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aerOS
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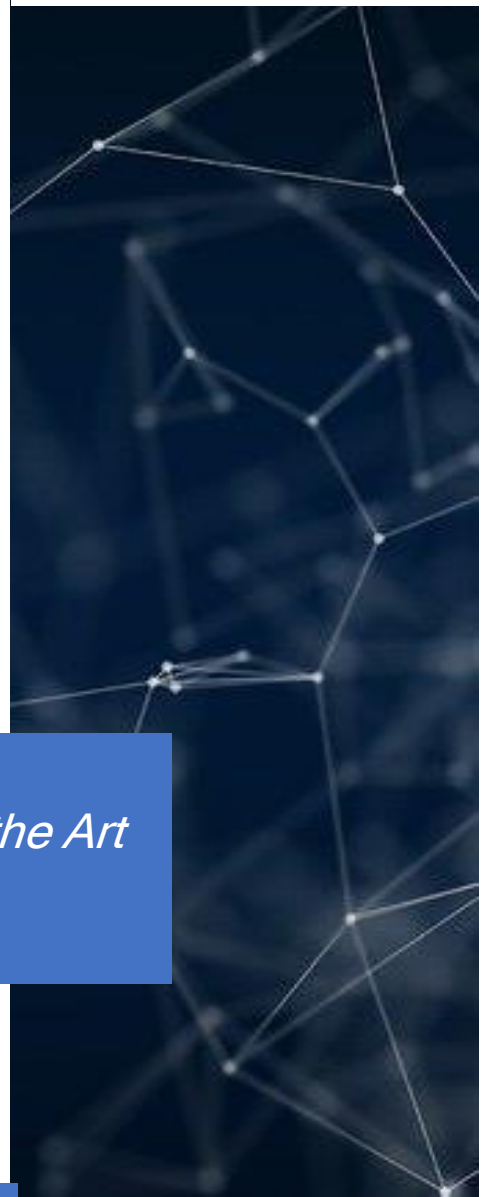

aerOS General Introduction

Workshop on State of the Art and Market Analysis

aerOS in numbers

- Call and Topic: HORIZON-CL4-2021-DATA-01-05 Future European platforms for the Edge: Meta Operating Systems
- Type of project: RIA
- Total budget: 11,828,857.50 €
- Grant Agreement Nº: 101069732
- Duration: Sep 2022- Ago 2025 (36 months)
- Project Coordinator: Carlos E. Palau Salvador (UPV)
- Field of action: Edge-cloud continuum, Frugal explainable AI, orchestration, virtualisation, networking, data governance and sovereignty, trustworthiness, decentralised computing
- Nº partners: 27
  - *From 11 countries* : Spain, Poland, Greece, Germany, Finland, Cyprus, Romania, Italy, Austria, Ireland, Switzerland.
  - *Experts in every area* : edge-cloud research in academia, edge-cloud deployments in the industry,5G, semantics, artificial intelligence, security, business, exploitation of results, communication service and infrastructure providers, stakeholders in manufacturing, agriculture machinery, maritime ports, energy production and telecom operators.

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aerOS partners

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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

DEMOKRITOS

innovalia ASSOCIATION

TTControl HYDAC INTERNATIONAL

SIEMENS

FIWARE FOUNDATION

Telefónica

COSMOTE

InQbit The Q-Bit Innovation

FOGUS INNOVATIONS & SERVICES

ERICSSON

IBS PAN

ic ficial solutions

INFOLYSIS

prodevelop

EUROGATE Container Terminal Limassol

Cyprus University of Technology

dst.

S21 SEC

JOHN DEERE

CloudFerro

electrum

POLITECNICO MILANO 1863

MADE Competence Center I4.0

SWITZERLAND INNOVATION PARK BIEL/BIENNE

nasertic

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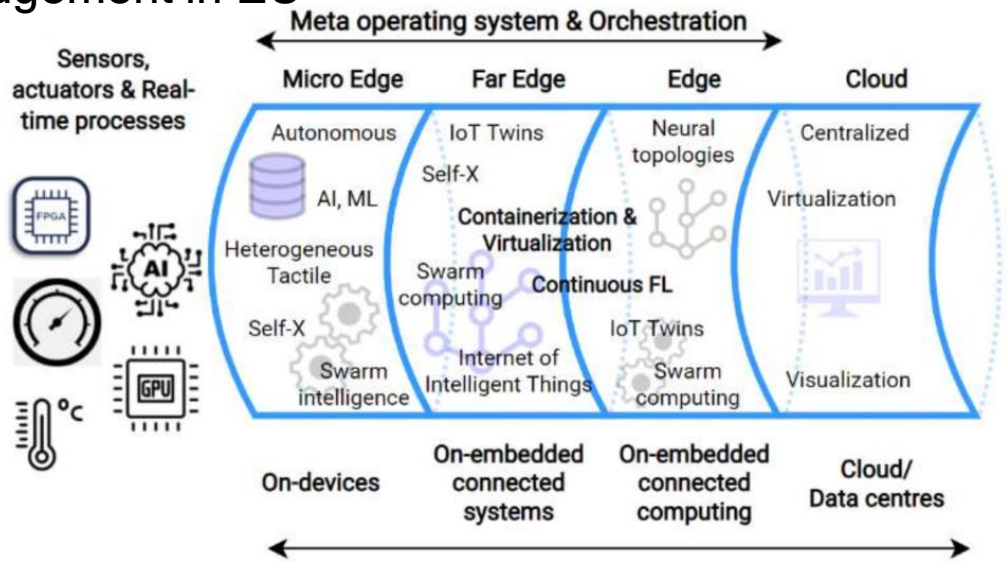
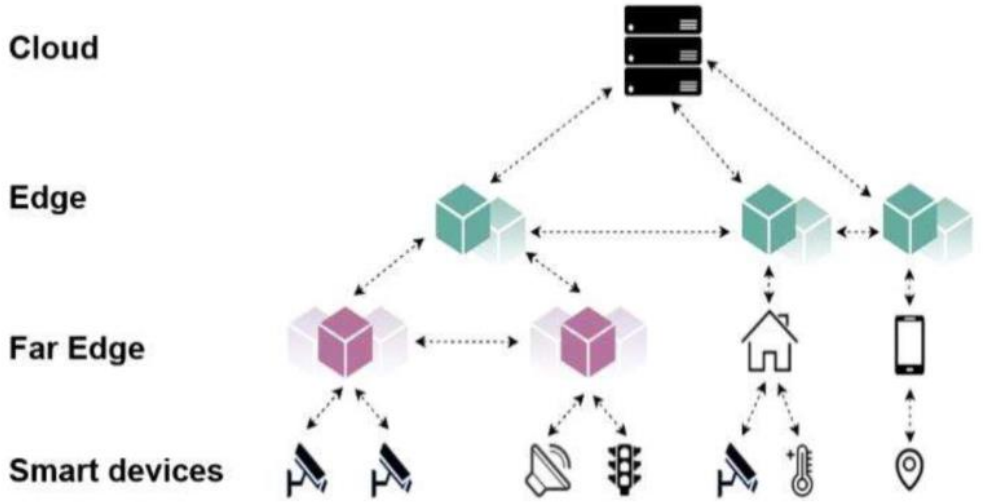
Context and origins

The **unprecedented data explosion** and the evolving capabilities of **virtual infrastructures**, set the scene for developing a **new paradigm** for data and compute resource management in EU





Processing needs to be performed closer to the data sources (often smart devices), in an effort to minimise latency, save bandwidth, improve security, guarantee privacy and increase autonomy

ISSUES

- Wide variety of deployment models and open standards
- Existing legacy investments
- The challenge of seamlessly integrating various edge technologies into a homogeneous "continuum" remains open
  - Cloud centricity and cost
  - Network management
  - All-around virtualisation
  - Security & trust

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Main goal and ideas

aerOS overarching goal is to design and build a virtualised, platform-agnostic **meta operating system for the IoT edge-cloud continuum.** As a solution, to be executed on any Infrastructure Element within the IoT edge-cloud continuum – hence, independent from underlying hardware and operating system(s)

aerOS will…

…deliver virtualised services to enable orchestration and efficient support for frugal, explainable AI

…expose an API available anywhere and anytime (location-time independent), flexible, resilient and platform-agnostic

…include a set of infrastructural services and features addressing cybersecurity, trustworthiness and manageability

via:

- …using context-awareness to distribute software task (application) execution requests
- …supporting intelligence as close to the events as possible
- …supporting execution of services using “abstract resources” (e.g., virtual machines, containers) connected through a smart network infrastructure
- …allocating and orchestrating abstract resources, responsible for executing service chain(s)
- …supporting scalable data autonomy

aerOS approach will be generic and directly applicable to any vertical

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Formal objectives

- O1: Design, implementation and validation of aerOS for optimal orchestration
- O2: Intelligent realisation of smart network functions for aerOS
- O3: Definition and implementation of decentralised security, privacy and trust
- O4: Definition and implementation of distributed AI components with explainability
- O5: Specification and implementation of a Data Autonomy strategy for the IoT edge-cloud continuum
- O6: Definition, deployment, and evaluation of real-life use cases (5)
- O7: Global ecosystem creation, maximisation of impact and Open Call conduction

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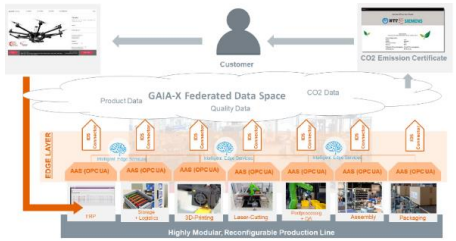
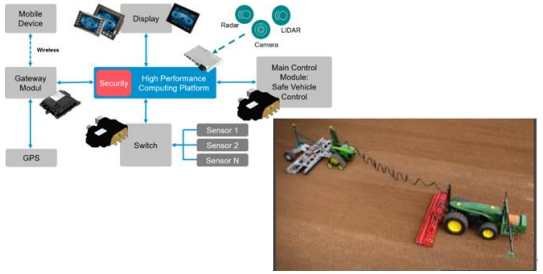
Use cases

Manufacturing: Data-Driven Cognitive Production Lines (Manufacturing Autonomy Level 4 – MAL4)

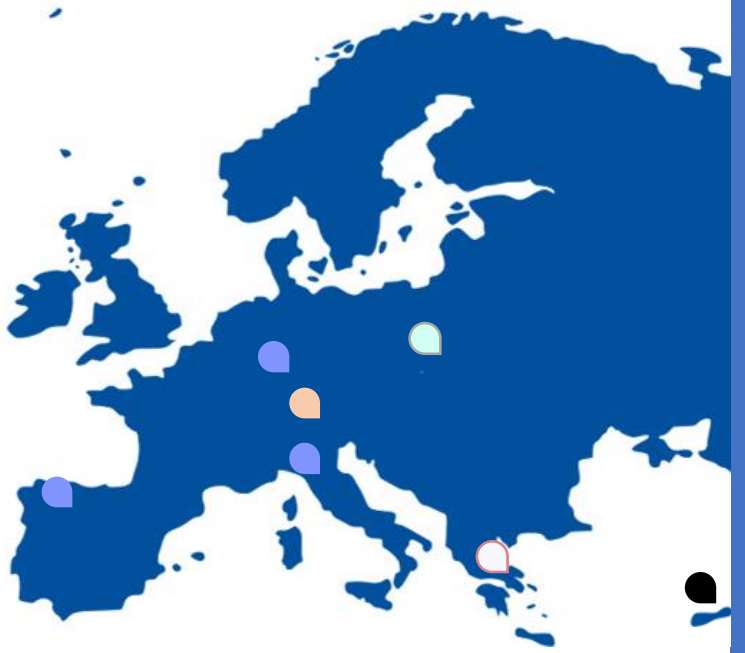


Machinery: High Performance Computing Platform for Connected and Cooperative Agricultural Mobile Machinery to Enable CO2 Neutral Farming (HPCP-F



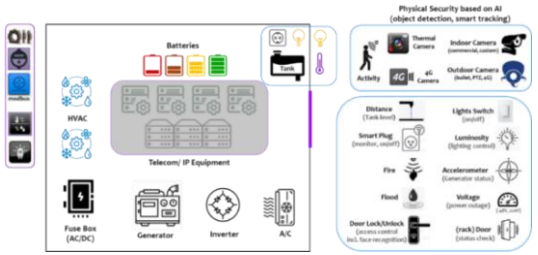
Renewable energy: Containerised Edge Computing near Renewable Energy Sources

