OASEES

Creating a Decentralised Autonomous Organization-(DAO-) based Programmable Swarm Solution, for the Support of Decentralizing AI Applications close to Data Generation Locations – The Innovative Vision of the OASEES project

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Table Of Contents

Introductory Framework

Introduction_(1)

- ***The huge increase in device connectivity and produced data has resulted in the extended growth of diverse intelligent processing services to create insights and exploit data in a multi-modal manner.***

- ***At present, the most powerful data processing usually takes place in a centralized way at the cloud - this offers the opportunity and the capability not only to scale, but also to allocate involved and available resources, both on demand and efficiently.***

Centralized Data Processing:

- ***It occurs when all data is collected to a single centralized storage area and processed upon completion by a single computer (with often very large architectures in terms of memory, processor and storage).***
- ***It offers several distinct benefits for the involved "actors" such as:***
  - ***It helps in reducing the cost(s) - as there is no emphasis on more hardware and machines to be involved;***
  - ***it provides more enhanced data security, and;***
  - ***it allows data & the program on each information system to become independent to other information systems, thus extending security and trust.***

Introduction_(2)

Cloud hosting:

- *It makes applications and websites accessible by using dedicated cloud resources.*
- *Unlike traditional hosting processes, the respective solutions are not deployed on a single server;*
  instead, a network of connected virtual and physical cloud servers hosts the application -or the website- to ensure greater elasticity and scalability.

"Key features" of this context may implicate for:

- ***applications and solutions being deployed on a cloud network** rather than an on-premises, single server;*
- ***resources can be scalable** to user needs;*
- ***involved entities/organizations only pay for the resources they practically use;***
- ***solutions are automated** and controlled by using APIs, web portals and mobile applications.*

Cloud hosting can offer flexibility and reliability:

- *As traditional hosting services offer limited bandwidth, **cloud hosting scales to accommodate traffic spikes or seasonal demands;***
- *hardware failures do not cause downtime, because sites and applications are hosted on a network of server; **thus, traffic travels across separate network interfaces, where it is segregated and secured.***

Introduction_(3)

However, centralized processing and cloud hosting can "bound" -or even "limit"- their services/applications to operate in a resource restricted manner, and may rely on large single entities to offer:

- ***Authentication;***
- ***data storage;***
- ***data processing;***
- ***connectivity;***
- ***vendor-locked environments for development and orchestration.***

This "limits" users from their data governance and identity management (IdM), as it:

- ***Prevents them from efficiently managing their identities and access;***
- ***restricts their visibility into identities and access privileges;***
- ***does not help them to implement any of the necessary controls for preventing potential inappropriate or risky access.***

Data governance: *Implicates for the sum of policies, processes, standards, metrics and roles being able to ensure that data is used effectively to help an entity to realize its objectives.*

IdM: *Includes polices and technologies to properly identify, authenticate and authorize people, groups of people or software applications through specific attributes (including user access rights and restrictions based on their identities).*

Challenges for a More Efficient Edge Processing

Towards a framework for OASEES More Efficient Edge Processing_(1)

- ***The fast progress of IT and telecom infrastructures, especially within the 5G/B5G era, supports the development of various platforms, that are focusing on the management and orchestration of edge infrastructure and services.***

- ***Edge processing occurs when the computation of data is carried out directly in the smart sensor node or at the gateway of the network.***
  - ***The aim is to save power consumption and ensure that data is kept confidential, thus allowing involved "actors" to analyze critical information at the node level and reduce anomaly detection time(s).***
  - ***The idea is to "put" basic computation as close as possible to the physical system, making the involved IoT device(s) as "smart" as possible.***

- ***Edge processing implicates for several distinct benefits such as:***
  - ***confidentiality, as data is not sent to the cloud and is locally stored on the device or the other equipment used;***
  - ***cost reduction, as latency and throughput of high-volume time-series asset data can be optimized*** *- reducing the amount of useless machine data sent and stored in the cloud enables real-time distributed applications and also eliminates the need for complex systems;*
  - ***lower latency, implicating that a minimal delay in the repair of equipment is essential for assets which are assessed as mission-critical.***

Towards a framework for OASEES More Efficient Edge Processing_(2)

