NEMO:

A Next Generation meta-Operating System for making AI as-a-Service an Integral Part of Network Self-Organization and Micro-Services Execution Orchestration

Dr. Ioannis P. Chochliouros & Mrs. Maria Belesioti (Hellenic Telecommunications Organization S.A. - OTE)

Presenter:

Dr. Ioannis P. Chochliouros

Head of Fixed Network R&D Programs Section / R&D Department, Fixed & Mobile

Hellenic Telecommunications Organization S.A. (OTE), Athens, Greece

NEMO Identity Card

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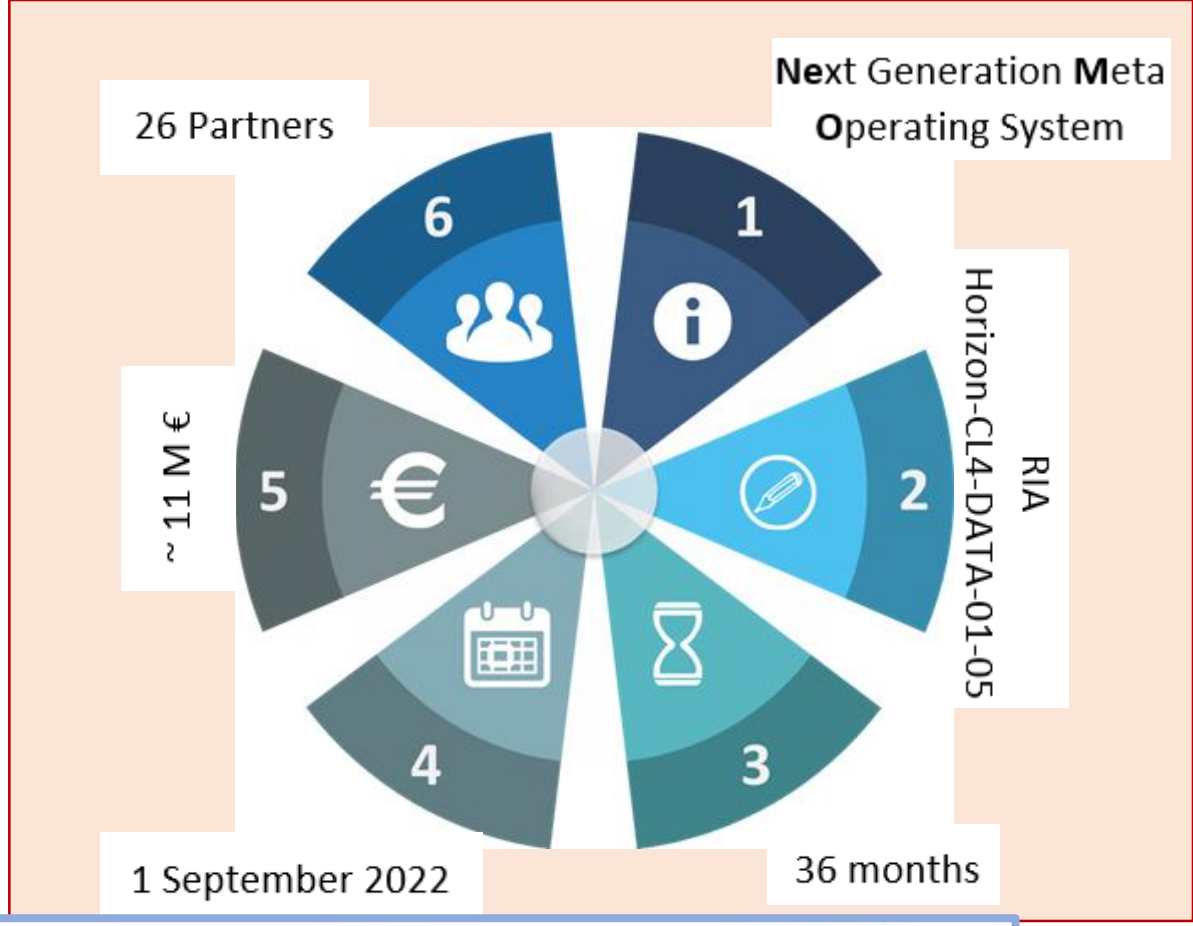
- *Funding Instrument:* **RIA (Research and Innovation Action)**
- *Coordinator:* **ATOS** – *Technical Coordinator:* Synelixis
- *Duration:* **36 months** – *Starting Date:* September 01, 2022
- *EU Contribution:* **10.5 M€** – *Cascading Funding:* **1.8 M€**
- **26 Partners – 9 Countries** (ES, FR,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