Maritime ports: Smart edge services for the Port Continuum



Smart Buildings:

Energy Efficient, Health Safe & Sustainable Smart Buildings



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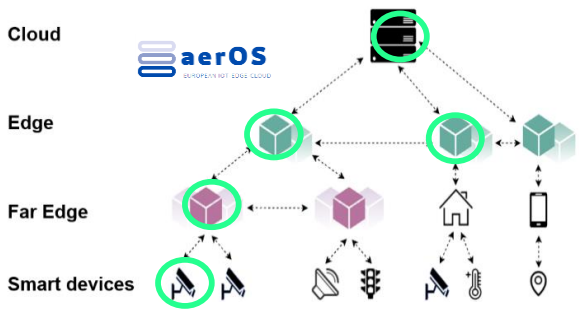
Summarised scope and impact

1 What are the technical innovative aspects of your proposed solutions?

Infrastructure Element (IE)

Orchestration

Zero touch, automated (AI-powered), in a heterogeneous continuum of resource federation



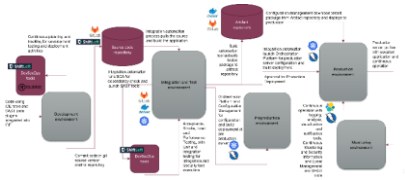
CIM
YANG
Metadata
Policies
Interoperability

Enhanced data autonomy

Cloud-native-like by design, everywhere

- Containerisation
- Virtualisation
- Dynamic deployment
- Reconfiguration
- Applicability

DevPrivSecOps



on resource constrained devices going beyond current cloud federated AI/ML FWs

Frugal XAI (FAI)

How would your project contribute to strengthening the European competitiveness in platforms supporting IoT and Edge? 2

TRL6-7 adoption and positive feedback from stakeholders: 80% of positive OC stakeholders feedback, 97% of requirements coverage, 85% usability testing and excellent HPC and AI benchmark performance.

Contributing towards European Data Economy with 3 data sovereignty initatives, 5 new data models and 10 contributions to EU official data spaces.

First European self-orchestration agent to spawn AI services regardless the (softwarised) network

Fostering trust in meta OS systems among Industrial actors increasing their participation in a 30%, connecting 50% more of equipment nodes (IEs in **aerOS**) and exchanging 80% more data.

Tackling the emerge of European open edge ecosystems by receiving 30 applications to **aerOS** OCs from SMEs, having 8 SMEs in total offering services through **aerOS**. 3 trademarks, 1 design rights registered, proper product licensing.

3 What do you expect as technical , social or economic impacts of your project?

- **Cover the gap** between data spaces reference trends and edge-to-cloud European computing OS
- Pose a **new paradigm** for better and faster data / resources / services orchestration along IoT edge-cloud continuum path.
- Alignment of Data Strategy, Industrial Strategy and the goals for Digital Decade in a single meta operating system platform transforming EU roadmap into a **smart investment**
- Nurturing of a growing start-up and SMEs **European ecosystem** on edge-cloud solutions
- Transparent usage of **trustworthy EU-promoted technologies** via user-friendly UIs and full control on the data flows in use and how they are processed and stored
- More **efficient** distributed computing and **data centers** aligned with EEA, UN sustainable goals and sustainable Europe initiatives
- Contribute towards the goal of 10.000 **climate-neutral** and secure edge **nodes by 2030**
- Lower **energy consumption** of IoT/Edge deployments

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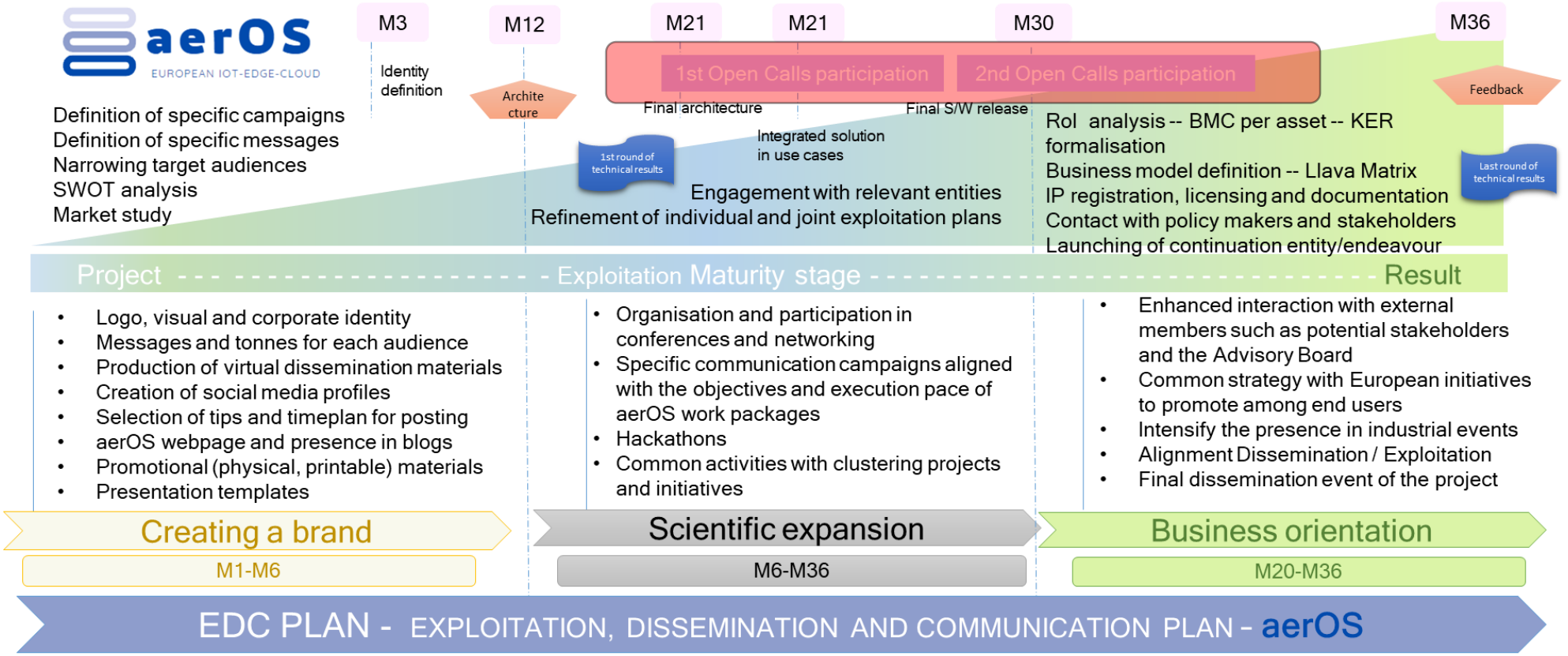
Impact Outreach Plan And Open Calls



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Impact Outreach Plan And Open Calls

- **Two** open calls to be conducted

	1st Open Call Schedule		2nd Open Call Schedule		
Sept-23	Announcement	M13	Announcement	M20	Apr-24
Oct-23 to Jan-24	Submission Phase	M14-M17	Submission Phase	M21-M24	May-24 to Aug.-24
Feb-24 to Mar-24	Evaluation Phase	M18-M19	Evaluation Phase	M25-M26	Sep-24 to Oct-24
Apr-24	Start Participation	M20	Start Participation	M27	Nov-24
Nov-24	End Participation	M27	End Participation	M34	Jun-25

- A total of **900k€** will be distributed to external third parties.
- Expected ~15 contributions (max.7 in the first, and min. 8 in the second) will be selected.
- Each open call will be funded with a fixed amount of **60k€**.
- Each open call funded proposal will have to focus **on one out of the five pilots**.

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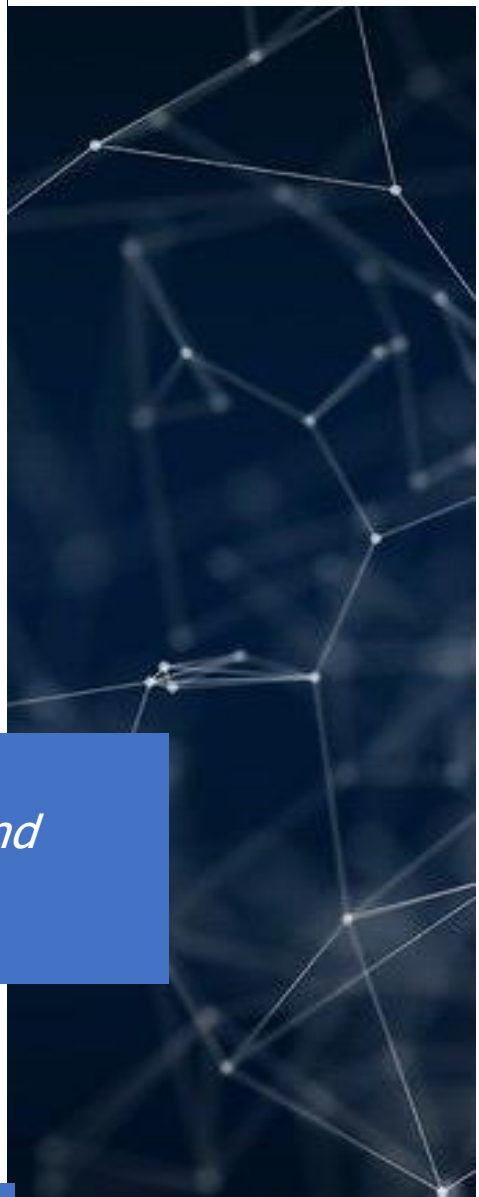

General introduction on objective of the Task and D2.1 contents

T2.1 -State of the art and market analysis

T2.1 - STATE OF THE ART AND MARKET ANALYSIS

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Administrative Information	
Leader	DST
Contributors	All Partners
Start Date	M1 - September 2022
End Date	M3 - End of November

Deliverable	
D. no	D2.1
Title	State-of-the-Art and market analysis report
Deadline	M3 - End of November
Type	Document - Report
Diss. Lev.	Public

Objectives

- **Analyse the SotA of aerOS**, gathering most recent insights into pertinent topics, e.g.: *IoT edge-cloud continuum architectures; Artificial Intelligence; scalability; cloud and edge federation; manageability and adaptability; automatic and dynamic network paradigms*
- **Analyse the addressed market of aerOS**, with attention on the different variables that are affecting and influencing it.

Main Approach

Starting from the SotA and the Market description in the Proposal, the task will deeply analyze mainly:

- technologies,
- existing solutions and providers
- external factor
- market size, trends and variables

with special focus on existing/proposed standards and research projects, Market POC and Business Solutions. In particular….

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T2.1 - STATE OF THE ART AND MARKET ANALYSIS

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Key Feature of the SoTA

- Objectives and Ambition of the Project
- Technological Stack of the Project
- Existing solution and standards
- Innovative trends

Key Feature of the Market Analysis

- Market definition, size and trends
- Target Users per each KERS and Target Segments
- Market Needs and Pain Points to be overcome by areOS
- Barriers to Entry
- Factor that influence the aerOS market (PESTLE)

Approach

Mapping key Technologies and solution

- Identifying trajectories
- Identifying Glossary
- Outline ambitions to go beyond the SoTA

Mapping Market

- Identifying the main market pillars that guides the areOS vision and development

Combining technologies to build a visionary solution

- Imagining what areOS ecosystem will be from the technological perspective and will look like from the Market actors perspective

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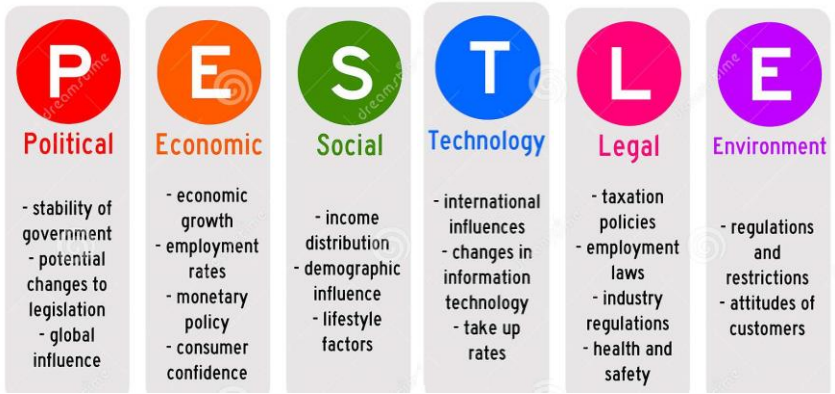
T2.1 - STATE OF THE ART AND MARKET ANALYSIS

Main Activities

- Desk research;
- Market studies/reports analysis;
- In-depth interviews with internal and external experts (EOB) and stakeholders;
- Focus Group
- Users' surveys (on-line questionnaire)
- Workshop

Methodologies

The Task will be focused on the political, economic, social, technological, environmental and legal factors that could affect aerOS now and in the future.