- ***Aiming to "meet" performance, cost and/or potential legal requirements, cloud resources are nowadays moving toward the edge of the network intending to "bridge the gap" between resource-constrained devices and distant but powerful cloud Data Centres (DCs).***

- ***Edge computing is an emerging computing paradigm, which refers to a range of networks and devices at or near the user.***
- ***"Edge" (which implicates for both edge devices and the network edge) is about processing data closer to where data is being generated, thus:***
  - ***enabling processing at greater speeds and volumes,***
  - ***leading to greater action-led results and experiences in real time.***

- ***The wide adoption of the recently coined fog and edge computing paradigms alongside conventional cloud computing creates a novel scenario, known as the "cloud continuum", where:***
  - ***Services may benefit from the overall set of resources,*** *so that to optimize their execution.*
  - ***Demands are set for novel management strategies,*** *enabling a coordinated/efficient management of the entire set of resources, varying from the edge up to the cloud.*
  - ***Key edge characteristics are addressed*** *(such as mobility, heterogeneity and volatility).*

Towards a framework for OASEES More Efficient Edge Processing_(3)

- ***However, with the aim of fully exploiting the potential of edge processing, a "more holistic solution" has been proposed, especially by embracing the context of the wider compute continuum:***
  - ***It allows the exploitation of hybrid IoT-Edge-Cloud infrastructures with great flexibility.***
  - ***It offers guarantee of high-performance.***
  - ***It includes both central infrastructures (public clouds & networks) and smart devices.***

- ***Commercial solutions for hybrid core/edge management (e.g. Azure Edge Stack) exist, but these are usually "closed", restricted to specific deployment scenarios*** *and* ***only provided as managed services*** *(i.e., not suitable for private (fully on-premises) deployments).*

Towards a framework for OASEES More Efficient Edge Processing_(4)

Parallel appearing challenges:

- ***Edge orchestration:***
  - ***It describes the ability to manage, automate and coordinate the flow of resources between multiple types of devices, infrastructure and network domains at the edge of a network.***
  - ***It allows businesses/organizations to efficiently route data resources, so that to avoid potential bottlenecks, reduce latency and scale their network as needed, per case.***
  - ***It aims to establish more intelligence to the network in which real-time network events, traffic or other dynamic requests can be handled automatically, at the edge.***
  - ***It helps reallocation of network resources across multiple devices or equipment used.***

- ***Security:***
  - ***Edge infrastructures can be highly dynamic, involving edge nodes and smart devices, possibly under varying status of ownership*** *(i.e., multi-actor environments).*
  - ***For guaranteeing data privacy & availability, it is essential to continuously verify the integrity of services & infrastructures, across the compute continuum.***

OASEES Concept: Features and Technology Challenges

OASEES Concept: Features & Challenges_(1)

- ***Massive increase in device connectivity and generated data:*** *Results in the* ***proliferation of intelligent processing services to create insights and exploit data*** *in a multi-modal manner.*
- ***The most powerful data processing operates in a centralized manner at the cloud:*** *This provides the* ***ability to scale and allocate resources*** *on demand and efficiently.*
- ***However, centralized processing and cloud hosting, "bound and limit" their services and applications to operate in a resource restricted manner:*** ***This affects entities' abilities to provide several features*** *(i.e.: authentication, data storage, data processing, connectivity).*
- ***Limitations are set to the users*** *from their* ***data governance*** *and* ***identity management****.*
- ***Existing solutions for edge device authentication require a centralized entity to trust them and authenticate them,*** *thus rendering a non-portable identification paradigm.*

OASEES Concept: Features & Challenges _(2)

OASEES aims to "directly address" such challenges,
by both delivering and promoting
a European, fully open-source, decentralized and secure
Swarm programmability framework for edge devices
and leveraging various AI/ML accelerators
(Field Programmable Gate Arrays (FPGAs), Spiking Neural Networks (SNNs), Quantum),
while supporting a privacy preserving Object ID federation process.