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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*****.**

Introduction – Responses from NEMO _(2)

- **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

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 _(2)

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 mOS Architecture

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 _(2)

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*

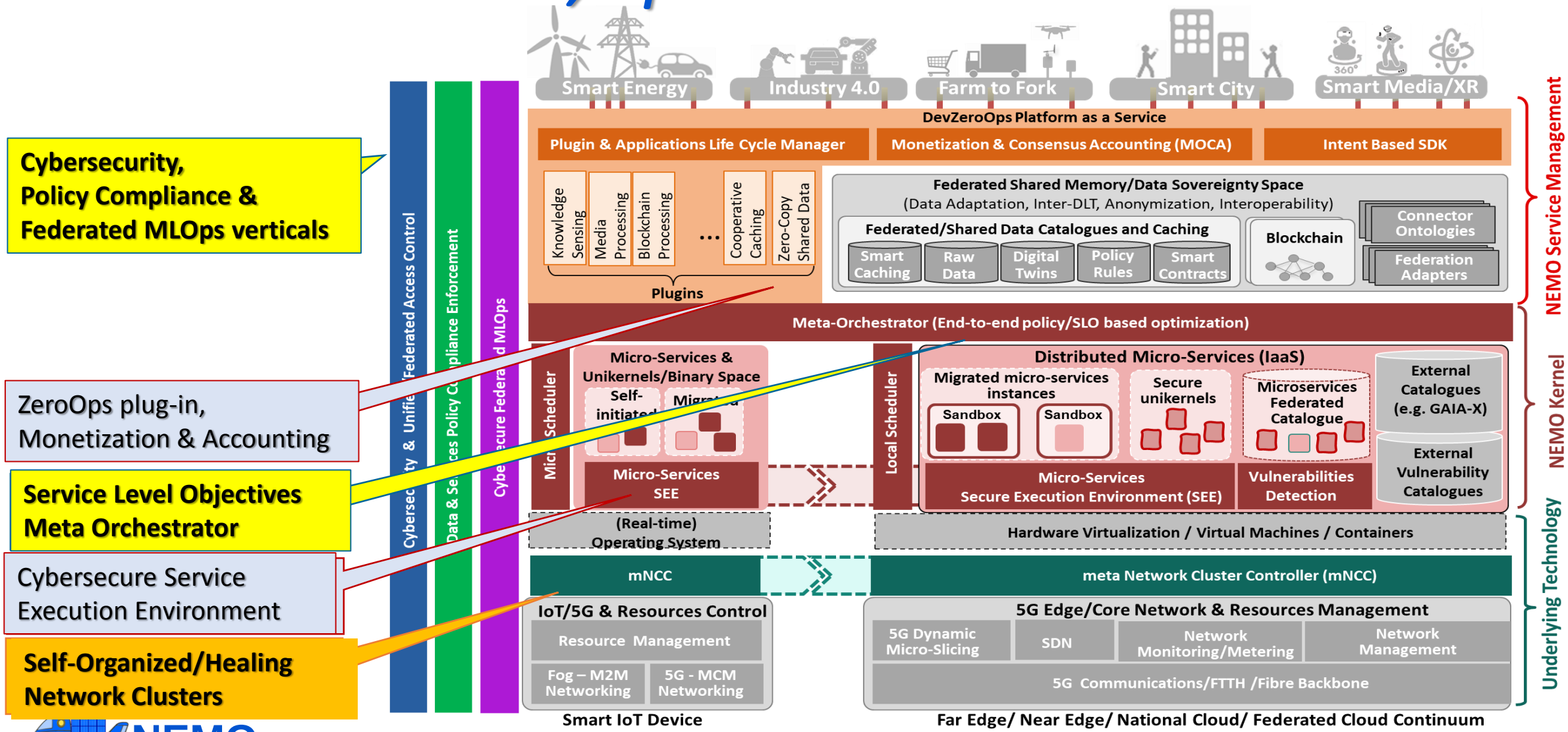
  with the aim of realizing a transparent AIoT-Edge-Cloud continuum.