So…the purpose of the **PESTLE** method is to better analyse the market aerOS is operating in now and how it can prepare for potential shifts.

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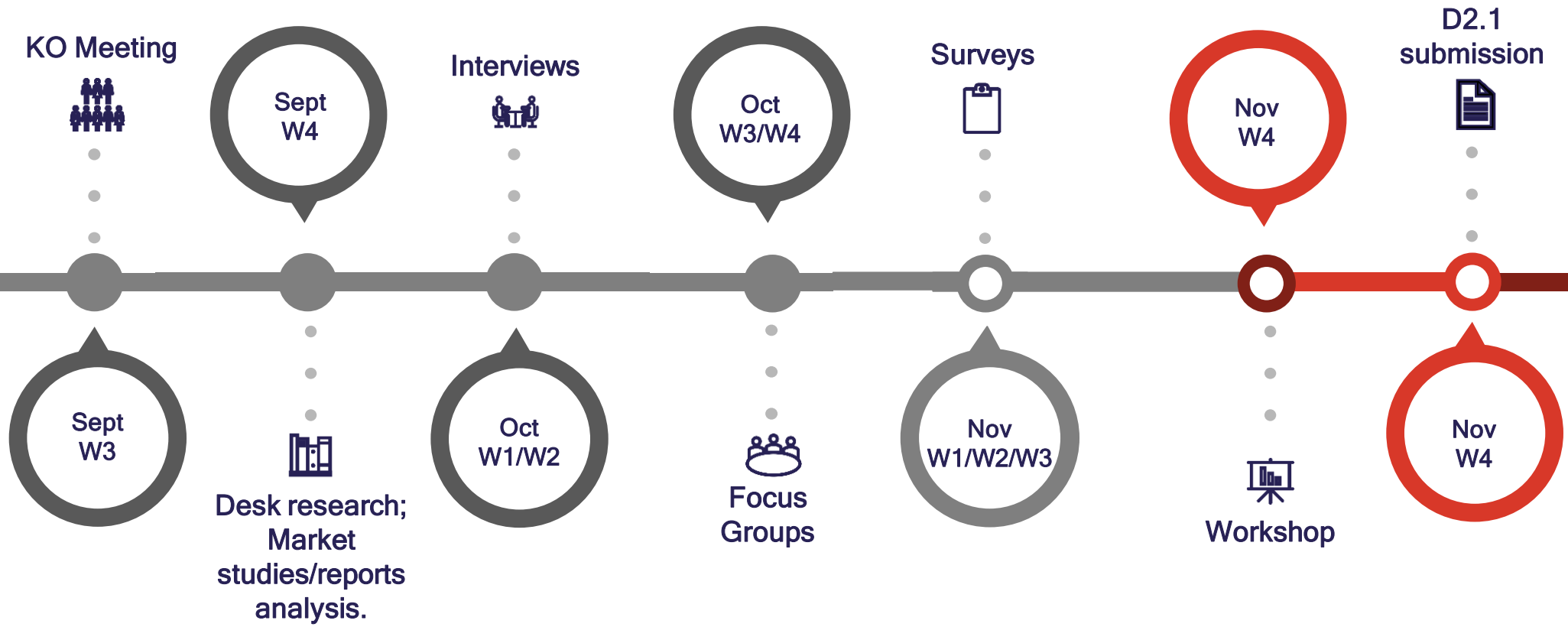
T2.1 - MARKET ANALYSIS



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T2.1 - STATE OF THE ART AND MARKET ANALYSIS

PESTLE in a nutshell

Political

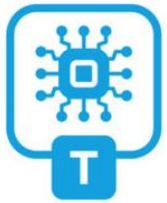
These factors determine the extent to which a government may influence the market of areOS. Political factors include tax policies, Fiscal policy, trade tariffs, etc.

Economic

These factors are determinants of an economy's performance that directly impacts the purchasing power of af the Target Market of areOS and change demand/supply models for that economy.

Social

These factors scrutinize the social environment of the market, and gauge determinants like cultural trends, demographics, population analytics, etc.



Technological

These factors pertain to innovations in technology that may affect the operations of areOS. This refers to automation, research and development, and the amount of technological awareness that a market possesses.

Legal

These factors have both external and internal sides. There are certain laws that affect the business environment in a certain country while there are certain policies that companies maintain for themselves.

Environmental

These factors include all those that influence or are determined by the surrounding environment. E.g, geographical location, global changes in climate, environmental offsets, etc.

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T2.1 - STATE OF THE ART AND MARKET ANALYSIS

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Consortium Clusters

- Pilots
- Links /TLs
- Coordination
- Other Tech. Partners

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T2.1 - STATE OF THE ART AND MARKET ANALYSIS

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Main Group Activities

- In-depth interviews with internal and external experts (EOB) and stakeholders;
- Focus Group with Research Partners
- Focus Group with Industrial Partners (including Tech & Use Cases)
- Users' surveys (on-line questionnaire)
- Final Workshop.

Activities per Clusters

Interviews	Focus Groups	Survey	Workshop
Coordinators (2)	Pilot - Manufacturing-production	Other Tech Partners	ALL
Links / TLs (5)	Pilot - Renewable energy sources		
	Pilot - Port Continuum		
	Pilot - Smart building		
	Pilot - Machinery of agriculture, forestry and construction		

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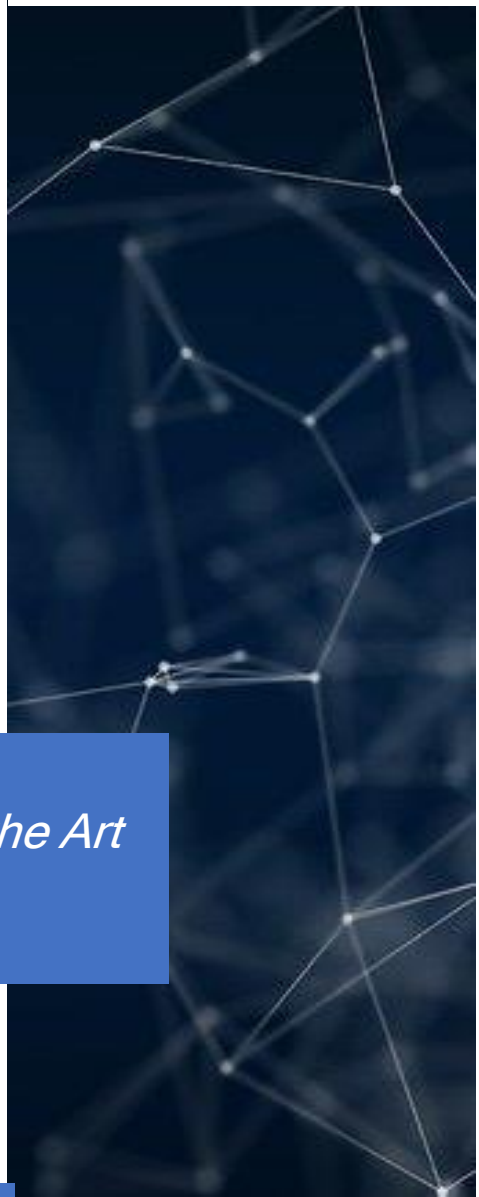

aerOS SotA of technology

Workshop on State of the Art and Market Analysis

Why the study of the state of the art?

- The technological landscape has changed since the proposal stage (October 2021).
- All partners are spotting the current trends and technologies to consider.
- Agree on some required terminology (continuum, edge, node, cloud, meta OS…)
- We reach a milestone (MS1): the prelude of technical work kick-off

		sep-22	oct-22	nov-22	dic-22	ene-23	feb-23	mar-23
		Year 1						
#	Name of the WP/task	1	2	3	4	5	6	7
WP1	Coordination and management			MS1				
WP2	aerOS reference architecture for the IoT-edge-cloud continuum							
T2.1	State of the art and market analisys			D2.1				
WP3	aerOS secure, scalable and decentralized compute infrastructure							
WP4	Delivering trustworthy applications intelligence at the edge							
WP5	aerOS integration, use cases deployment and validation							
WP6	Impact creation			MS1				

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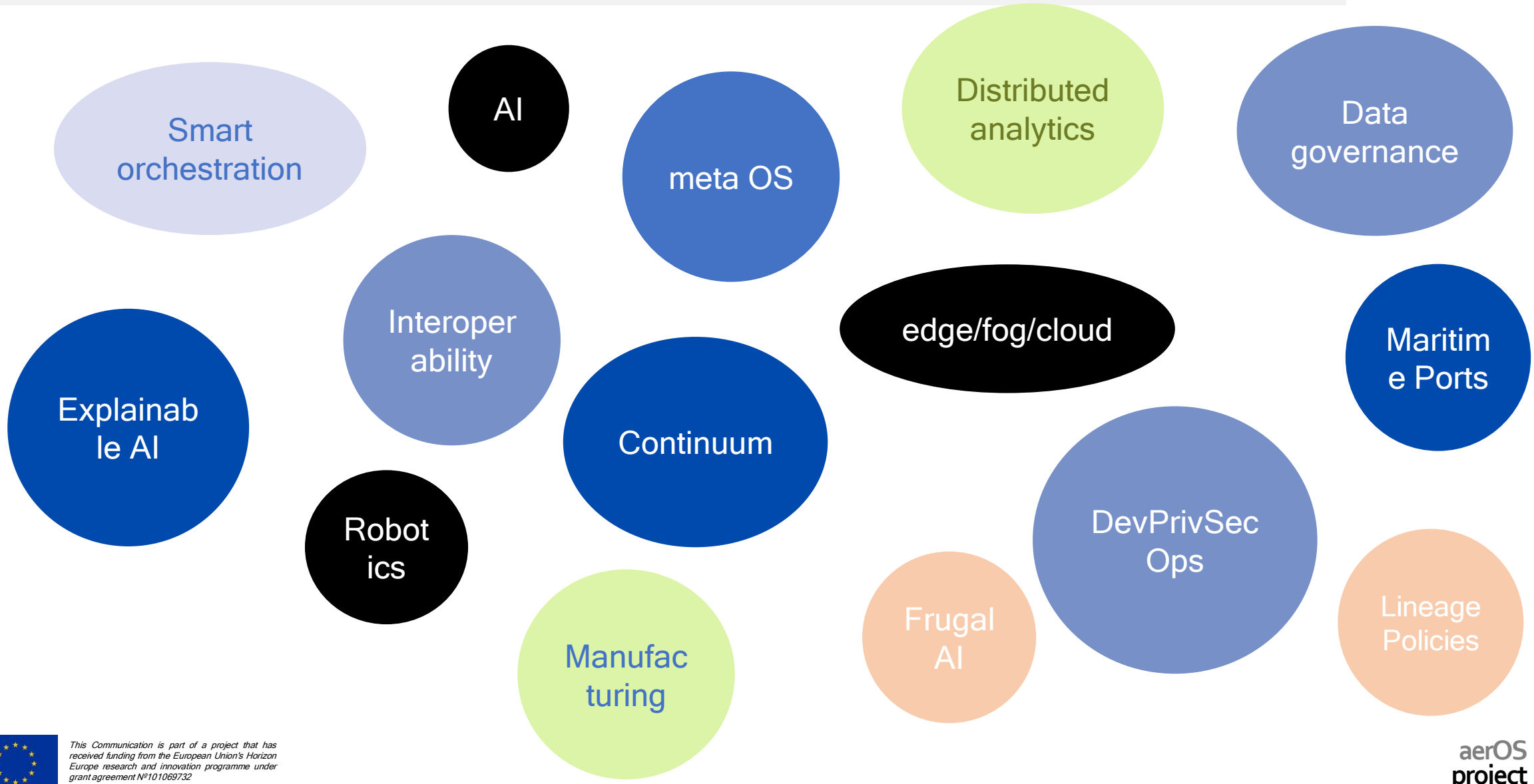
What does aerOS cover?