OASEES Concept: Features & Challenges_(3)

Intended actions:

- **Managing the *lifecycle of services* across the compute continuum by orchestrating heterogeneous resources in the cloud, WAN, edge and smart device domains:**
  - ***Resources from CPUs, GPUs, NPUs, FPGAs bespoke chips and Quantum processors are to be pooled and jointly managed to optimize ML at the edge****, for maximum performance and energy efficiency.*
  - ***Adaptors to popular public clouds will also be integrated****, for supporting E2E services with the appropriate QoS guarantees at WAN network level.*
- **Promoting the *development of decentralized ML/AI edge services* by means of an SDK (Software Development Kit) and *in the form of Decentralized Applications (DApps),* in a user-friendly notebook-style abstractions for data scientists and engineers.**
  - ***DApps can operate autonomously, typically through the use of smart contracts****, that run on a decentralized computing, blockchain or other distributed ledger system.*
  - ***This will essentially realise the vision of Decentralized Artificial Intelligence as-a-Service (DAIaaS).***
  - ***Decentralized Artificial Intelligence (DAI) allows for the isolation of processing*** *without the downside of aggregate knowledge sharing.* ***It enables the user to process information independently****, among varying computing apparatuses or devices.*

OASEES Concept: Features & Challenges_(4)

Intended actions (cont'd):

- ***Supporting multi-actor/multi-domain deployments****, by:*
  - ***Enforcing security and trustworthiness;***
  - ***enabling the federation with peer OS instances in other administrative domains*** *(multi-domain operation) and;*
  - ***fostering monetization by advertising/trading capabilities and resources in third-party Marketplaces*** *(including the* ***Marketplace of the European Open Science Cloud (EOSC)*** *- EOSC's ambition is to provide European researchers, innovators, companies and citizens with a federated and open multi-disciplinary environment where they can publish, find and re-use data, tools and services for research, innovation and educational purposes).*

Research Topics

OASEES Concept: Research Topics _(1)

Research Topics

- *Programmable Frameworks for Swarm and Edge Computing*
- *Support for Heterogeneous Dynamic Infrastructure via Enhanced Platform Awareness (EPA)*
- *Edge Infrastructure Sharing and Monetization*
- *AI-enabled Data Processing for Hyper-distributed Applications*
- *Trustworthy and Secure Edge*
- *Blockchain-backed IoT Governance*

OASEES Concept: Research Topics _(2)

Programmable Frameworks for Swarm and Edge Computing:

- ***Existing management and orchestration frameworks*** *are focusing either on* ***cloud management, NFV MANO, SDN-based network control*** *or* ***on IoT-focused edge platforms.***

- ***OASEES aim is to "go beyond" existing control systems and APIs into an open programmable Swarm framework,*** ***to enable an IoT-to-edge-to-cloud continuum*** *where services can be developed,* ***benefiting from:***
  - *(i)* ***an IoT-to-edge-to-cloud infrastructure model*** *enabling to characterize a wide variety of related resources, building further on existing State-of-the-Art (SotA),* ***such as OCCI*** *(****Open Cloud Computing Interface****);*
  - *(ii)* ***a de/composable service model based on SotA such as TOSCA*** *(****Topology and Orchestration Specification for Cloud Applications****),* ***allowing to characterize which among the components require:***
    - *performance profiling and/or allow hardware acceleration,*
    - *security measures (monitoring, anomaly detection, etc.), or*
    - *particular reliability or QoS-based control loops.*
  - *(iii)* ***a security-aware and intelligence-aware SDK enabling lifecycle management*** *and asymptotic orchestration of data rich services.*

- ***OASEES' target is to employ a transactional model for the lifecycle of services,*** ***which can enable partial provisioning, migration, roll-back and or tear-down of individual components,*** *ensuring service integrity.*

OASEES Concept: Research Topics _(3)

Support for Heterogeneous Dynamic Infrastructure via Enhanced Platform Awareness (EPA)

- ***EPA is a well-known capability of recent resource management and orchestration systems** either in the context of Virtual Machines (e.g., OpenStack, Open Source Management) or in the context of Containers.*

- ***The fact:** Cloud computing resources are becoming increasingly heterogeneous and are simultaneously distributed across smaller DCs at multiple locations.*
  ***The trends:** A rapidly increasing adoption of accelerators in the near future.*

