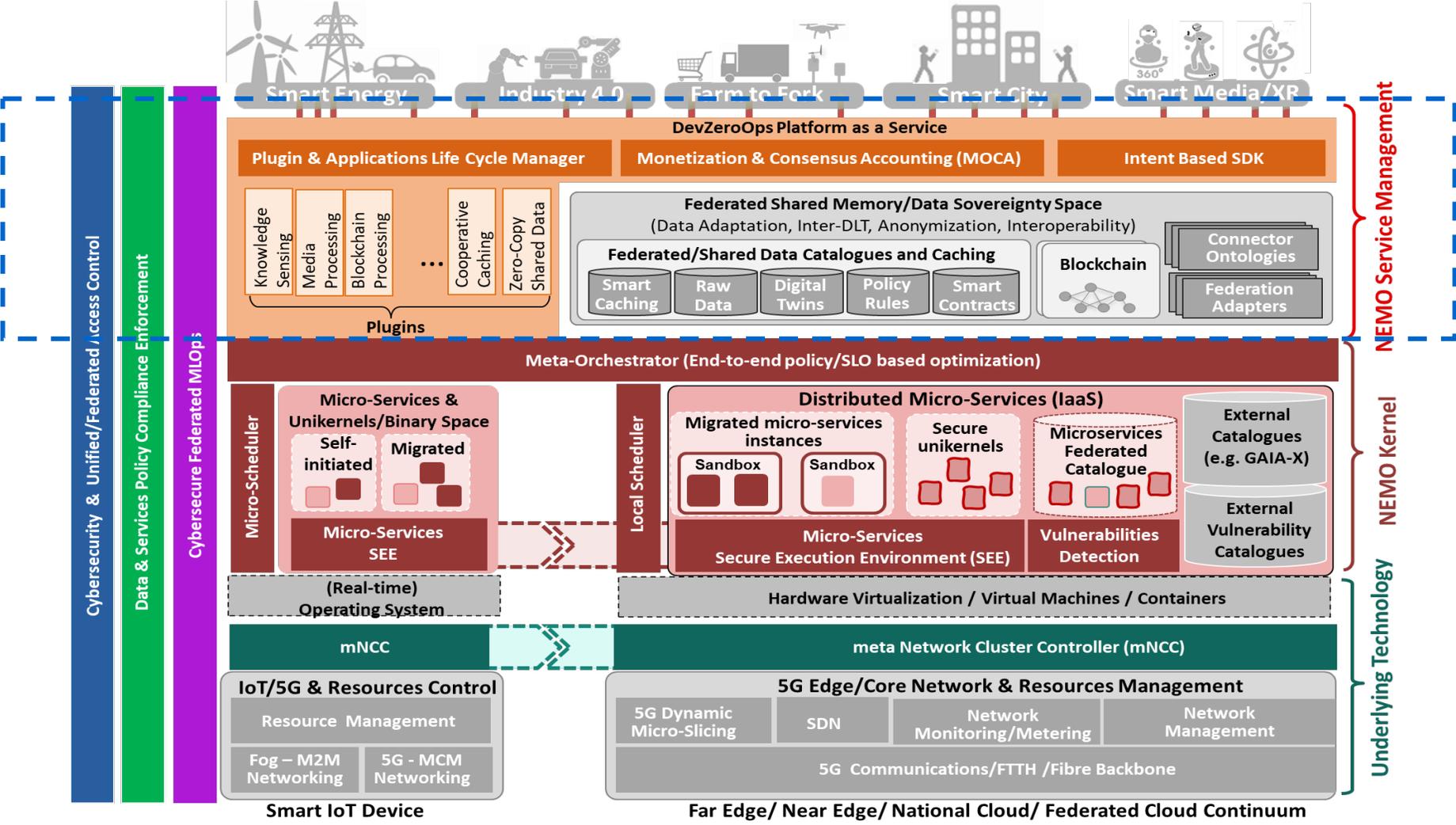
Specific actions:

- **The cyber-security of data sharing federation will be based on DLTs.**
- **Insights from other EU projects (SOFIE and PHOENIX) will be used to:**
 - *introduce the novel CMDT (Cybersecure Micro-services' Digital Twins) concept;*
 - *offer DLT (Distributed Ledger Technology) traceability, and;*
 - *offer DT (Digital Twin) scalability to micro-services instances.*
- **The NEMO Data Space will be open to support technologies for green and responsible data management.**