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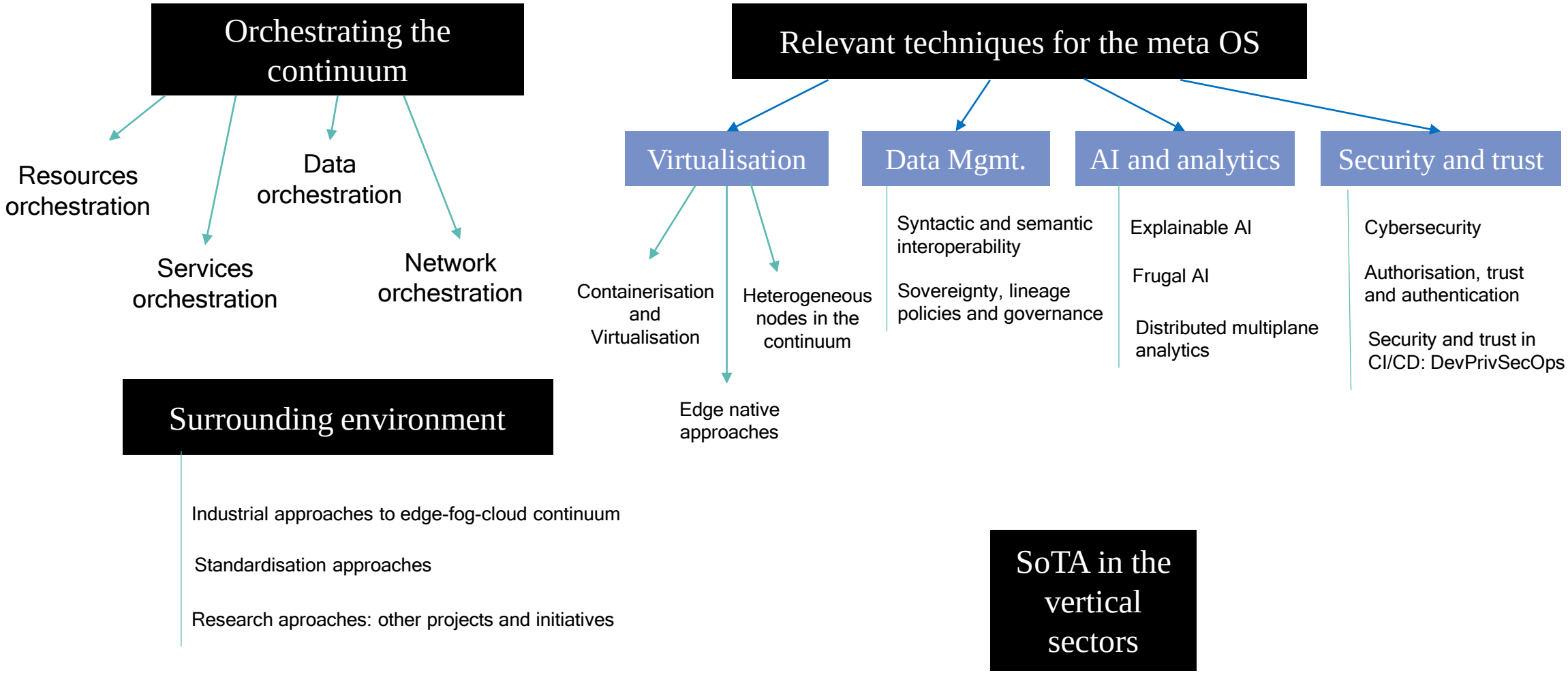
Ordering the study



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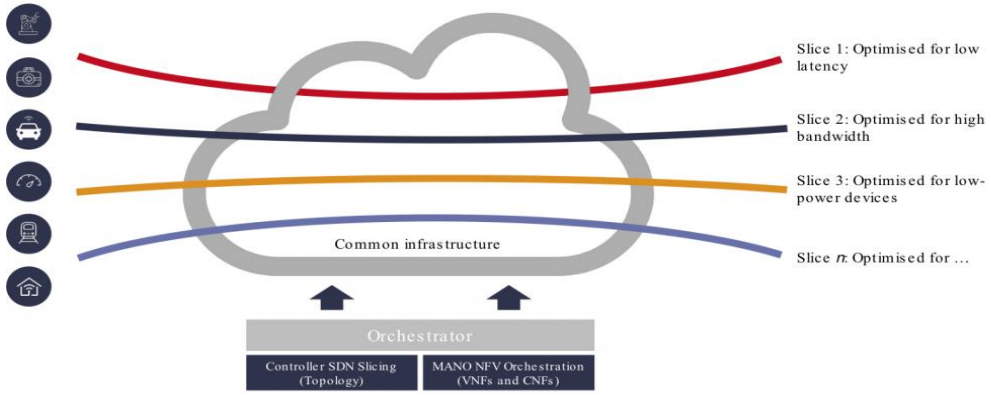
Orchestration of network, resources, services and data

NETWORK ORCHESTRATION

"**Smart networking orchestration**" = virtualization and control of network resources and functions as a service.

Very relevant in the continuum as topologies and equipment for network traffic will vary and can be very inefficient if not managed dynamically.



	Current techniques / technologues	Issues
Infrastructure virtualization	VXLAN, NVGRE or STT (not devised for IoT-continuum)	Usual techniques cannot support essential dynamism, flexibility, and scalability.
Network programmability	SDN (OpenFlow – NOX/POX controller, FloodLight, Beacon, Maestro.	
Network Functions	NFV and network exposure (CAPIF, SEAL). CNFs to adjust to cloud-native. NetApps	There are not edge-native prepared technologies and require very specifig usage of non-legacy network equipment.

Breakthrough: **aerOS** will integrate relevant technologies relying on open source elements of connectivity, IoT, NFV and network orchestration.

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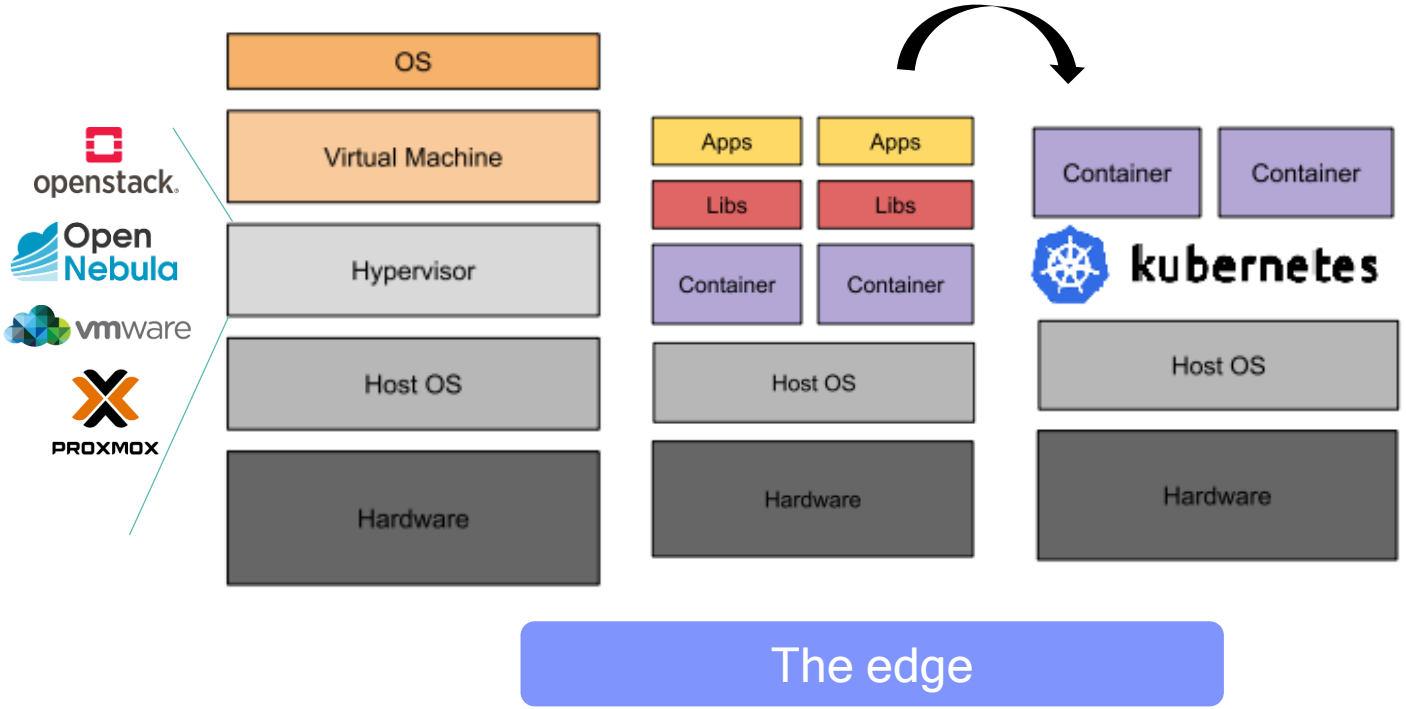
Containerisation, virtualisation and edge-native approaches



- Less resources (VMs no sense)
- Heterogeneity of underlying OS
- A mix of static and dynamic demand
- Not uniform configurations
- Cloud-native aspects do not have their edge equivalent YET.

- OS oriented to allow microservices run in the edge
  - BalenaOS
  - Pantavisor
  - EVE-OS
  - …
- Lighter distributions ok Kubernetes to bring those advantages to edge devices
  - microK8s
  - K3s
  - K0s
  - Akri
  - KubeEdge
- Serverless architectures at the edge
  - OpenFaaS
  - Knative

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Orchestration of network, resources, services and data

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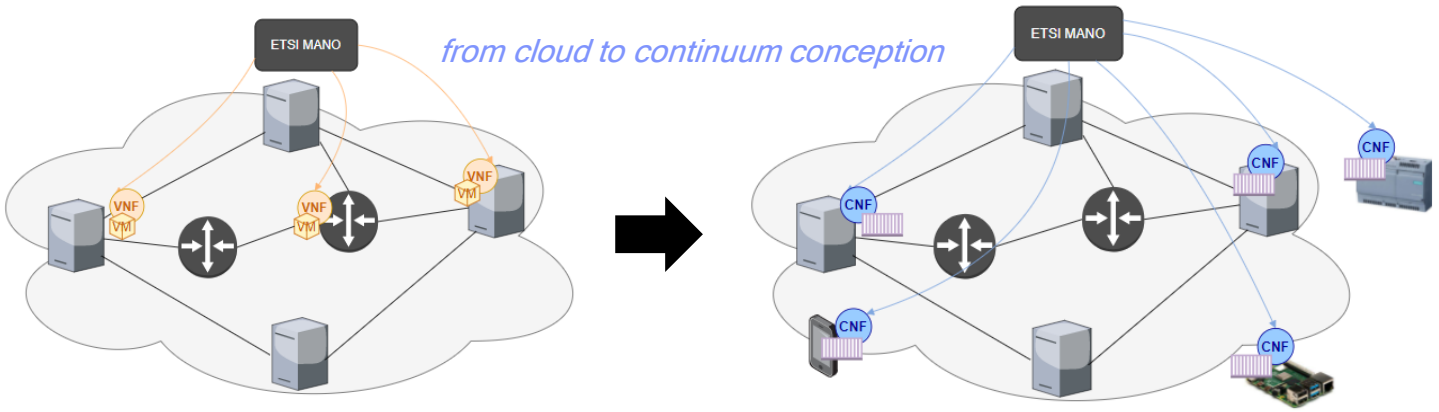
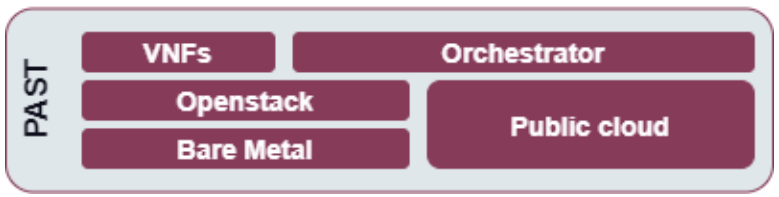
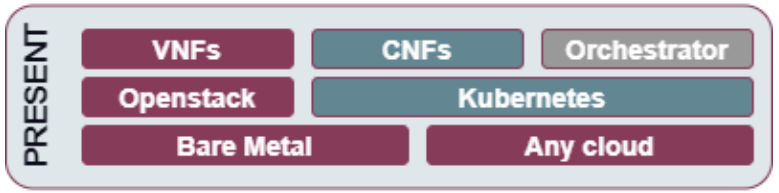
RESOURCES & SERVICES ORCHESTRATION

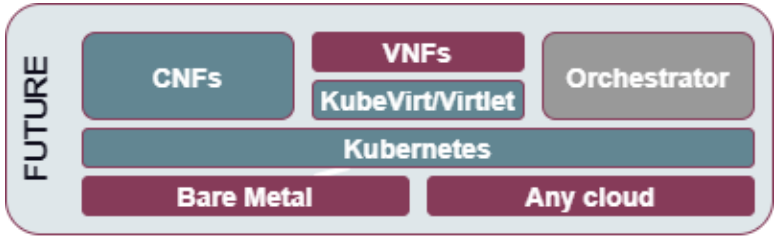
Service orchestration is the distribution of services on the nodes of a network. Services can be applications, micro-services, or containerized environments which can be stand-alone or communicate with each other.