- ***OASEES will enable the discovery and pooling of edge platform acceleration capabilities so that to:***
  - *Create a holistic view of all the different capabilities available in the distributed edge environment, and;*
  - *optimize placement decisions.*

- ***Actions:***
  - *Leverage the proposed OASEES' agents operating over such heterogeneous infrastructures, platforms and smart devices and collect device capability information to be stored in OASEES' central repository.*
  - *Run customizable optimization algorithms to select the "best mapping" of the service demands on the physical infrastructure.*

OASEES Concept: Research Topics _(4)

Edge Infrastructure Sharing & Monetization:

- ***OASEES aims to realize "sharing" of services across distributed edge-based infrastructures,*** *thus suggesting a cross-layer orchestration mechanism between involved network, computation and storage services* ***(as in ETSI MEC ISG).***

- *The* ***Mosaic 5G initiative*** *has already proposed some APIs allowing for an easier cross-domain orchestration of services and federated resource management.*
- ***OASEES aims to combine existing and SotA technologies to develop an E2E Cross-domain service framework, for achieving optimal resource management and consumption.***

- ***The intended framework will allow third-party service providers to offer their services through a service marketplace.***

  This capability can be perfectly aligned with the "neutral host" paradigm ***(being an "attractive" business model that expands to 5G/6G infrastructures).***

OASEES Concept: Research Topics _(5)

AI-enabled Data Processing for Hyper-distributed Applications:

- ***Numerous of analytics processes, varying from factory automations to autonomous vehicle operations or safety-critical applications rely on the continuous, low-latency flow and processing of data to generate results within a short timeframe.***

  Although edge computing seems to be an "attractive alternative", the majority of the existing computing techniques (used in the cloud and/or on premises) are usually not directly applicable to the edge, due to the diversity of computing sources, lack of resource management and distribution of data.

- ***OASEES aims to rely on secure data spaces for storage and privacy-preserving ML technologies (i.e., Federated Learning), allowing users to train and share their models without compromising the sovereignty of their data.***

- ***Edge analytics shall benefit from increased trust and faster response times to changing environmental conditions through the adoption of MLOps (ML Operations) principles, for continuous monitoring, treating ML assets consistently with all other software assets.***

OASEES Concept: Research Topics _(6)

Trustworthy and Secure Edge:

- ***The highly distributed and heterogeneous nature of the OASEES infrastructure and operating environment dictates architectural design around a form of "Zero-Trust" Architecture, as only trustworthy and secure edge nodes shall be authorised to participate.***

- ***This implicates for deployment of a "mixture" of existing and cutting-edge technologies, such as Trusted Computing attestation and cloud-native secure identities with SPIFFE (Secure Production Identity Framework for Everyone).***

- ***OASEES aims to use only nodes with a trusted hardware, firmware and Operating System (OS) environment, preventing from hardware supply chain attacks, bootkits, rootkits and malware.***

OASEES Concept: Research Topics _(7)

Blockchain-backed IoT Governance:

- ***Blockchain – as a decentralized distributed database – enables sharing of trustworthy information among different nodes part of a certified network.***
  Blockchain's main technological features are: Decentralization, availability, information immutability and non-repudiation properties.

- ***OASEES aims to to present an agile architecture that support heterogeneous technological devices, enabling easy integration of blockchain technology.***

  The edge and cloud components of OASEES will generate and process different information.
  Blockchain and smart contracts will serve as a software connector among various architectural components, by enabling exchanging a particular set of information in a trustworthy manner.

- ***With the help of a smart contract, OASEES will enable decentralized autonomous software agents to play a role in certifying edge and cloud devices, which further can be identified in a decentralized manner by using the notion of a Decentralized Identifier.***

Use Cases

OASEES Concept: Use Cases _(1)

Use-Cases: Overview

- ***Smart Edge-Connected Node for the Analysis of Voice, Articulation and Fluency disorders in Parkinson Disease (PD)***
- ***Electrical Vehicles (EVs) Fleet Coordinated Recharging to Support Optimal Operation of Electricity Grid***
- ***Drone Swarm over 5G for High Mast Inspection***
- ***Swarm Powered Intelligent Structural Safety Assessment for Buildings***
- ***Robotic Swarm powered Smart Factory over I4.0***
- ***Smart Swarm Energy Harvesting and Predictive Maintenance Wind Turbines***

