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NExt generation Meta Operating Systems (NEMO) and Data Spaces: Envisioning the future

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Introduction

Motivation

Data spaces are the vehicle for data-driven innovation; they present a great opportunity for European industries by providing a framework for the ethical and responsible use of data.

Efficient delivery of services within Data Spaces mandates **for efficient use of resources across the IoT and Cloud/Edge Continuum with enforceable security and privacy mechanisms.**

Herein, we present the **NExt generation Meta Operating System (NEMO)** architectural approach and how it can be extended to embrace Data Spaces.

We provide a case study for a FIWARE-based **Industrial Data Space connector for NEMO**, enabling us to organize and valorise large pools of data.

Challenges

IoT proliferation has revolutionized the way data is collected and analyzed and introduced unique challenges:

- Heterogeneity of systems and administrative domains raised compatibility as well as ethical/legal compliance issues.
- Furthermore, the distribution of computational power across the continuum introduces hardware heterogeneity, needs for improved resource orchestration, scalability, interoperability etc.
- Traditional Operating Systems are not designed to support the growing diversity of devices and the seamless orchestration of resources across the continuum.
- The concept of a meta Operating System (metaOS) is designed to address these challenges by providing hardware-agnostic abstraction, holistic resource orchestration and management, optimization through use of virtualization and intelligent scheduling, advanced security (hardware attestation, hypervisor-level isolation etc.) for the cloud-edge environment.
- **The multitude of data generated require a Data Spaces framework for ethical exploitation and improved governance.**
- **Hence, metaOS and Data Spaces can be considered complementary, in the sense that metaOS can ameliorate management of the data sources, while the Data Space can ameliorate access to the data themselves. How do we connect the two architectural paradigms?**

Data Spaces & Meta Operating Systems

Data Spaces

Why do we need Data Spaces?

Data is essential for growth, innovation and social and economic development and constitutes the centre of digital transformation. In a society where the amount of data continually increases, seamless data flow is considered a prerequisite for creating new market opportunities that future services will enable.

Until now, data warehouses have been used as central databases for structured data unification. The vision for European Data spaces is to offer a decentralized solution by facilitating data availability, either structured, semi-structured or unstructured, via secure peer-to-peer communication.

The Data Spaces are trustworthy and standardized infrastructures, ensuring secure data exchange and sharing across several stakeholders by implementing specific policies.

For instance, the needs for cross-sectorial flow of information requires awareness of sector-specific Data Governance policies, and tight control of access and use privileges. Data pooling and sharing mechanisms need to operate at scale while fully aligned with EU legislation, such as the General Data Protection Directive and the Data Governance Act, as well as newer legislation, such as the AI Act. **Security and Transparency and EU legal compliance need to be built-in.**

Overview of Open Source Data Space Connectors

Connecting to data sources is a critical challenge tackled by Data Space Connectors.

Eclipse Dataspace Components (EDC), powered by the specifications of the GAIA-X AISBL Trust Framework and the IDSA. **The International Data Spaces Association (IDSA)** reference architecture is the starting point to build international data spaces. Growing list of modules and easily extensible. **The FIWARE Data Space Connector** follows the NGSI (Next Generation Service Interfaces) API developed by FIWARE and standardized by ETSI but can also support R**ESTful API.**

Many open-source data connectors exist!

EdgeDS Connector (Fraunhofer IST), EGI DataHub Connector, The Gate Dataspace Connector, The TRUE Connector, The OneNet Connector (based on the TRUE Connector), Prometheus-X Connector (MIT), TNO Security Gateway etc.

Meta Operating Systems

The NEMO approach from DevOps to DevZeroOps

NEMO considers that as zero-code tools and ontology-assisted NLP evolve, they bring faster development cycles, that should be complemented by zero-touch orchestration and management.

NEMO focuses on **intent-based (zero-code) microservice programming** as well as DevZeroOps deployment and migration. While commercial deployment and orchestration solutions exist (Kubernetes, RedShift etc.) the nature of the AIoT edge requires **opportunistic migration to be the norm, rather than the exception!**

NEMO's ambition is to facilitate easy, zero admin knowledge, almost instantaneous deployment to ideally any AIoT device, and address the current ecosystem need to integrate and bundle all such mechanisms, tools and major plugins to a metaOS, installable as a (semi-)automated/autonomous SW package.