- *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



NEMO

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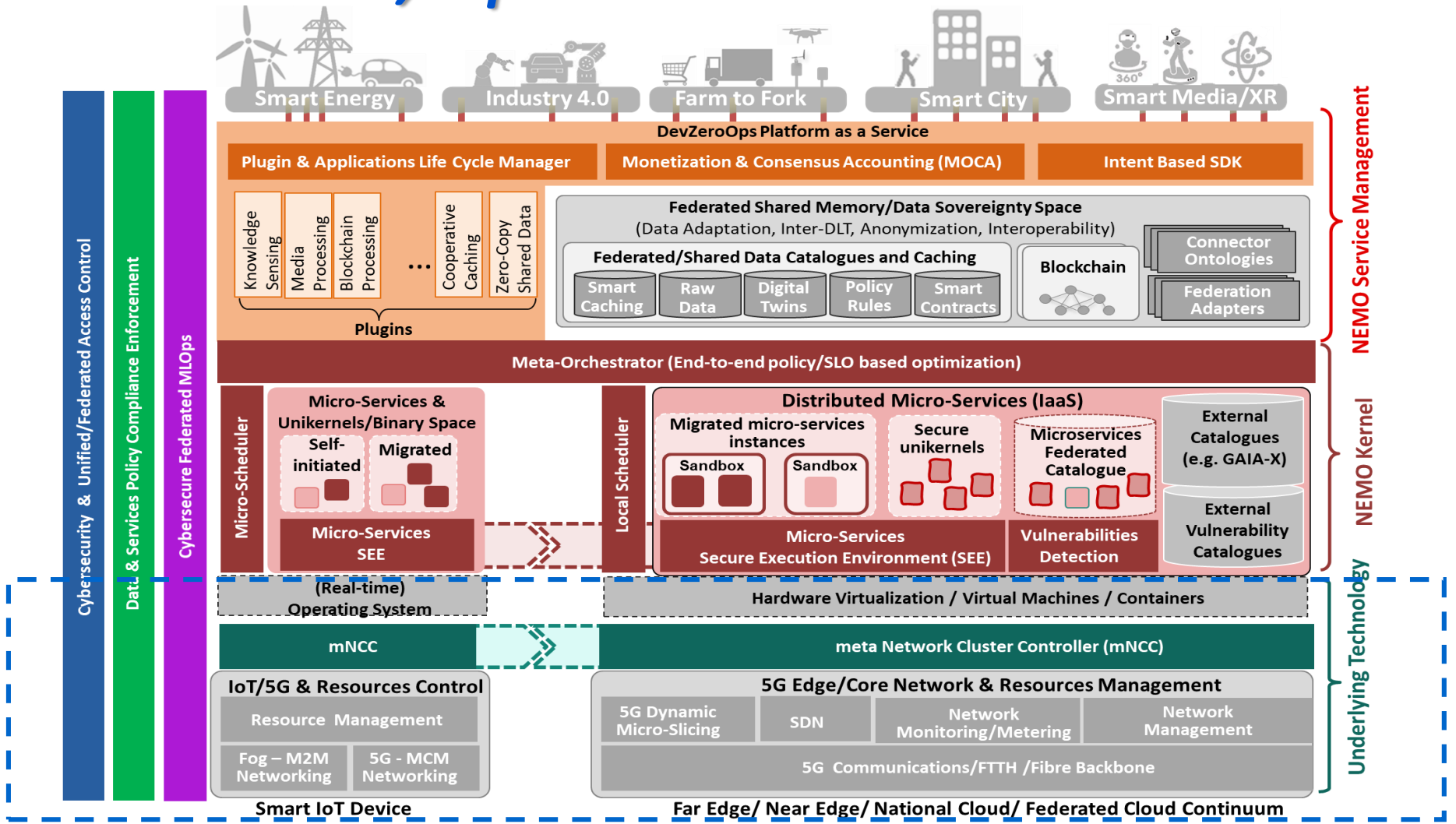

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NEMO mOS Architecture

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 meta Network Cluster Controller (mNCC):*** ***i. to interface independent and different tools and protocols,*** *and;* ***ii. to replace*** *one technology with another.*