- Huge change depending on orchestration decision engine and approach.
- Centralization (hierarchical) or decentralization seem now orthogonal and could be both leveraged.
- Knowledge of the infrastructure (metadata of the infrastructure elements) is key.
- Scalability is one of the main concerns: AI for optimal selection of node (ILP problem, DRL approach) and convergence times (DQN-based offloading).







Breakthrough: **aerOS** will integrate relevant technologies, such as AI and cybersecurity on top of resource managers (e.g. ETSI MANO) to provide CLA & zero-touch orchestration leveraging ongoing standards and open source initiatives.

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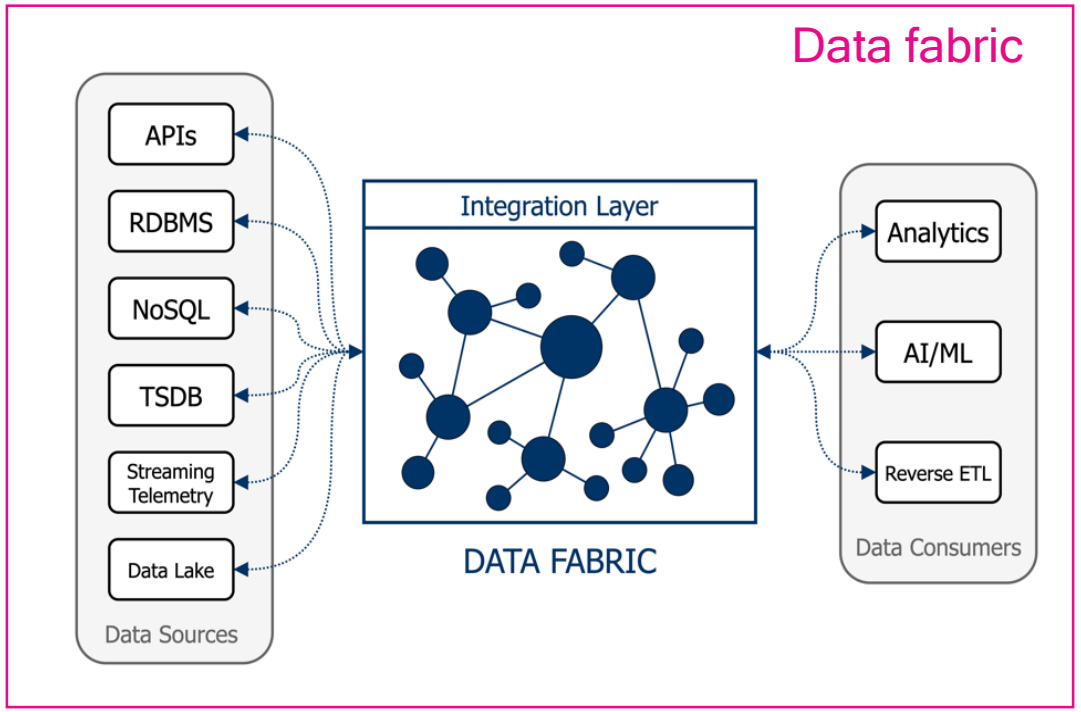
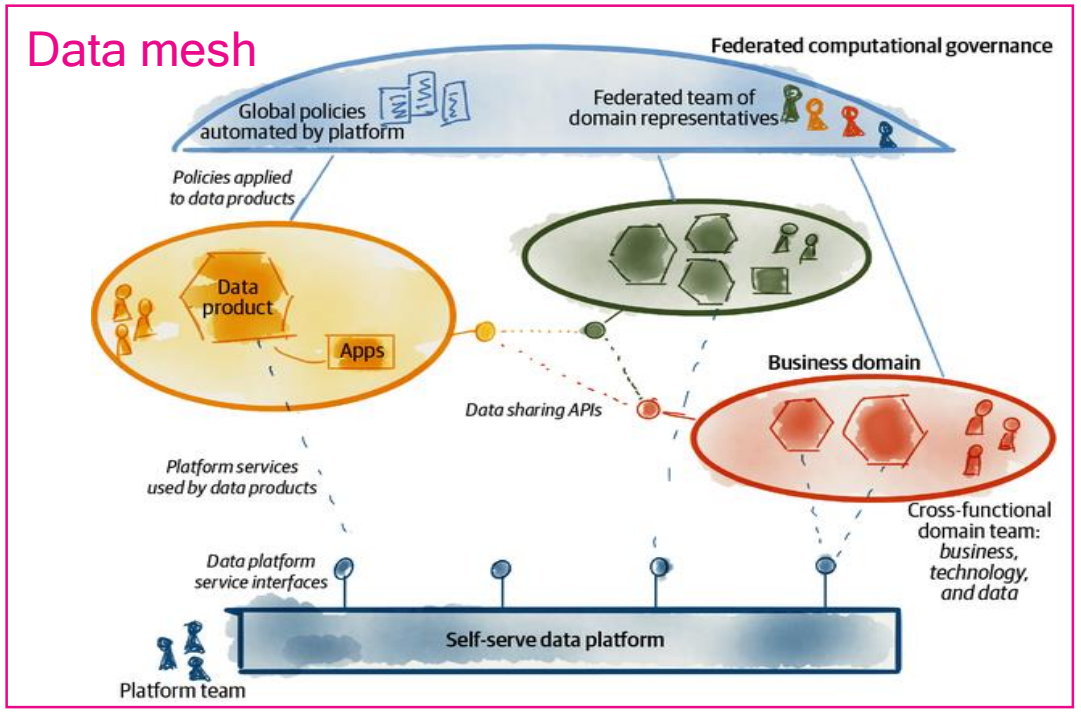
Orchestration of network, resources, services and data

DATA ORCHESTRATION

How to understand the amount, variety, diversity in type, format and origin of the data generated in a continuum (e/f/c)?



IBM, K2View, Informatica, data.world, Stardog , or Talend.



K2View or data.world

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Data synctactic, semantic interoperability and governance

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Representing “semantically annotated” data

Annotation frameworks RDF, JSON-LD, OWL, ERD-UML

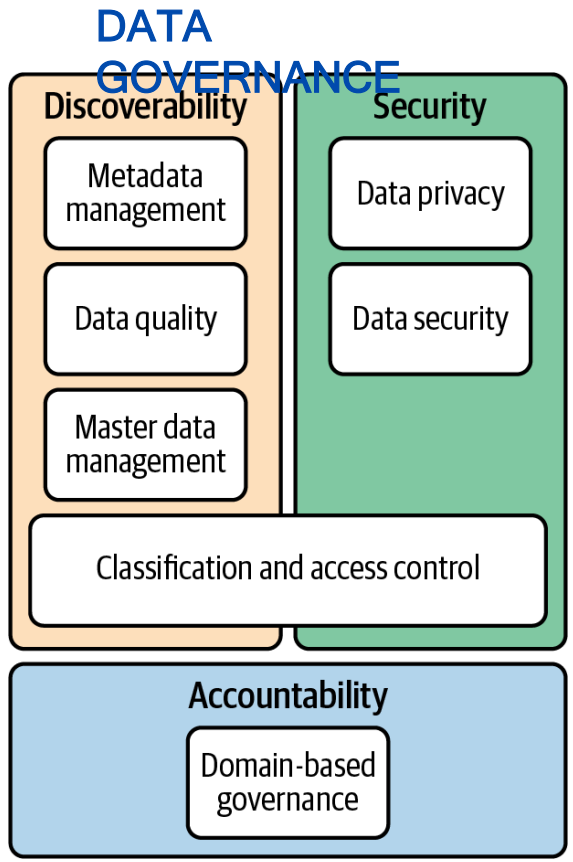
“ontologies”
- Generation tools: Ontomalizer, ReDeFer
- Existing: GeoSPARQL, QU, OM, PROV-O…

Translators Stream processing technologies: Apache Kafka, Storm, Flink enriched by streaming semantic translators: IPSM, Jelly.

Semantic interoperability — Data exchange based on a uniquely defined common meaning

XML, SOAP, JSON… — **Syntactic interoperability** — Common data formats and common data structure protocols

HTTP, TCP/UDP, MQTT, AMQP… — **Technical interoperability** — Technical connection



The purpose of data governance is to build trust in data

metadata management tools or data catalogues

GDPR, PII management, data access policies, authorisation

Data owners and governors

aerOS will develop effective mechanisms to distribute data across IoT edge-cloud continuum, proposing smart, dynamic semantic translation and a solid governance framework so that the integrity and the performance are not compromised.

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Advanced AI and distributed multiplane analytics

moves the code and models for training a centralised cloud and closer to the locatio collected

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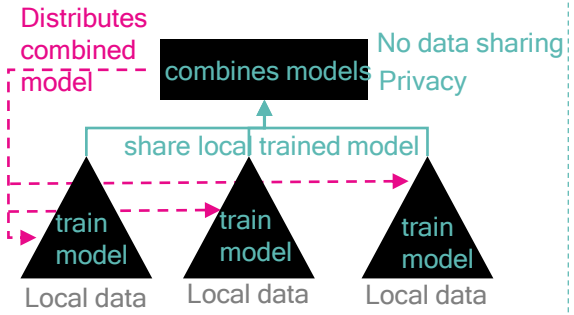
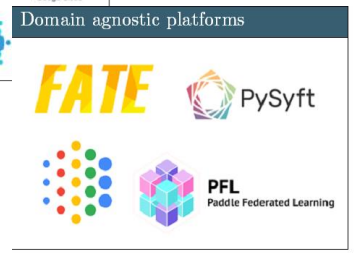
Federated Learning



※ Data unbalance
※ Cost of communication
※ Resources constrained
※ "Model combination" is always an open research field



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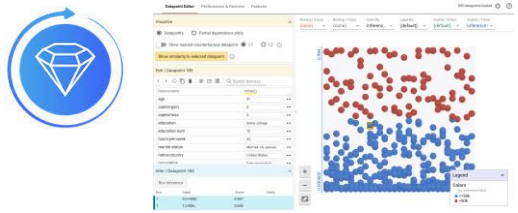
Explainable AI

- Explainable data

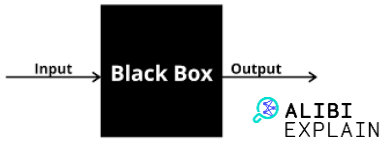


- Explainable predictions

SHAP InterpretML

- Explainable models

RuleX SKATER



※ **Not designed for the edge-to-cloud continuum!**

Frugal AI

Deep Learning methods

- AMOUNT OF DATA USED
- COMPUTING POWER

= PERFORMANCE

FRUGALITY SCORE TRADEOFF

- Transfer learning
- Zero-shot learning
- Few-shot learning
- Active learning
- Hybrid AI
- Synthetic data gen. & augm.