NEMO metaOS Architecture

NEMO metaOS: Integration of diversified SW/HW resources

The functional stack is designed to support dynamic and opportunistic orchestration and management and is composed of three layers:

The Kernel Layer is the core interface between the virtual and physical infrastructures. As the **underlying elements** can be diverse, the kernel becomes a meta control plane over existing container orchestration clusters. The **Service Management Layer** provides workload lifecycle management and provides security, privacy, accountability, identity management etc.

In order to integrate Industrial Data Spaces (or create a metaOS Data Space shared by metaOS Instances), additional MetaOS functionalities (beyond the core) need to be in place, which can be implemented as **plugins, onboarded by the Intent-based API.**

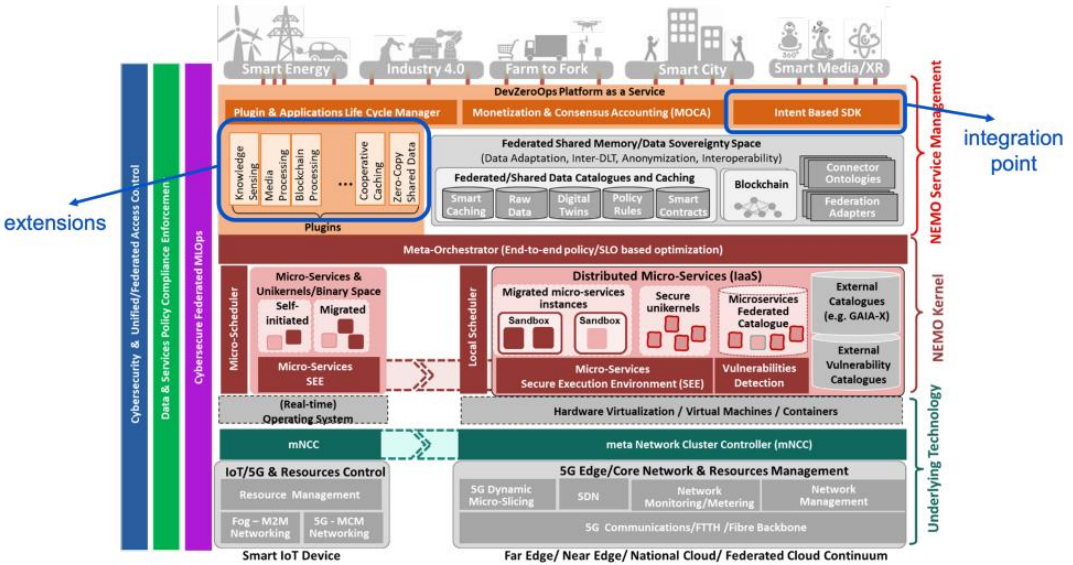
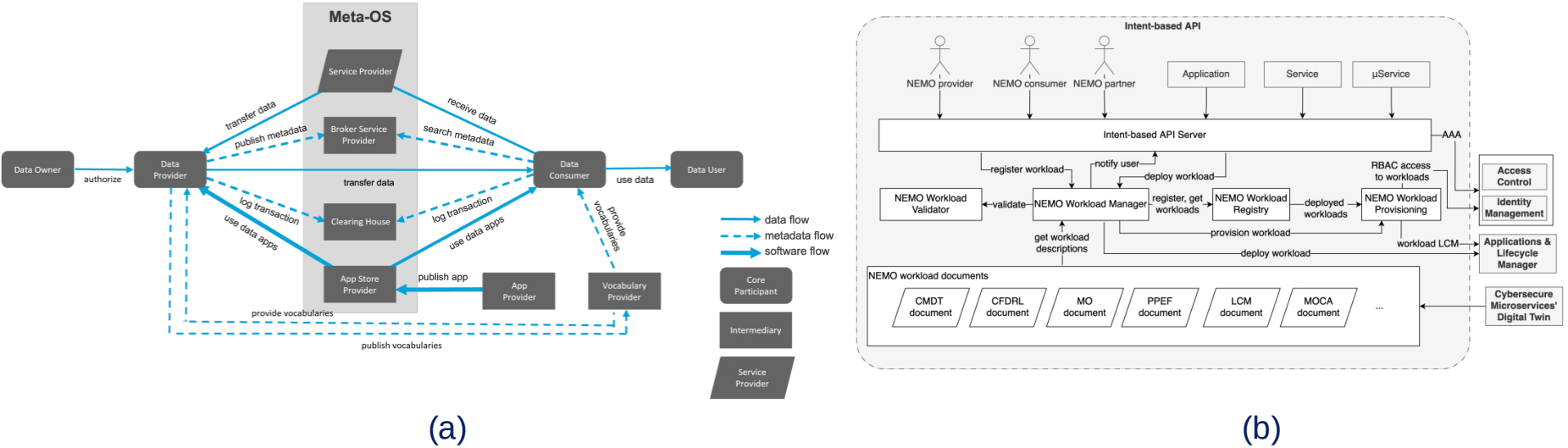


Figure 1: NEMO architecture.