OASEES Concept: Use Cases _(2)

Smart Edge-Connected Node for the Analysis of Voice, Articulation and Fluency disorders in Parkinson Disease:

- ***Voice alterations and oral communication disorders, especially in articulation, are present in 40-80% of patients with PD.***
- ***Instrumented voice analysis allows an early identification of these distortions, in order to design or adapt supportive interventions.***
- ***It also allows the identification of changes in voice parameters for predicting the worsening of disease.***

➢ ***OASEES aims to develop an intelligent edge device capable of sensing, recording and analysing patients' utterances, as well as providing smart, adaptive and personalised guidance on rhythm and intonation.***
The system shall be usable both in rehabilitation centres during sessions with therapists and at home.

The edge devices will operate and be monitored over the OASEES Decentralised Autonomous Organization (DAO), supporting real-time monitoring of the health information in a trusted and private manner *(i.e., by adopting a privacy-by-design approach when collecting and treating patients' acoustic data).*

Devices will operate in the form of swarm and be able to be updated automatically *and also leverage the AI edge accelerators for advanced processing and insights.*

OASEES Concept: Use Cases _(3)

EVs Fleet Coordinated Recharging, to Support Optimal Operation of Electricity Grid:

- *In a power infrastructure power network, congestions can occasionally take place in the operated electricity grid.*
- *Surplus of generated power can generate reverse power flows through the LV distribution network substation, which is generally designed to handle only unidirectional electricity flows thus leading to significant issues.*
- *To avoid such abnormal operation, EVs can be offered a dedicated EV fleet platform to "match" their charging needs with proper network time and space requirements.*

➢ *OASEES aims to demonstrate the capability of deploying and coordinating, in a scalable and near real-time way, the operation and management of swarms of IoT-based devices (e-vehicles), which will be coordinated and programmed through the OASEES SDK and orchestration platform.*

➢ *The EVs will be requested to be charged when surplus of PV generated power is available, with a view to increase the share of self-consumption.*

The charger will be communicating with EV driver and with car battery management system to predict if the requested flexibility will be available in due time.

OASEES Concept: Use Cases _(4)

Drone Swarm over 5G for High Mast Inspection:

- ***Autonomous drone inspections** can provide tower companies and operators with the data and insights they need to expand their infrastructures.*

➢ ***OASEES' autonomous drone software will gather high resolution aerial data and generate accurate 3D models and a 360-degree panoramic view of an antenna's location.***

***Stakeholders shall be able to: see exactly** "hat is in the LoS from the location; **identify** potential obstructions, and; **establish** the distance from nearby existing antennae.*

***OASEES will integrate the DAO paradigm for the self-organized operation of a drone swarm, which will rely on the tight consolidation of the networking** (5G-RedCap, 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks)) **and edge acceleration technologies** (SNN), **with mutual benefits for each system** (i.e.: the networking system should be able to find **better transmission channels** towards neighbors and/or **better end-to-end paths** towards faraway drones; the SNNs will serve as a **power efficient accelerator technology** mounted in the drone, to provide **fast and accurate detection of mast defects**).*

A successful operation of drone swarms in a self-organized manner requires the integration of the networking and computational systems.

OASEES Concept: Use Cases _(5)

Swarm Powered Intelligent Structural Safety Assessment for Buildings:

- *The structural condition of critical infrastructures is usually inferred by processing data from local sensors.*
- *Collection of structural data helps in decision making in critical times (e.g., post-earthquakes, strong wind, heavy snows)*

➢ *Currently, collection of sensor data takes place on customers' premises and then data is transferred to a remote Decision Support Software (DSS) for decision making; however, this is inefficient, and causes data privacy concerns and increased response time.*

It would be beneficial to migrate to a distributed DSS architecture, with components both at the edge and the central cloud.

➢ *OASEES will integrate:*

- *Installation of the respective edge devices close to the sensors, and;*
- *Composition and deployment of a distributed DSS application via the use of a dedicated SDK.*

➢ *Sensor data will be locally pre-processed at the edge and then will be forwarded to the cloud, for high-level monitoring and dissemination.*
This will lead to a much more robust system, higher reliability and less dependence on human intervention.