NEMO Technological Innovation in a Nutshell

Full Stack, open source meta-OS



NEMO mOS Architecture

Aim	Response - Actions
Developing a DevZeroOps Platform as-a-Service (PaaS)	Introduction of a DevZeroOps layer, offering: <i>(i) Full stack automated operations;</i> <i>(ii) greatest flexibility;</i> <i>(iii) improved developers' productivity;</i> <i>(iv) direct monetization and sustainability.</i>

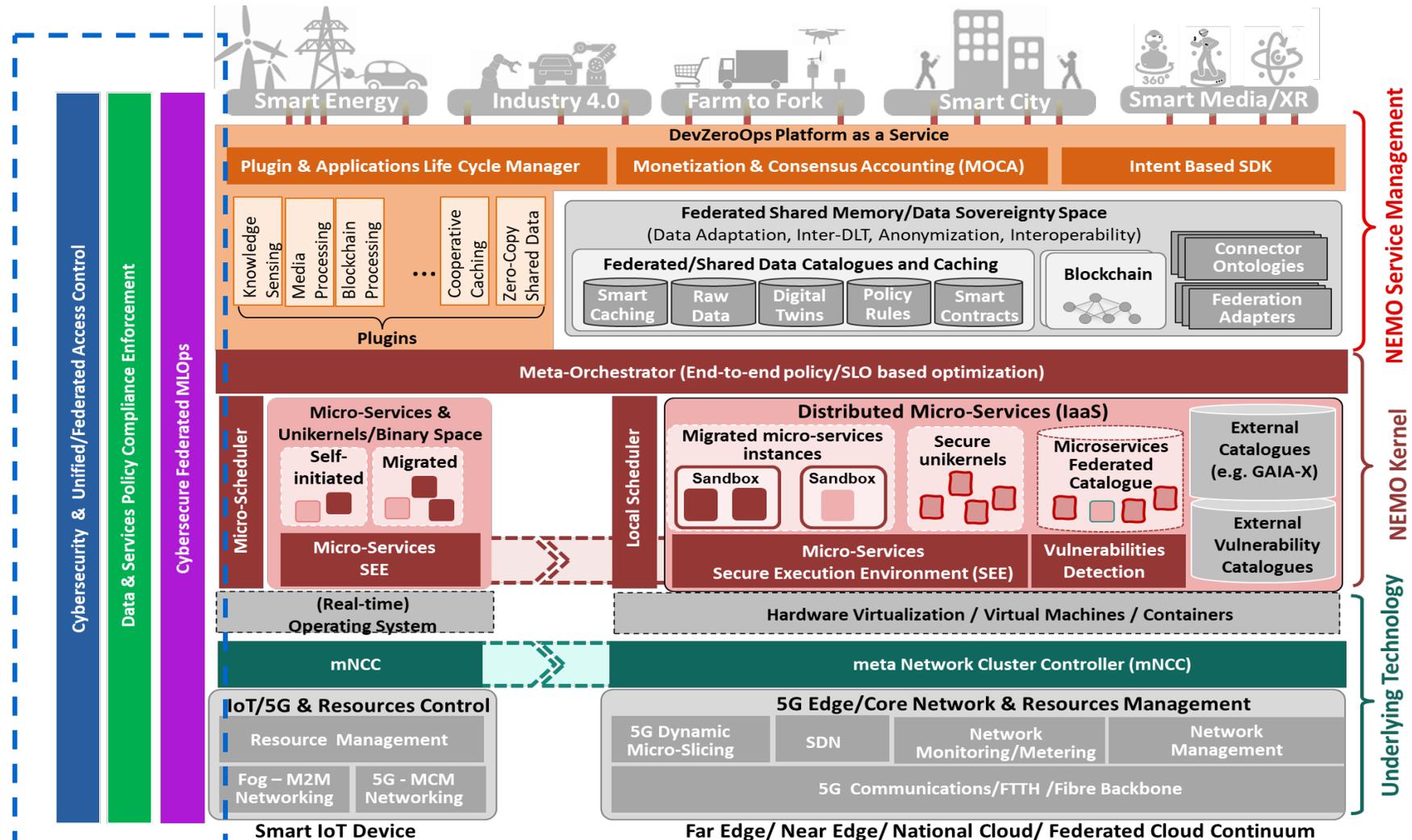
Specific actions:

- **Developing a flexible Plugin & Applications Life-Cycle Manager** to: *(i) enable over the air and on-time deployment of required plugins and; (ii) keep NEMO “kernel” size tiny, while enabling cognitive auto-configuration.*
- **Interfacing external plugins and microservices catalogues (e.g. GAIA-X, SONATA)** to offer a “living” collection of functionalities, published under open source license.
This approach will allow third parties to select among the components and create new innovative IoT services.
- **Offering of a “Intent Migration as a Service”:** Towards ZeroOps deployment, this task will fully automate traditional manual processes and deliver configurations towards full-stack automated operations (i.e.: service provisioning, resource configuration, applications life cycle management and automated response to infrastructure issues).
- **Inclusion of MOCA (Monetization and Consensus-based Accountability) to support pre-commercial exploitation in a multi-user, multi-operator, multi-tenant environment.**



NEMO Technological Innovation in a Nutshell

Full Stack, open source meta-OS



NEMO mOS Architecture

<i>Aim</i>	<i>Response - Actions</i>
Broader support of all mOS activities	Introduction of 3 distinct Vertical Layers

Cybersecure Federated MLOps (Machine Learning Model Operationalization Management) Layer:

- **Offers efficient on-device intelligence** in the form of decentralized, cybersecure FML/DRL to be used as integral part of any IoT node decision or (semi-) autonomous operation.
- **Realization of research towards cybersecure FML** to identify malicious/suspicious IoT nodes.

PRESS (Privacy, data Protection, Ethics, Security and Societal) & Policy compliance Layer:

- **NEMO will enforce PRESS via multi-faced policies**, able to cope with the different aspects of the applications life cycle (security, privacy, costs, environmental impact, etc.).
- **Multiple relevant paradigms** from the cloud-native world **will be researched and selectively adapted** to cope with core network utilization/performance, PRESS and native encryption.

Cybersecurity & Unified/Federated Access Control Layer, that:

- **Offers cloud native cybersecurity;**
- **interfaces with various authentication and authorization frameworks** (e.g. 5G-AKA, EAP-AKA), and;
- **adopts the federated ID approach of GAIA-X**, along with encryption and identity verification.



NEMO - Pilots and Use Cases



NEMO Pilots and Use-Cases

Pilot 1: Smart Farming, Greece

- Aerial Precision Bio-Spraying
- Terrestrial Precision Bio-Spraying

Pilot 2: Smart Energy & Smart Mobility, Italy

- Smart Grid Flexibility
- Smart Mobility/City

Pilot 3: Smart Manufacturing & Industry 4.0, Germany

- Fully automated indoor logistics/supply chain
- Human-centered indoor factory environment safety

Pilot 4: Smart Media & XR, Greece

- Round of Athens Race
- XR Time Machine

Verticals

✓ **Farming**

✓ **Energy**

✓ **Mobility/transportation**

✓ **Industry 4.0**

✓ **Media/smart city & XR**



NEMO Pilots and Use-Cases

Pilot 1: Smart Farming, Greece

Combination of multiple types of ground micro-climate/soil/leaf information stations, agri-drones, semi-autonomous mobile robots and wearable devices to reduce spraying and support organic olives harvesting

Aerial Precision Bio-Spraying:

- Aims to protect the olive trees from olive fruit fly**, while preserving the organic certification.
- Combination of micro-clima data and real-time video analysis of the crop, from visual and multi-spectral cameras located on semi-autonomous drones flying over the olive trees plantation.**
- Validation of the execution of real-time CF-DRL based video analysis on the drone, applying migration of the video analysis task and dynamically adjust drones' trajectory to introduce optimal, precision aerial bio-spraying only in areas of interest.**

Terrestrial Precision Bio-Spraying:

- Organic insecticides preserve the bio-certification, but require frequent spraying**, while in larger quantities increase the cost and may also affect the bees.
- The scope is to **use semi-autonomous robots equipped with cameras to locate weeds and enable optimal precision spraying with organic insecticide** (pyrethrin).
- Using NEMO CF-DRL, involved robots will be able to act**, by avoiding workers (safety) and trees (operating reasons).