Distributed multiplane analytics

Analytics on:
- **The distributed IE elements.**
- **The networking domain.**

Big Data is thrown away

Local models would allow relevant, valuable info to be considered

Software functions embedded in IEs and network devices.

data iku dask databox

aerOS project

Security, integrity, trust and DevPrivSecOps

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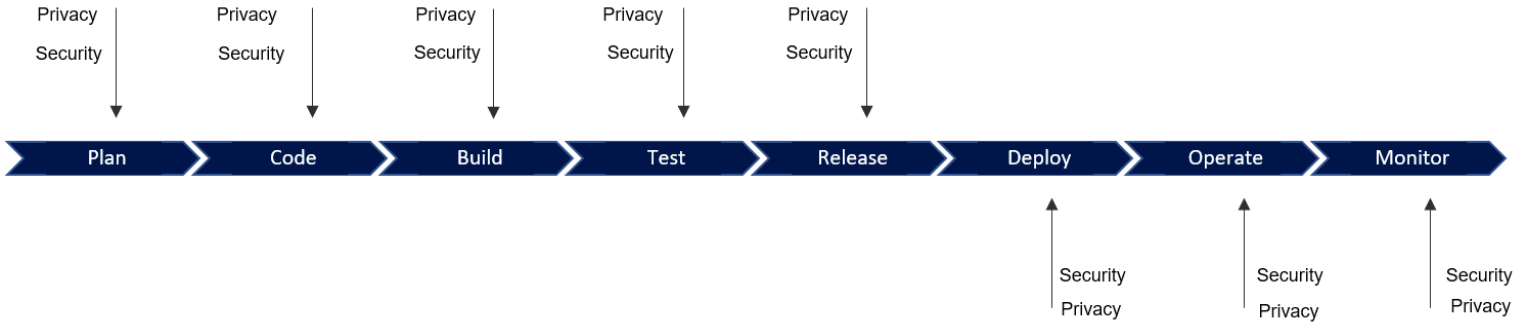
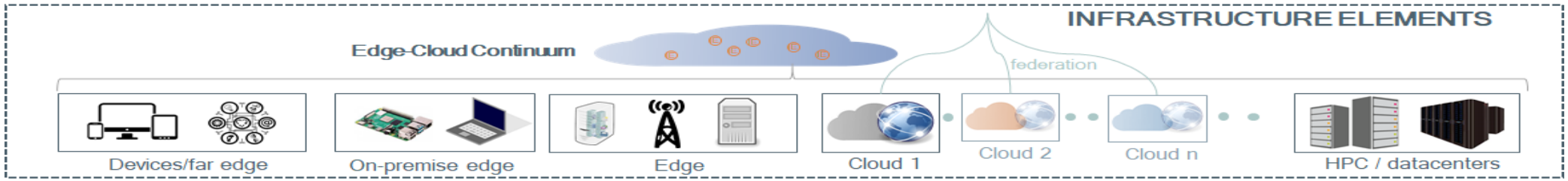
Continuous CI/CD



Deployment in the continuum



SW injection, DoS, eavesdropping, HW security… — **Security** → **Intrusion Detection Systems, FW updates, RBAC, PBMC, access control**

Data privacy, privacy leakage, location data leakage — **Privacy** → **Crypto. primitives, anonymisationk-anonymity** (l-diversity, T-closeness, differential privacy & hashing functions), **decentralization, aggregation**

Trust level identification, defamation, collision — **Trust** → **Trust evaluation, trust management** (FIDO, TEE, Hyperledger Fabric)

Breakthrough: **aerOS** will deliver highest levels of security, privacy and trust, while keeping high performance, using lightweight SotA techniques, such as concise binary object representation signing and encryption, lightweight attestation, and lightweight consensus

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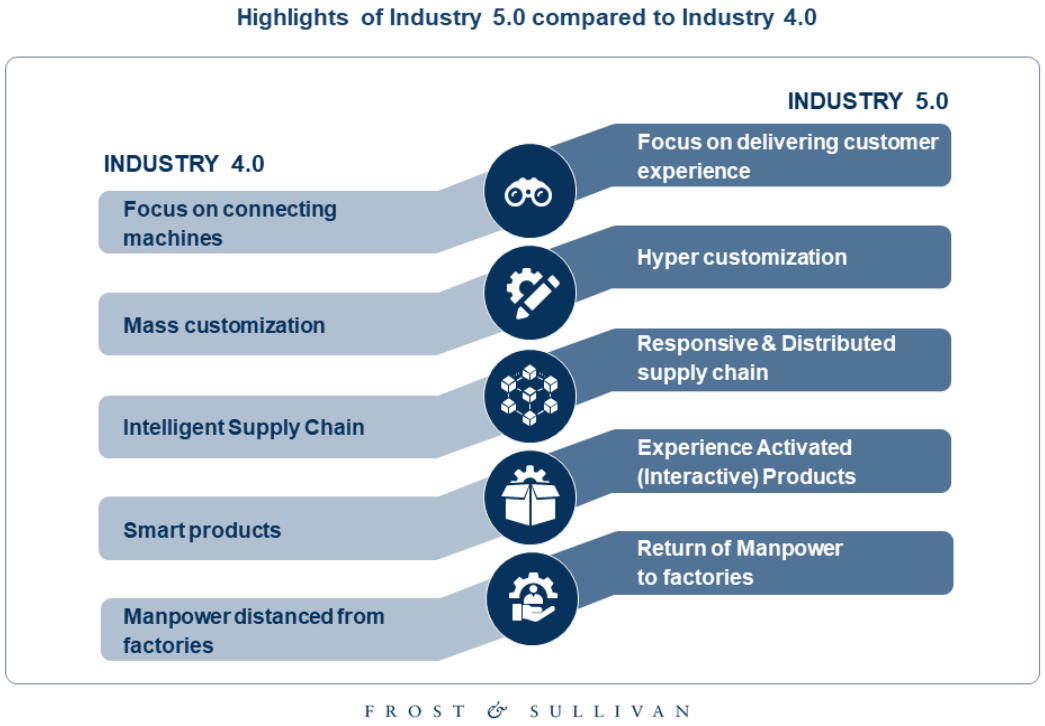
Sorrounding ecosystem – Industrial approach



Reference architectures for the Edge/Cloud continuum by Industrial clusters/reference organizations:

- RAMI4.0
  - SOA architecture covering the whole product licfecycle, considering all objects like IT systems or machines.
- IIRA
  - Cross-Industry (energy, healthcare, manufacturing, and transportations) similar to RAMI4.0
- OI4.0
  - Simplify the deployment of intelligent assets into the EDGE operations of a factory on a plug&play fashion
- IDSA-RAM
  - Data spaces for trust and privacy in decentralized outlook.
- FIWARE Industry RA
  - FIWARE generic enablers, open source, CEF-valid.
- DFA SDA RA
  - EC promoted, Zero X Manufacturing Environments

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Sorrounding ecosystem – standardisation landscape

Standard \ SDO		OMG	IEC	IETF	ETSI	FF, TMForum, OASC	IEEE
Data Exchange and Modelling	Data distribution Service (DDS)	DDS					
	OPC UA		IEC62514				
	Yet Another Next Generation (YANG)			RFC7950			
	Next Generation Service Interface-Linked Data (NGSI-LD)				ISG CIM		
	Smart Data Models					SDM	
Networking and communication	Time Sensitive Network (TSN)						IEEE802.1
	Deterministic Networking (DetNet)			RFC8557,8578,8655,8938, 90555,9025,9037, 9016, 9024, 9056			

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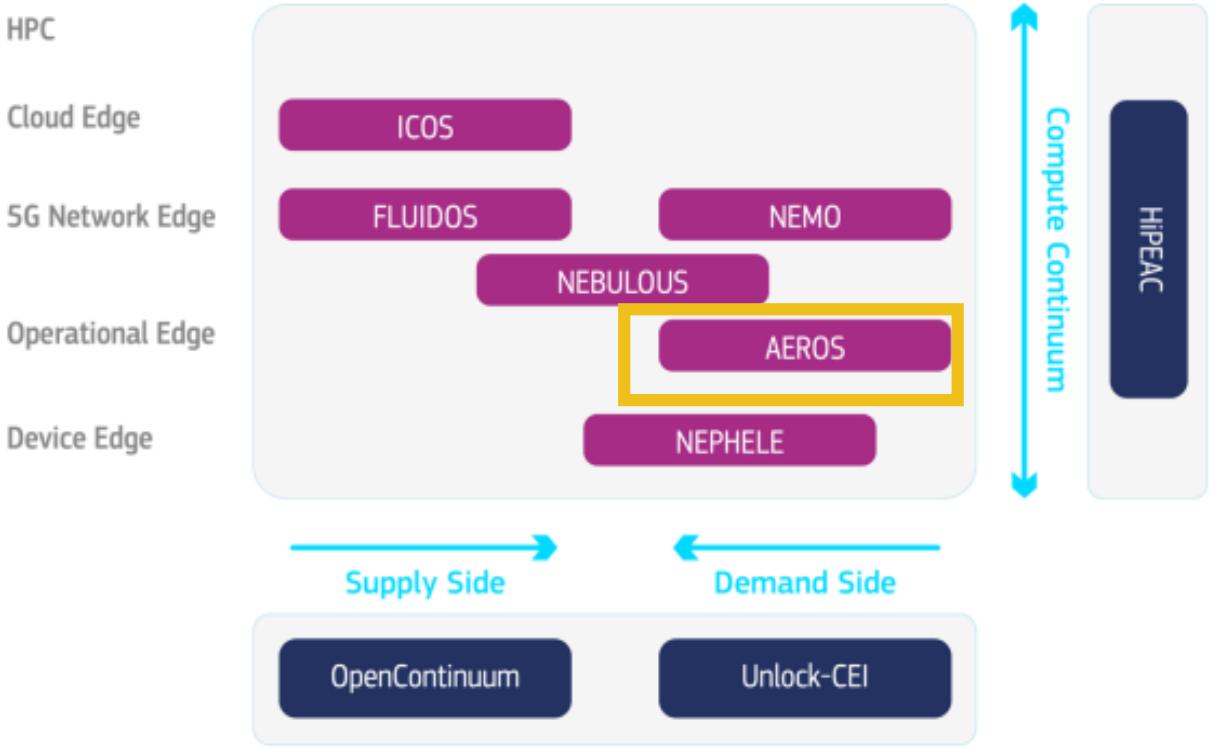
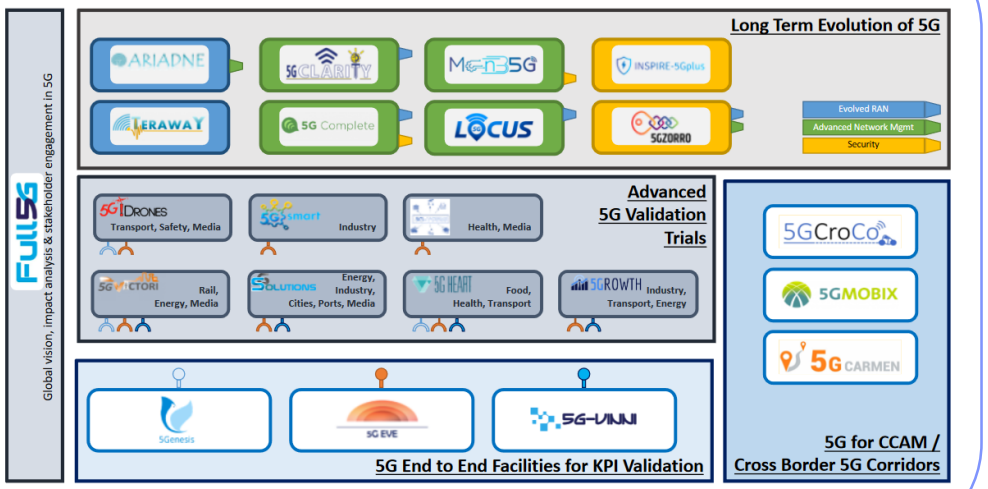
Sorrounding ecosystem - other projects and initiatives



Related 5G projects



Very related projects NOT belonging to the cluster

assist-iot · PrEsto Cloud · KC · EU IoT · NEXT GENERATION IoT · ACCORDION · DECENTER · SERRANO

Loosely coupled related but still relevant projects for aerOS

necos · AADON · UNICORE · DataCloud · ATMOSPHERE · PLEDGER · AI SPRINT AI IN SECURE PRIVACY-PRESERVING COMPUTING CONTINUUM · FASTEN · MORPHEMIC