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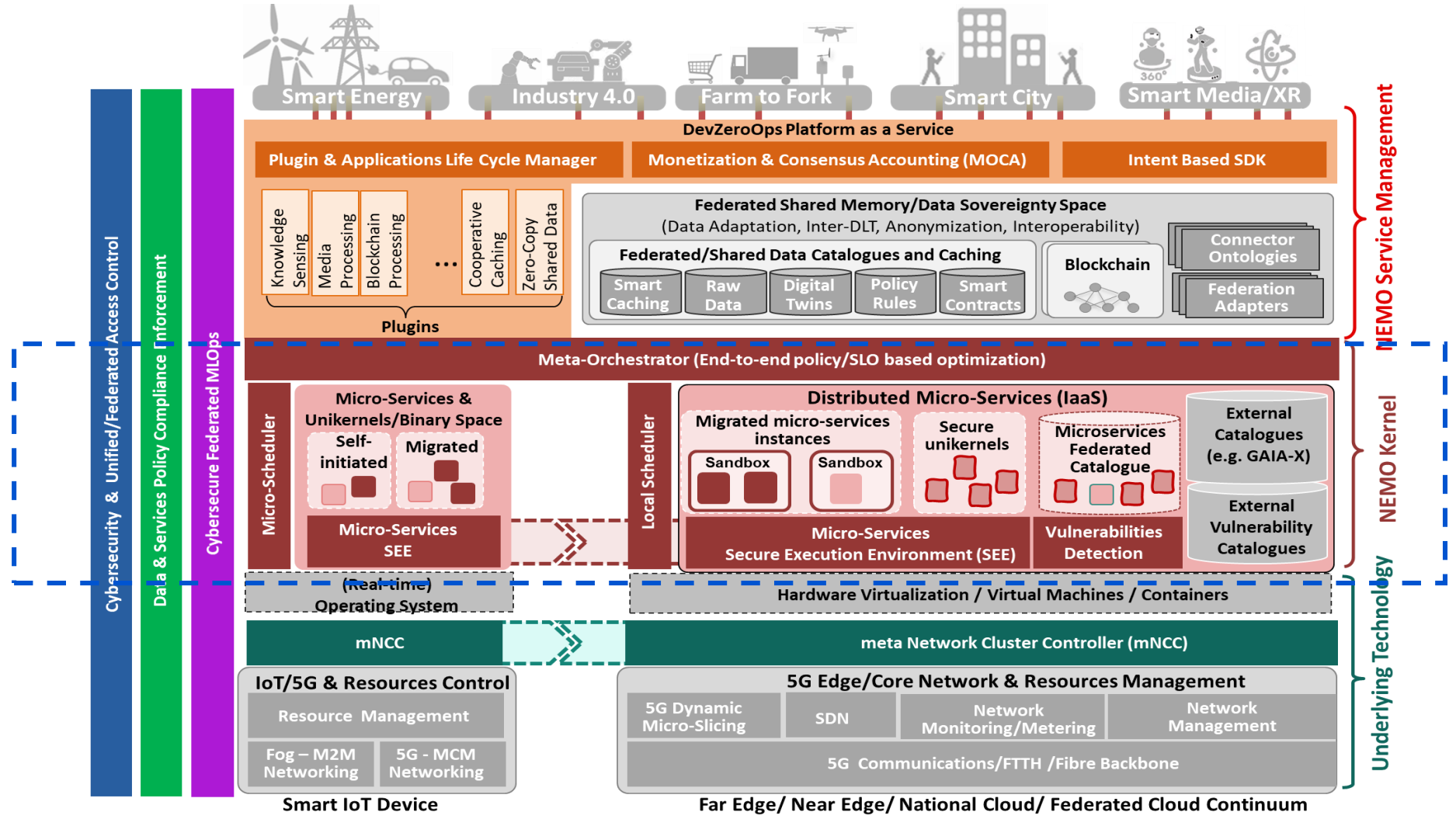
Full Stack, open source meta-OS