NEMO Pilots and Use-Cases

Pilot 2: Smart Energy & Smart Mobility, Italy

Combination of energy data collected from high tech power sensors, smart meters, PV cell controllers **to optimize the grid operations.**
Data collection via IoT devices, charging stations, EVs and video analysis of cameras **to model/train distributed AI models on parking prediction.**

Smart Energy Flexibility:

- ✚ Aims to **improve distribution grid operation and the power quality** and **reduce impact on the grid** due to voltage variations caused by reverse power flows.
- ✚ **NEMO will investigate advanced AI/ML based analytics to identify potential local energy grid discrepancies and monitor power quality**, to **provide timely alarms** when the system is approaching unstable operational boundaries, being able to lead to power failures.
- ✚ **Offering of benefits for balancing intermittent feed-in from Renewable Energy Sources (RES).**

Smart Mobility City:

- ✚ Aims to **improve RES load balancing** via EV (Electric Vehicle) chargers.
- ✚ **Intends to predict traffic flow/parking prediction** via EV chargers and parking positions for Mobility.
- ✚ **Realization of driver-friendly scenarios for smart city mobility and dispatchable charging of EVs based on RES demand-response, along with human-centred smart micro-contracts and micro-payments.**



NEMO Pilots and Use-Cases

Pilot 3:
Smart Manufacturing & Industry 4.0,
Germany

Improvement of mass production and safety in factories with high levels of automation.

Fully automated indoor logistics/supply chain:

- ✚ This use case targets **ADAS (Advance Driver Assistance System) manufacturing**.
- ✚ The aim is to fully automate controlled material picking from Auto Store and autonomous transfer to the production line.

Human-centred indoor factory environment safety:

- ✚ **Provision of a high precision AGV (Automated Guided Vehicles) localization layer** merging real-time localizations info, obtained from cognitive sensors (safety cameras, radar and lidar).
- ✚ A high speed and ultra-low latency (Time Sensitive Networking-TSN) private wireless network will support massive data uploads to the edge cloud facilities, where AI functions will detect the position of each body and build a “safety shell” around it, to ensure human-centred safety.
- ✚ Federated CF-DRL will enable model transfer learning to the AGVs, to enable autonomous avoidance of potential collision between AGVs, or between a worker and an AGV.

NEMO Pilots and Use-Cases

Pilot 4: Smart Media/City & XR, Greece

Combination of multiple heterogeneous smart wearables, 3D video projectors, advanced AR/VR/XR headsets and low cost devices (i.e.: smartphones and tablets)

Round of Athens Race:

-  **Related media content will be captured by many spectators along the running circuit by using smartphones, a few professional and CCTV (Closed-Circuit Television) cameras.**
-  **Incoming content will be automatically processed, annotated and rendered (partially on the device using already trained AI/ML models and partially at the edge), while a selection will be directly broadcasted (e.g. via social media) based on location info of the (top) runners and interesting events during the race.**
-  **Audience will be able to: (i) improve its contributions, and; (ii) interact with contributors in case of specific race incidents.**

XR Time Machine:

-  **“Pushing” the boundaries of immersive experience by optimizing multi-sensorial stimuli via effects such as wind, heat, vibration, in addition to audiovisual (AV) and tactile.**
-  **Creation of an environment that will enable multiple users to interact with virtual or augmented/XR worlds (e.g., ranging from a virtual trip to a house in Ancient Greece to augment dinosaurs in today's world).**



NEMO – Summary & Future Work



NEMO - Vision

Towards creating and supporting:

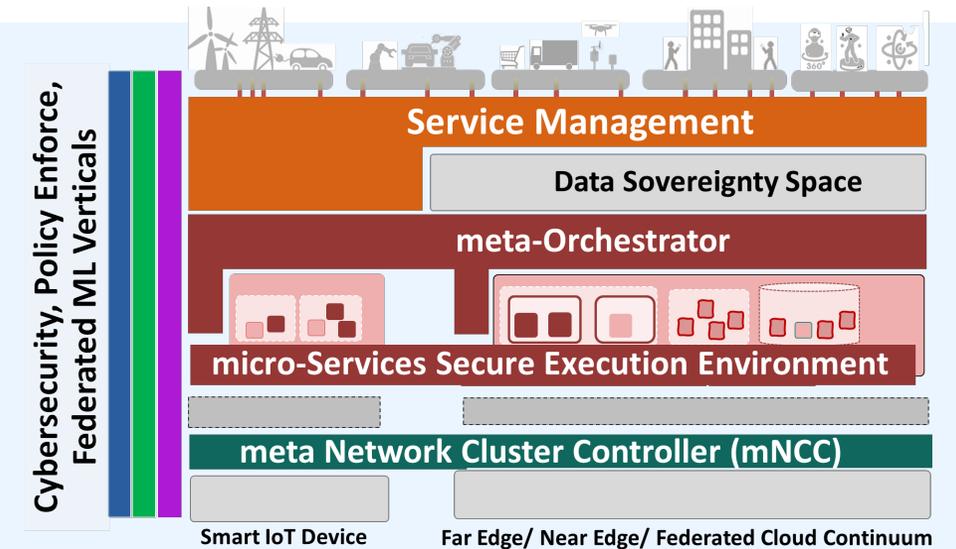
- ***On-device Intelligence*** to enable AIoT (inter-)acting as self-aware, (semi-) autonomous entities
- ***Transparent IoT-to-Edge-to-Cloud continuum***
- ***Intent-based*** DevZeroOps tools and plugin mechanisms
- ***Open and modular meta-Operating System (mOS)***
- ***Massive AIoT applications and high penetration in the market***