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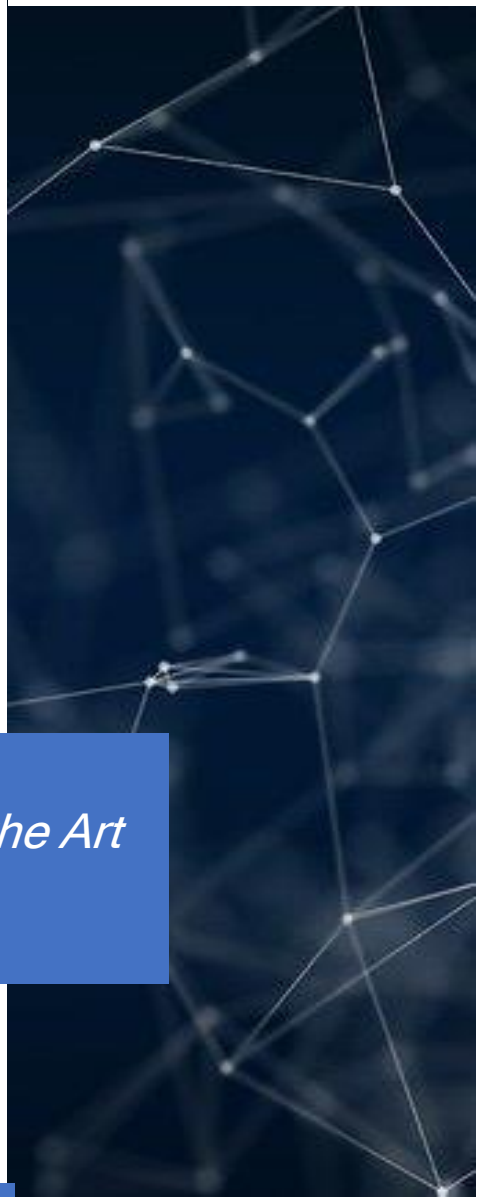

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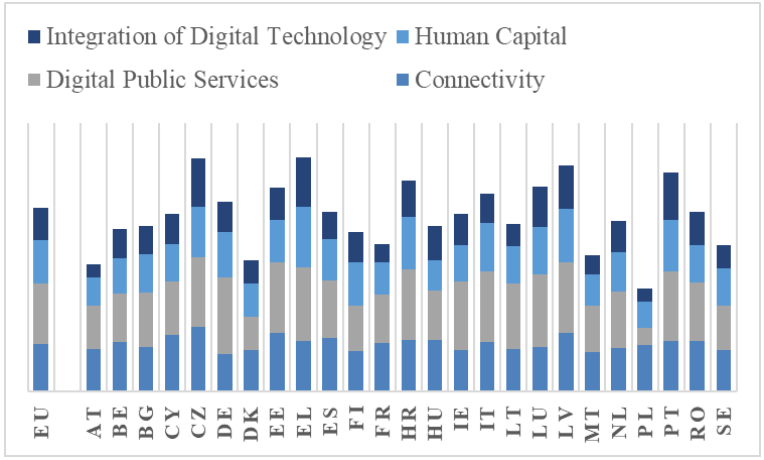
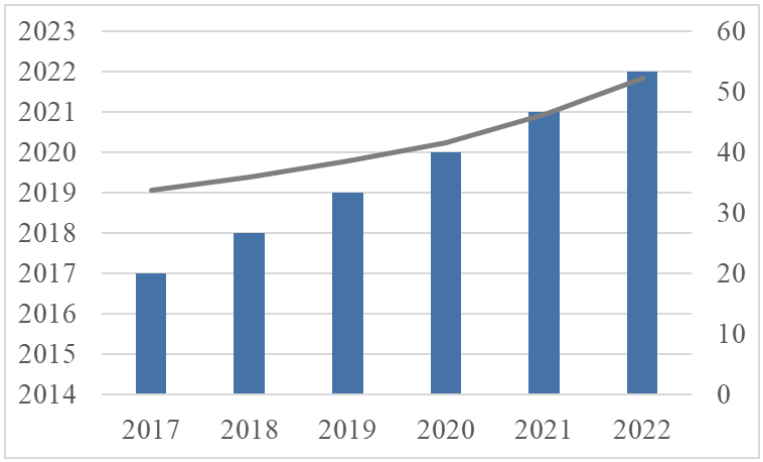
Market Analysis

Workshop on State of the Art and Market Analysis

MARKET ANALYSIS

Unfortunately, at the moment Europe shows a profound **skill gap** regarding digital skills and ICT personnel. Indeed, more than **42% of Europeans are lacking even basic digital skills**, and more than 57% of businesses have trouble hiring ICT staff. This criticality becomes clearer when looking to the **Digital Economy and Society Index (DESI).**





The growth of the digital market will lead to the **emergence of new necessities**: the increase in the number of connected devices and in the volume of data, combined with evolving networks, is arising the instance for lower latency and faster speed together with increasing capacity for data storage. In this context, cloud and edge computing will play a key role in addressing the emerging needs of the market. Their importance also lies in their interrelation with the most important current market trends.

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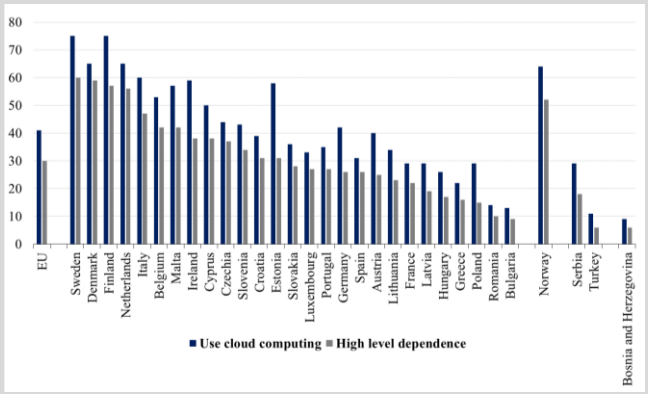
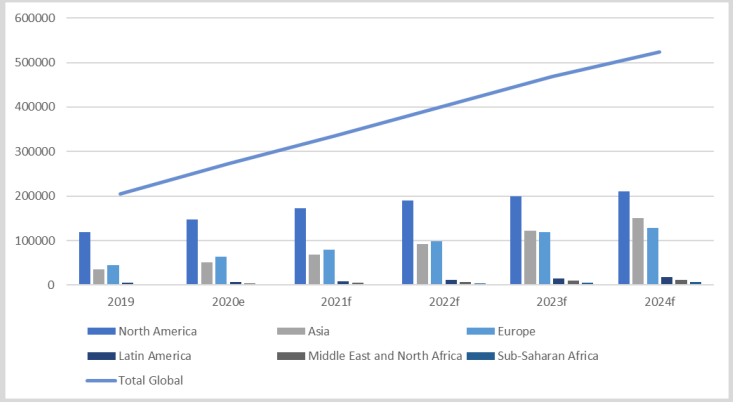
CLOUD COMPUTING

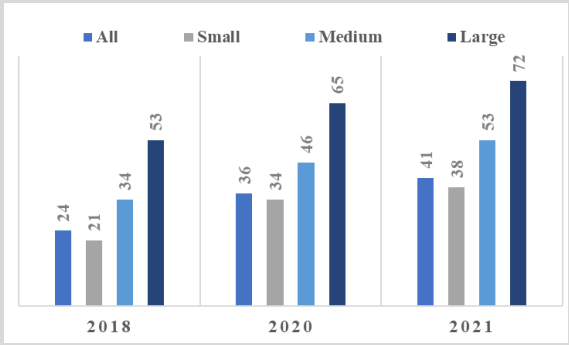
30% of all European enterprises show a high dependence on cloud computing services, amounting to almost 3/4 of all enterprises using cloud computing services throughout the whole Europe.

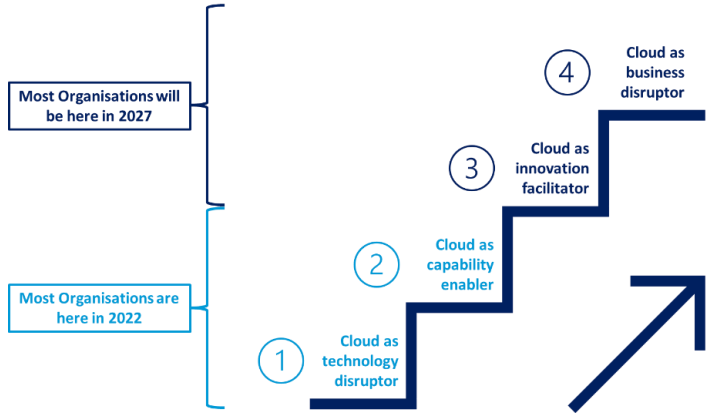




The percentage of users of cloud computing services has increased significantly, **rising from 24% in 2018 to 41% in 2021.**

The use of cloud computing services in the EU also **varies greatly depending on the size of the company** taken into account.





The transition to cloud as a business disruptor will be rather rapid. While most businesses are currently in phases 1 or 2, both of which represent a still-relatively underdeveloped stage of the market (where cloud computing cannot yet provide all its potential opportunities), in just 5 years the majority will have moved into phases 3 or 4, which represent the most mature stages of the market (where cloud computing can manifest its **full potential**).

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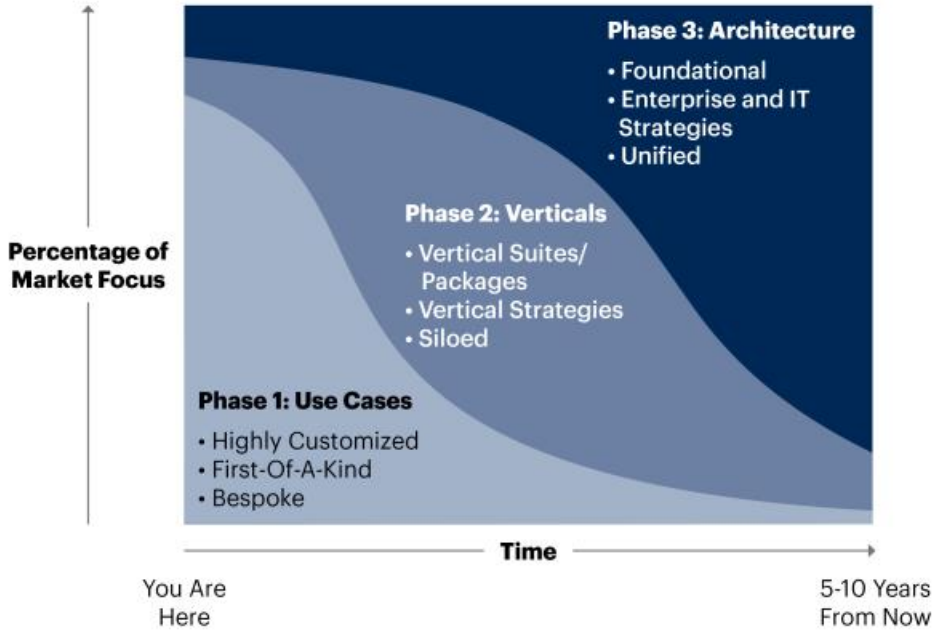
EDGE COMPUTING

Edge computing responds to the current technological trends and needs such as: increasing need for decreased latency, on-the-edge processing of an increasing volume of local data, resilience to network failure and, finally, confidentiality of data.

Currently, the edge computing market is rapidly expanding and evolving, considering that the market features a high number of use cases, characterised by different specific industries and requirements (e.g., low latency, high volume of data), leading to the presence of many solutions that are first-of-a-kind and highly customised and do not present a broader edge computing strategy.