NEMO Intent-based API



(a) (b)

Figure 2: (a) Integrating Industrial Data Spaces – the metaOS can host/provision the required services like the Clearing House, App Store Provider etc. (as defined in the IDSA reference architecture) (b) Intent-based API: It validates, registers and provisions NEMO workloads (plugins, services etc.). A common workload description format is implemented as NEMO workload documents (descriptors, security, accounting information, how services can be exposed etc.)

On-boarding and deploying a Data Space Connector as a plugin

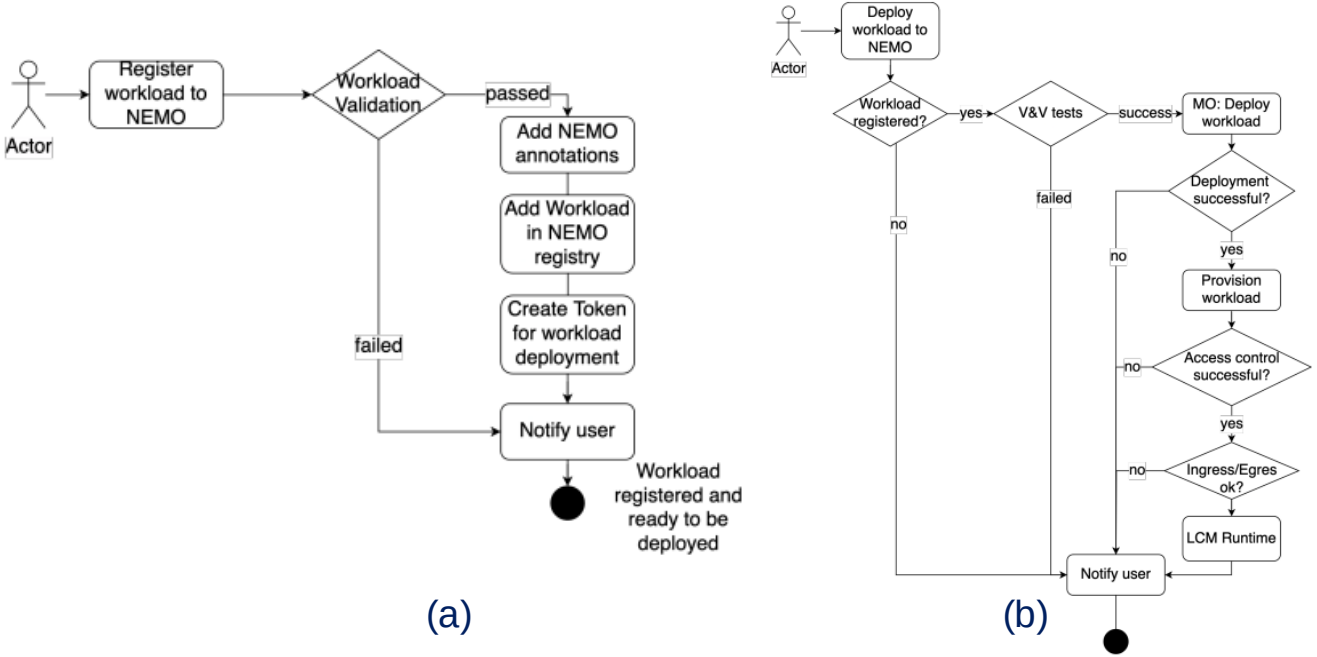
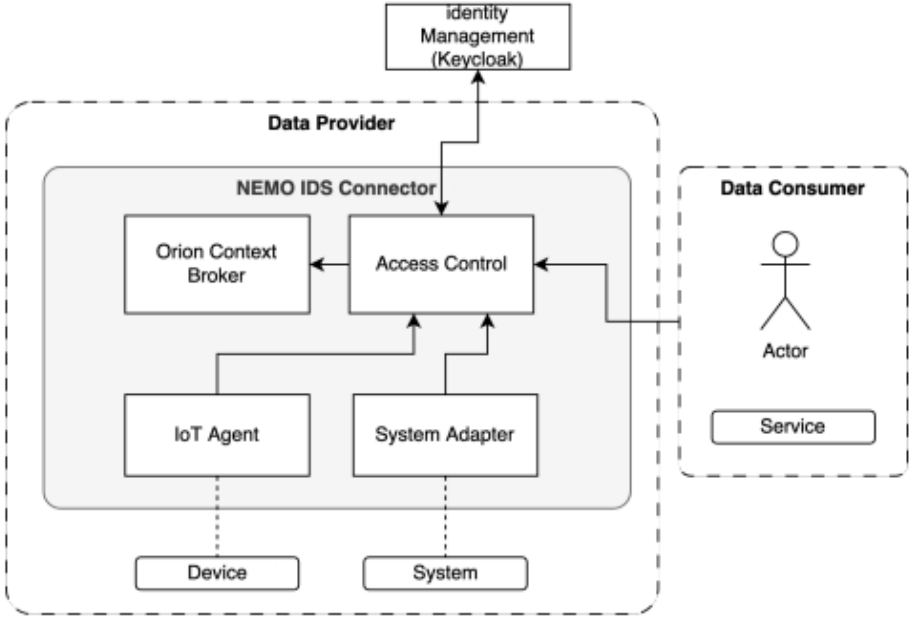