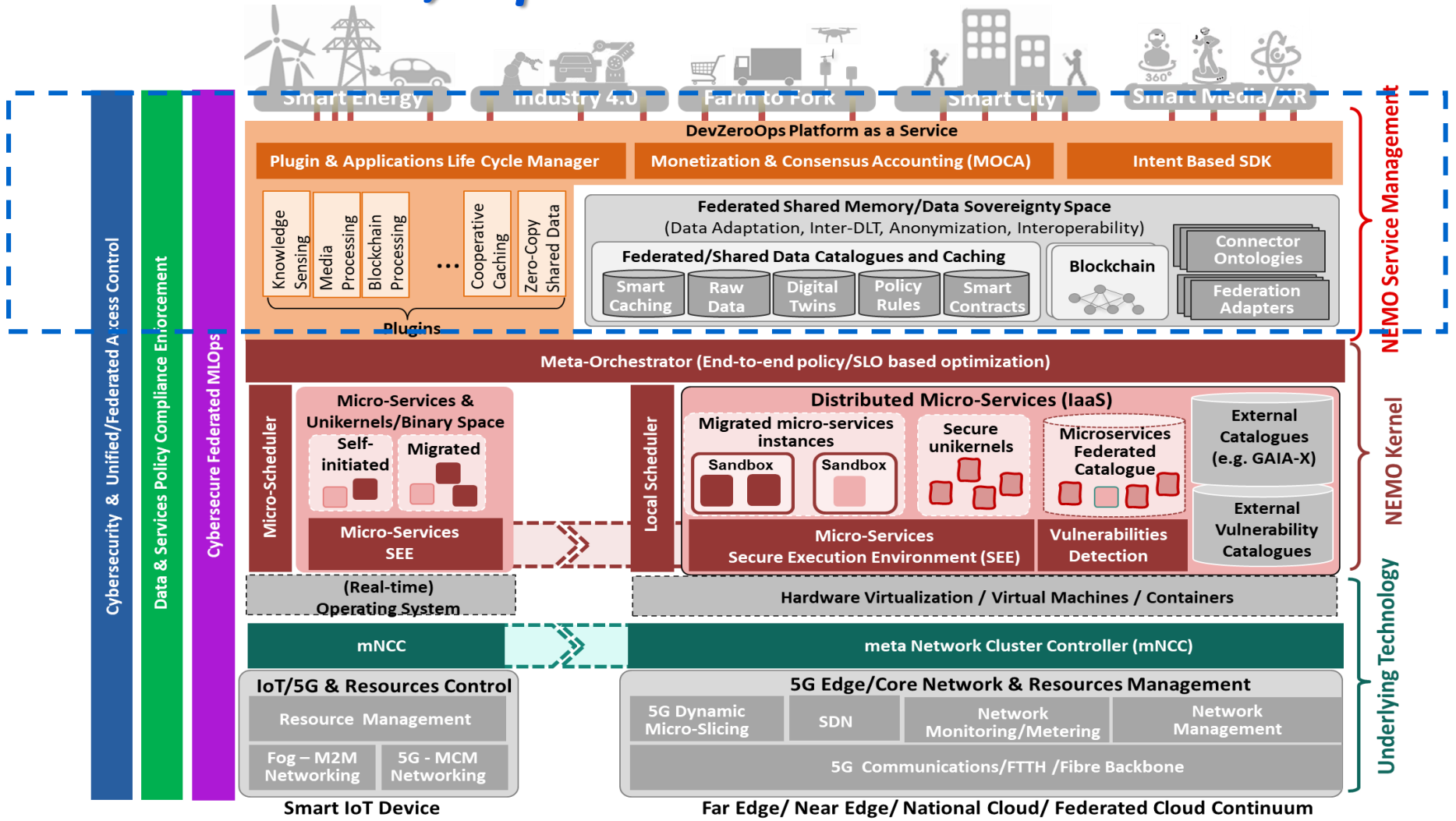
NEMO mOS Architecture

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

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

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

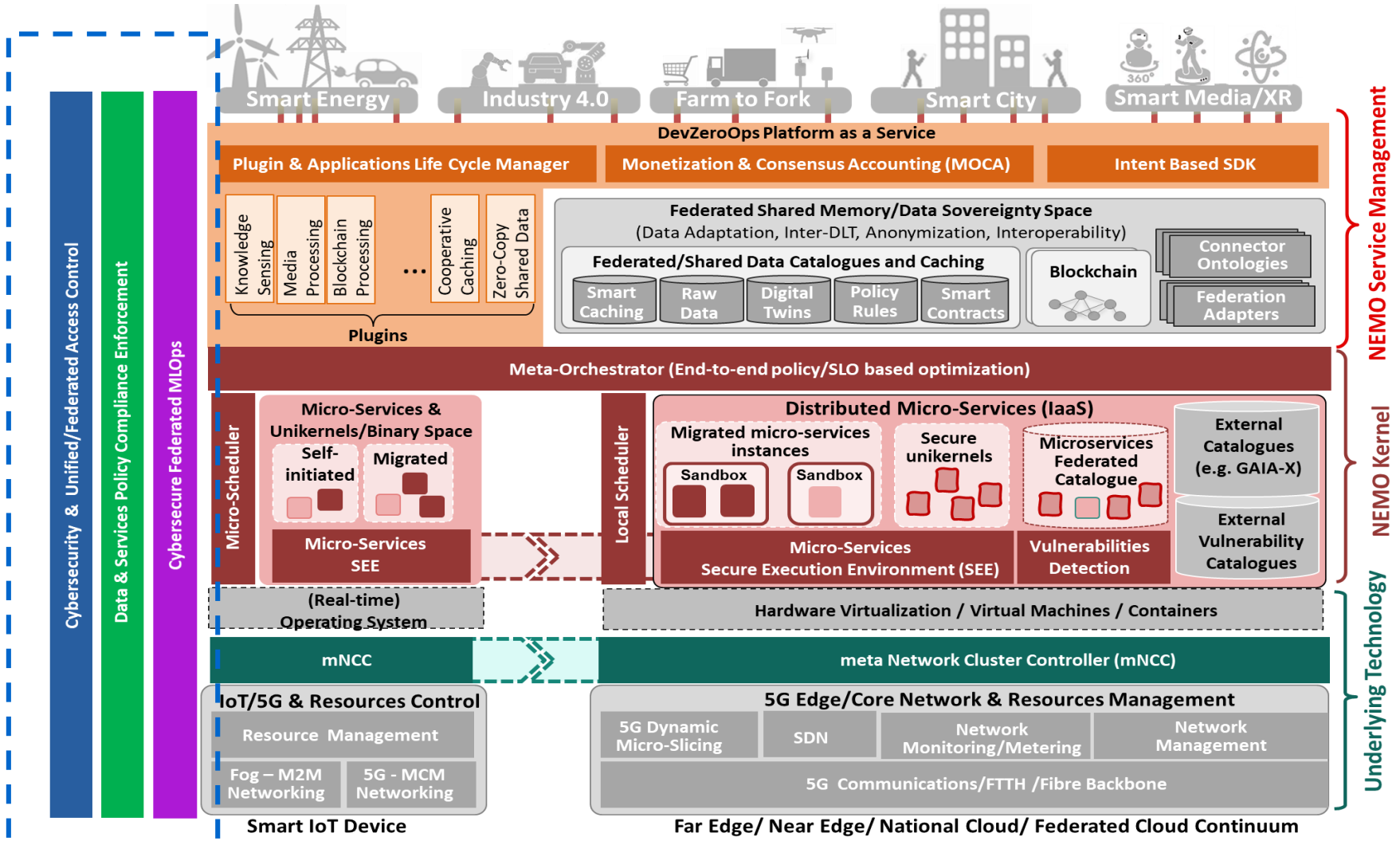
NEMO Technological Innovation in a Nutshell
Full Stack, open source meta-OS



NEMO mOS Architecture

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

NEMO Technological Innovation in a Nutshell
Full Stack, open source meta-OS



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NEMO mOS Architecture

Aim	Response - Actions
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 (Cybersecure Federated Deep Reinforcement Learning) 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 todays' world).