OASEES Concept: Use Cases _(6)

Robotic Swarm powered Smart Factory for I4.0:

- ***Development of a fully automated system for the production of furniture in all stages of processing:*** *from the standard panel to the assembly of the cabinet (including assistance by industrial anthropomorphic robots for dangerous and low added value tasks), by collaborative robots in the final stages of assembly, insertion of hardware, glue dispensing and finishing, and AMR (Autonomous Mobile Robots) self-driving for flexible interconnections between different cells and islands.*

➢ ***In OASEES the focus is about developing a finishing (sanding) machine, to satisfy medium and large companies requiring the highest quality: this deals with sanding of "complex" geometry pieces of furniture (e.g. doors) via an automatic sanding system based on the application of a collaborative anthropomorphic robot.***

The aim is about implementing an automated manufacturing process for semi-finished wood panels to be transferred from one station to the sanding machine and from there to the other station via AGVs (Automated Guided Vehicles), coordinated and programmed by the OASEES orchestrator and SDK for line supervision, relieving human operators.

The challenge is the incorporation of DAO functionality for HITL (Human in the Loop) decision making for I4.0.

OASEES Concept: Use Cases _(7)

Smart Swarm Energy Harvesting and Predictive Maintenance Wind Turbines:

- ***Maintenance of wind farms represents a cost of 20% of the total project.***
- ***Inspection of turbine blades is essential to optimize operation and maintenance.***
- ***BAMS (Blade Acoustic Monitoring System) is a new (portable, non-intrusive and manufacturer-independant) system for inspection and predictive maintenance of wind turbine blades, based on acoustic signals.***
- ***BAMS can detect structural failures, wear, ice, corrosion, or dirt on blades.***

➢ ***OASEES aims to develop novel IoT-based meters to support on-the-fly programmability.***
The device swarm will be based upon IoT sound transducer (microphones) applied to wind turbines.

The main goal is to extend the capabilities of BAMS, to be able to function as an IoT device in swarm mode.

The simultaneous capture and processing of data from a considerable number of wind turbines will create a BAMS network.
All acquired data will be transmitted to the cloud, processed securely, and analyzed by using ML algorithms, thus ***allowing the sensors to: learn from each other (improved calibration, noise suppression, etc.); improve and obtain better metrics and; optimize failure prediction on the blades.***

Overview – Concluding Remarks

OASEES: Overview & Concluding Remarks _(1)

OASEES envisions a holistic approach for edge data processing, aiming to:

- ***Disrupt current practices which heavily rely on non-European cloud AI data processing, and;***
- ***"push" AI training and inference at the edge of the network, while being vertical agnostic.***

OASEES: Overview & Concluding Remarks _(2)

OASEES targets several specific measurable objectives, each one associated with "key results" and all being accompanied with dedicated KPIs.

OASEES's explicit aims:

- ***Designing a decentralized, agile and secure architecture for collaborative smart nodes at the edge,*** ***supporting heterogeneous device communication, backed by the DAO paradigm integration;***
- ***building a secure, trustworthy and decentralized edge ecosystem*** ***with native device support for a portable digital identity that does not depend on any centralized authority;***
- ***structuring rapid development kits (RDKs) for an open programmable framework across different smart edge nodes,*** ***while incorporating efficient cloud-to-edge continuum intelligence across heterogeneous target environments;***
- ***demonstrating the framework and programmability toolkit in a set of six different vertical use cases and evaluating the benefits across different sectors;***
- ***maximizing business impact of the expected results*** ***and fostering the creation of an open-source community around the proposed -per case- solutions, to support market viability.***

OASEES: Overview & Concluding Remarks _(3)

OASEES will operate in multi-domain configurations and the corresponding system(s) shall enable users to:

- ***Discover and select available platforms, services and capabilities pertinent to their needs;***
- ***develop AI services as well as automate lifecycle management operations;***
- ***deploy and manage AI workflows across the compute continuum;***
- ***configure service performance constraints;***
- ***interactively explore data and exercise MLOps;***
- ***verify the integrity of infrastructure and services across the continuum.***

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Thank you for your attention!

https://oasees-project.eu/

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