Figure 3: a) Registering a Data Space Connector as a NEMO workload. After passing the Intent-based API validation checks (against NEMO workload requirements, document requirements, security checks, dependency checks etc.) the connector plugin is registered as a workload to be deployed; b) Deploying a registered workload.

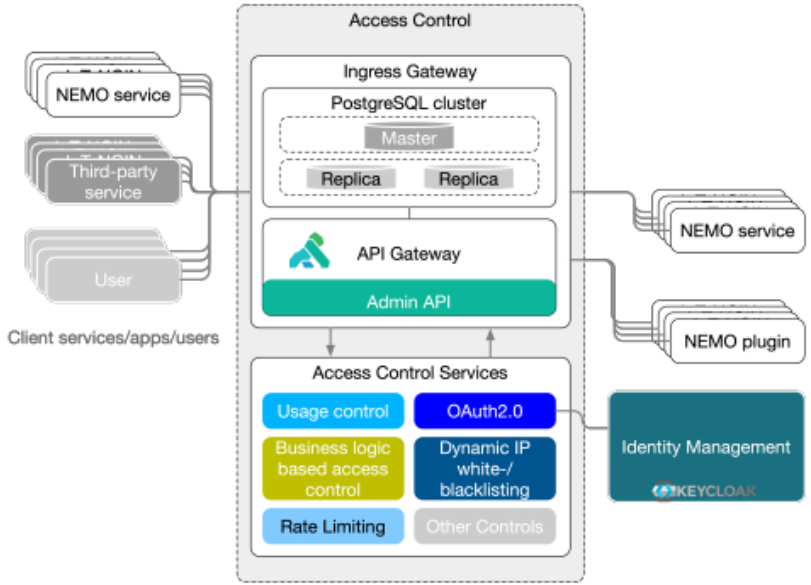
NEMO descriptor & annotations include: versioning info, VIM compatibility info, deployment requirements, secure execution requirements, access control criteria etc. The NEMO consumer uses the token to request deployment. If the workload passes the Validation and Verification checks (based on the annotated information) the API will communicate requests to the rest of the NEMO components (meta-orchestrator, Role-based Access Control, Plugins Lifecycle Manager etc.)

Data Space Connector Architecture & Case Study

Proposed Connector architecture and FIWARE Case Study



(a)



(b)

Figure 4: (a) Proposed architecture for a FIWARE-based Industrial Data Space Connector based on the Orion Context Broker; goes through the Access Control component that controls accesses to privileged information (b) FIWARE IDS case study: Access control criteria need to be respected by both sides and go beyond authorization and authentication (it may include blacklisting, rate limiting etc.)

Conclusions & Acknowledgements

Conclusions

NEMO has been designed to bring powerful orchestration and management to the AIoT-Edge-Cloud Continuum.As a comprehensive Meta-OS solution, NEMO is perfectly situated to connect with European Data Spaces and leverage the value of cross-sectorial data flows.

The Consortium posits that connecting with data spaces is the future of every system that aims to exploit powerful data resources and save time in organizing input.

We also show that although NEMO had not initially considered connection to Data Spaces in its core architecture, its design has proven to be flexible enough as it provides the tools to integrate with Data Spaces.

As future work, we aim to extensively validate the proposed IDS connector in NEMO and verify data commercialization through the metaOS infrastructure.

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Thank you

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