NEMO - Overview

1) Technological Innovations

- ◆ Full stack, fully configurable, cloud-native, data aware meta-OS
- ◆ Bring intelligence closer to data/make AI integral part of meta-OS
 - Self-Organized/Healing Network Clusters/5G/6G Integration
 - Cybersecure micro-Service Secure Execution Environment (mSEE)
 - SLO/EE based self-optimized meta-Orchestrator
 - ZeroOps Plug-in mechanism
- ◆ Cybersecurity, Privacy Compliance & Federated ML verticals



2) Strengthening the EU competitiveness

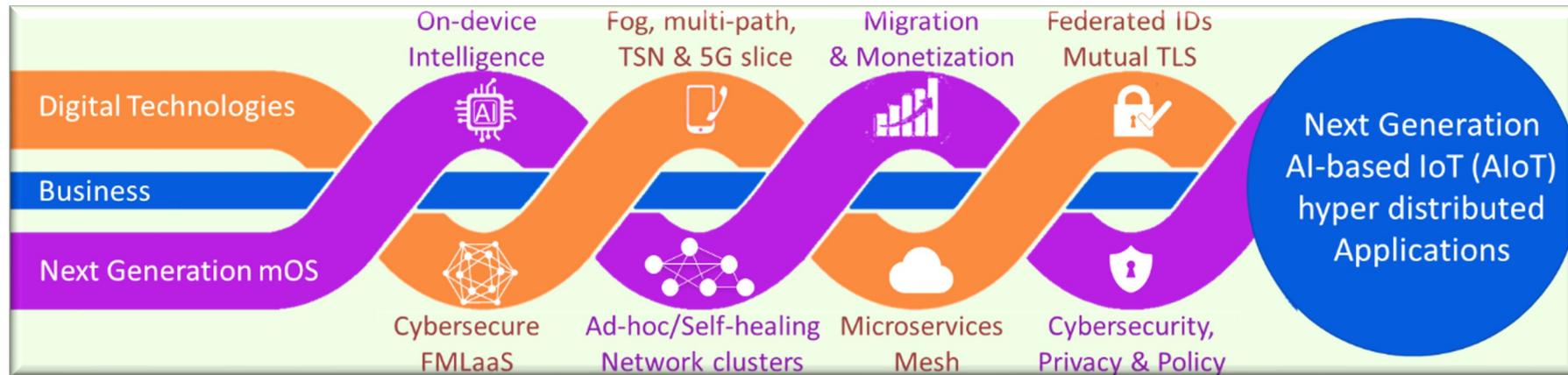
- ◆ Fully compatible with DataSpace evolution/standards
- ◆ Pre-commercial exploitation components (MOCA)
- ◆ FAIR datasets/Smart-X Labs (Farm, Energy, Mobility, Industry, Media)
- ◆ Widespread penetration
- ◆ 1.8M€ for testing and adoption via 2 Open Calls

3) Expected Impact (Technical, Economical, Environmental and Social)

- ✓ Novel components, tools, methods
- ✓ Dataspace & IoT-Edge continuum integration in reality
- ✓ New paradigms in Smart-X Apps delivery
- ✓ Push processing to cloud => directly reduce CO₂
- ✓ Smart Agriculture: reduce pesticides/spraying/soil erosion....
- ✓ Closing the digital gap by enabling Smart-X Edge processing
- ✓ Reinforcing competitiveness via open-source & Open Calls



NEMO - Opportunities



- ➔ Massive AIoT deployment in diverse operational environments.
- ➔ On-device AI closer to data sources to support smart apps and ensures privacy.
- ➔ On-demand IoT/5G ad-hoc/hybrid clouds with high availability and flexibility.
- ➔ Cybersecurity and privacy in tasks and SLO vs CO₂ optimization.
- ➔ Easy development, ZeroOps deployment data monetization and new business models.
- ➔ Engagement of communities and ecosystems to enable sustainability.

NEMO - Opportunities

Realising Next Generation AIoT-Edge-Cloud



Thank you for your attention!

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