NEMO – Summary & Market Impact

NEMO - Vision

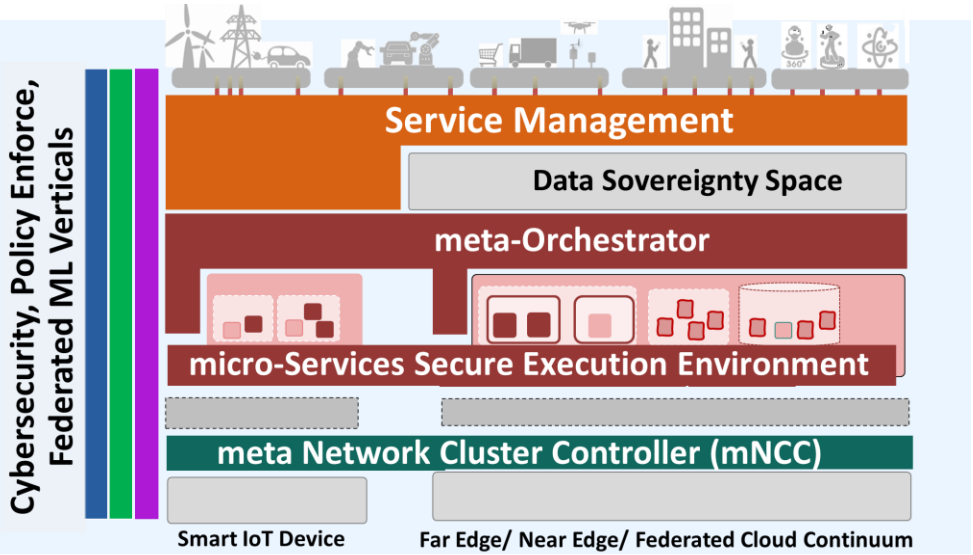
Towards creating and supporting:

- ***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**



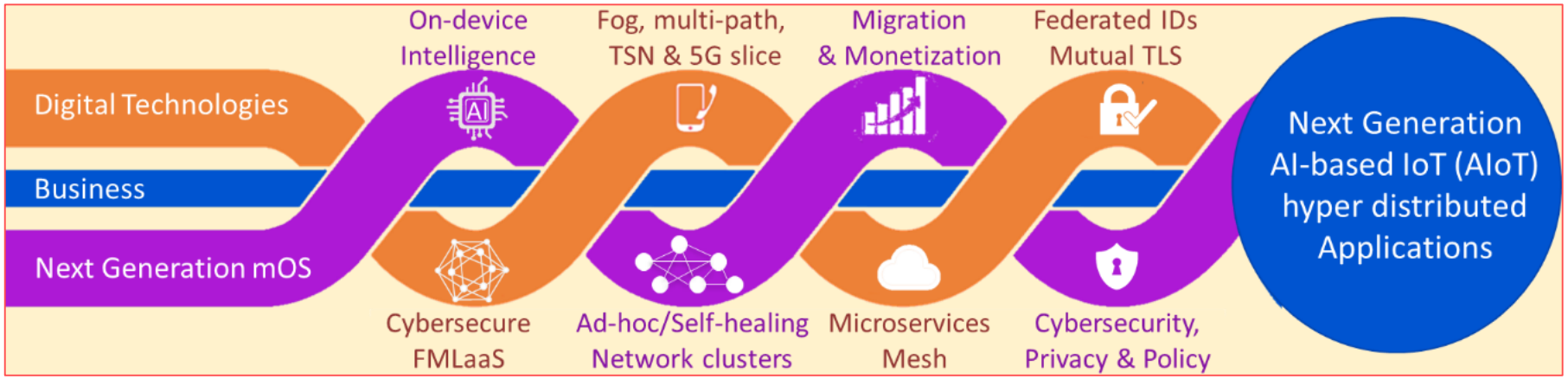
2) Strengthening the EU competitiveness

- **Fully compatible with DataSpace evolution/standards**
- **Pre-commercial exploitation components**
- **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)

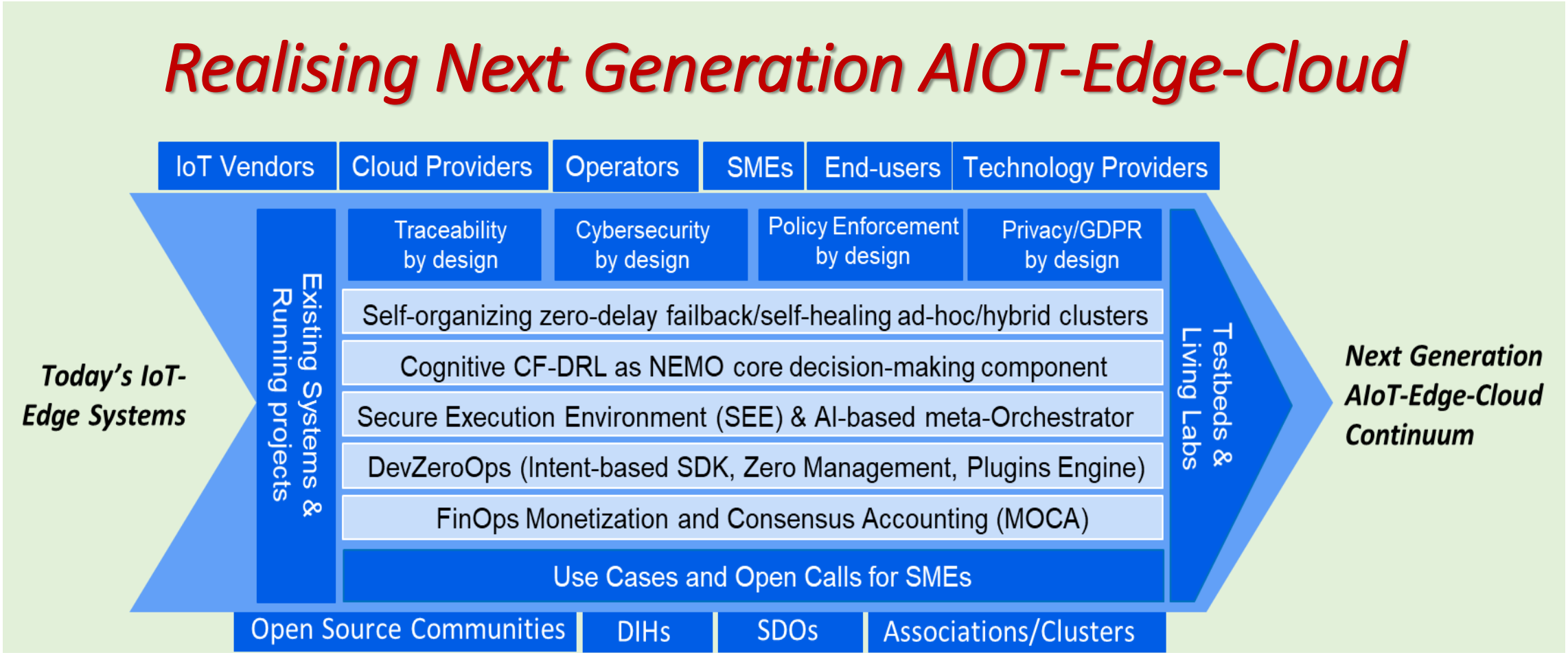
- ✓ **Novel components, tools, methods**
- ✓ **Dataspace & IoT-Edge continuum integration in reality**
- ✓ **New paradigms in Smart-X Apps delivery**
- ✓ **Push processing to cloud => directly reduce CO_2**
- ✓ **Smart Agriculture**: *reduce pesticides/spraying/soil erosion….*
- ✓ **Closing the digital gap by enabling Smart-X Edge processing**
- ✓ **Reinforcing competitiveness via open-source & Open Calls**

NEMO - Opportunities



- **Massive AIoT deployment** *in a great diversity of operational environments*.
- **On-device AI closer to data sources**, *to support smart apps* and to *ensure privacy*.
- **On-demand IoT/5G ad-hoc/hybrid clouds** *with high availability and flexibility*.
- **Cybersecurity and privacy** *in tasks and SLO vs CO_2 optimization*.
- **Easy development**, **ZeroOps deployment data monetization** and **new business models**.
- **Engagement of communities and ecosystems** *to enable sustainability*.

NEMO – Opportunities _(2)



Thank you for your attention!

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Contact Information:

Dr. Ioannis P. Chochliouros
Telecoms Engineer, M.Sc., Ph.D.,
Head of Fixed Network R&D Programs Section

Hellenic Telecommunications Organization S.A. (OTE)
(Member of the DT Group of Companies)
Division of Core Network DevOps & Technology Strategy, Fixed & Mobile
Research and Development Department, Fixed & Mobile
Fixed Network R&D Programs Section

1, Pelika & Spartis Street
15122 Maroussi-Athens
Greece

Tel.: +30-210-6114651
Fax: +30-210-6114650
E-Mail: *ichochliouros@oteresearch.gr; ic152369@ote.gr;*

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