Industry	% of total edge use cases	2025 hardware value[1]	Industry	% of total edge use cases	2025 hardware value[1]
Travel, transport, and logistics	24%	~$35B–$43B	Advanced industries	10%	~$5B–$13B
Cross-vertical	9%	~$32B–$40B	Healthcare	10%	~$5B–$13B
Retail	10%	~$20B–$28B	Infrastructure	6%	~$4B–$11B
Media and entertainment	1%	~$17B–$25B	Chemicals and agriculture	5%	~$4B–$11 B
Public sector and utilities	10%	~$16B–$24B	Banking and insurance	1%	~$2B–$7B
Global energy and materials	13%	~$9B–$17B	Consumer	4%	~$1B–$5B
					Total: ~$175B–$215B



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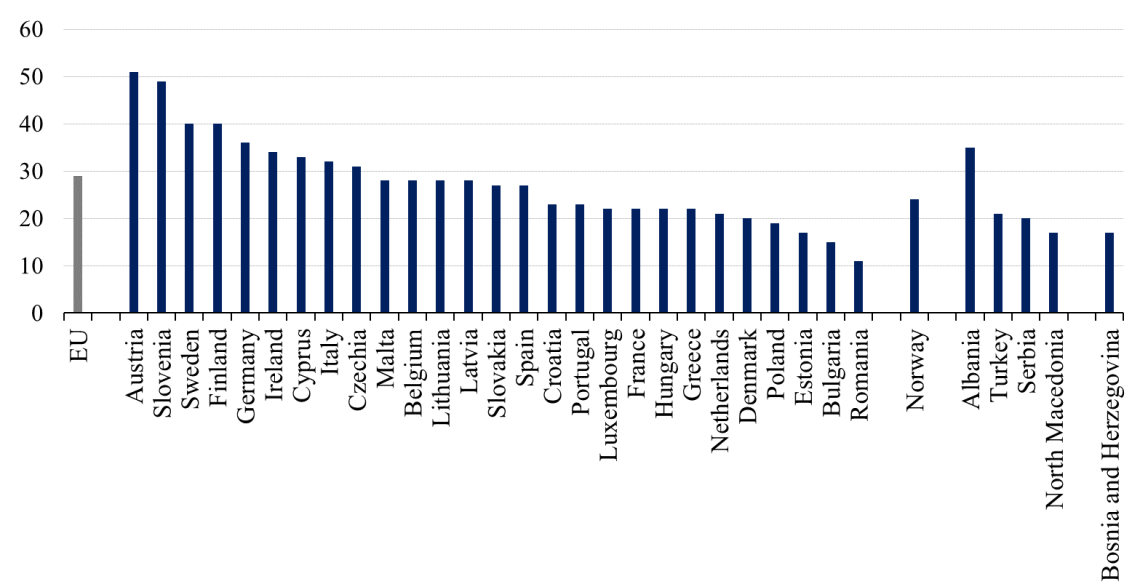
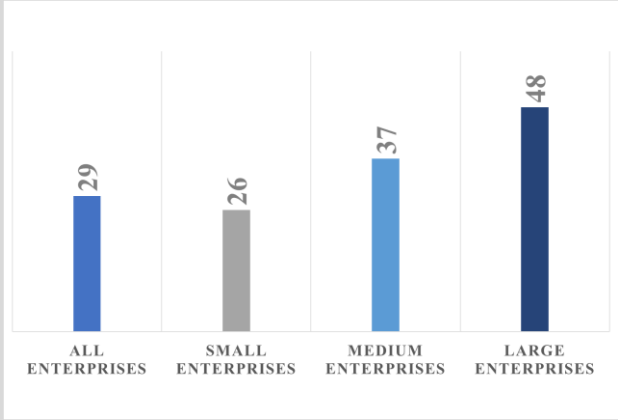
INTERNET OF THINGS

IoT can be used for several purposes: it can both help companies in improving their productivity and assist business in decision-making, as well as gather new insights thanks to the data collected. IoT market is experiencing a strong growth, as in 2022 it has been valued at $ 478.36 billion and is currently projected to reach $ 2,465.26 billion by 2029, with a **CAGR of 26.4% in the 2022-2029 timespan**.

In the European Union, only 29% of enterprises uses IoT devices, with large differences between Member States



These values do not only vary significantly among countries, but companies also show very different levels of IoT use according to their size.



Currently, almost 3/4 of the companies uses IoT for security reasons, e.g., smoke detections or smart alarm systems, with almost the same rate among the different company size categories. Another important purpose for the employment of IoT in companies is the achievement of a better energy consumption management

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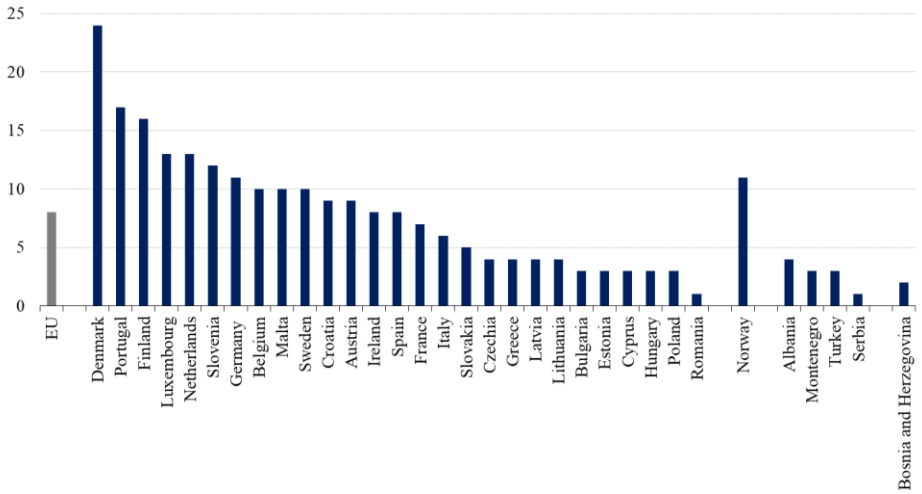
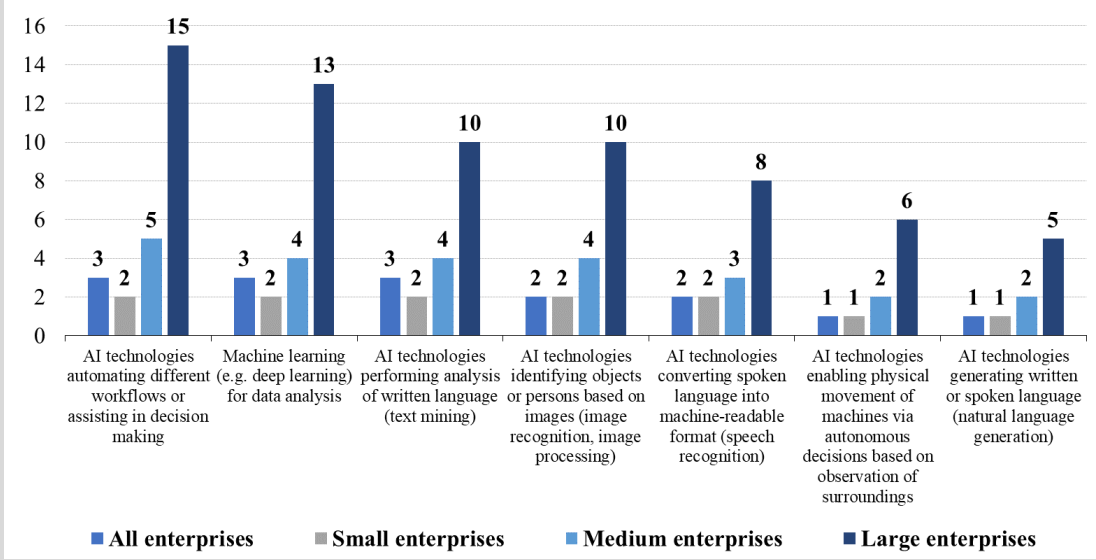
ARTIFICIAL INTELLIGENCE

Artificial Intelligence technology has significantly grown in the last years, making it easier and more affordable to be implemented. This phenomenon goes hand in hand with a strong effort for innovation, reflected in a higher number of **patents** registered from 2015 to 2021, with a **compound annual growth rate of 76.9%**, as the number of patents filed in 2021 is **30 times higher than 2015**.

In Europe, the adoption of Artificial Intelligence by companies is still in its infancy, with **only 8% of companies in EU using at least one of the AI technologies** (e.g., text mining, NLP, deep learning), 4% using at least two and 2% at least three types of AI technologies





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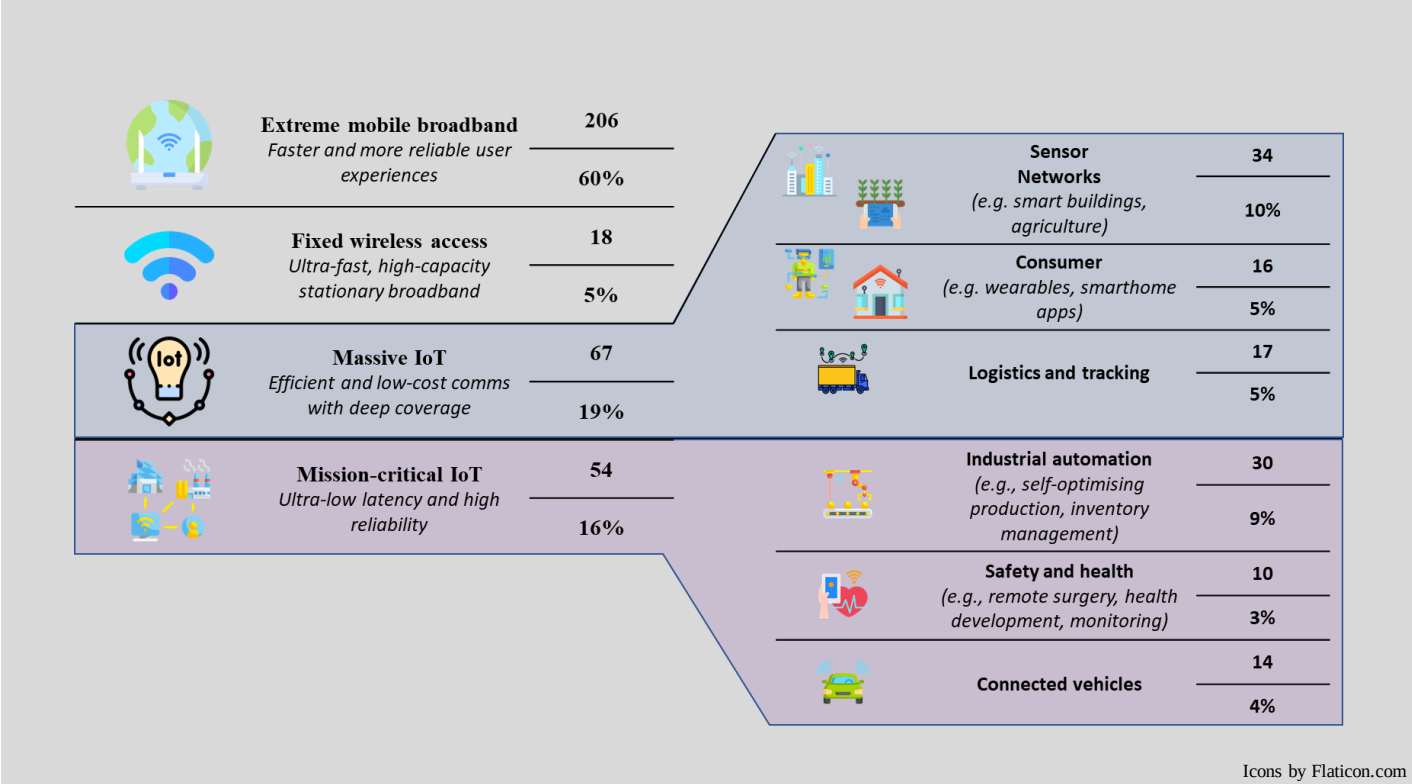
TELECOMMUNICATION

The current telecommunication market offers numerous opportunities for all the players involved, such as those derived by the **growing adoption of IoT devices and use of Artificial Intelligence**, and the potential to increase mobile and wireless connection as an alternative to the wired one. At the same time, there are **several challenges** the sector has to face, such as the high capital investments and licence fees or the continuous evolution in technology and regulation, or the extremely dynamic competitor landscape.

49% of the world population not using internet, with Europe showing rates of individuals not using the internet (17%) far lower compared to the world average, and with the 15.3% is not covered by 4G networks, with a **large gap between rural population (29%) and urban population (5%)**.

A significant **gap between Europe and North America** can be observed, though, with regard to the percentage of households not covered by **5G**: indeed, while North America records only 36%, European rates were more than twice as high, with a rate of 76%.



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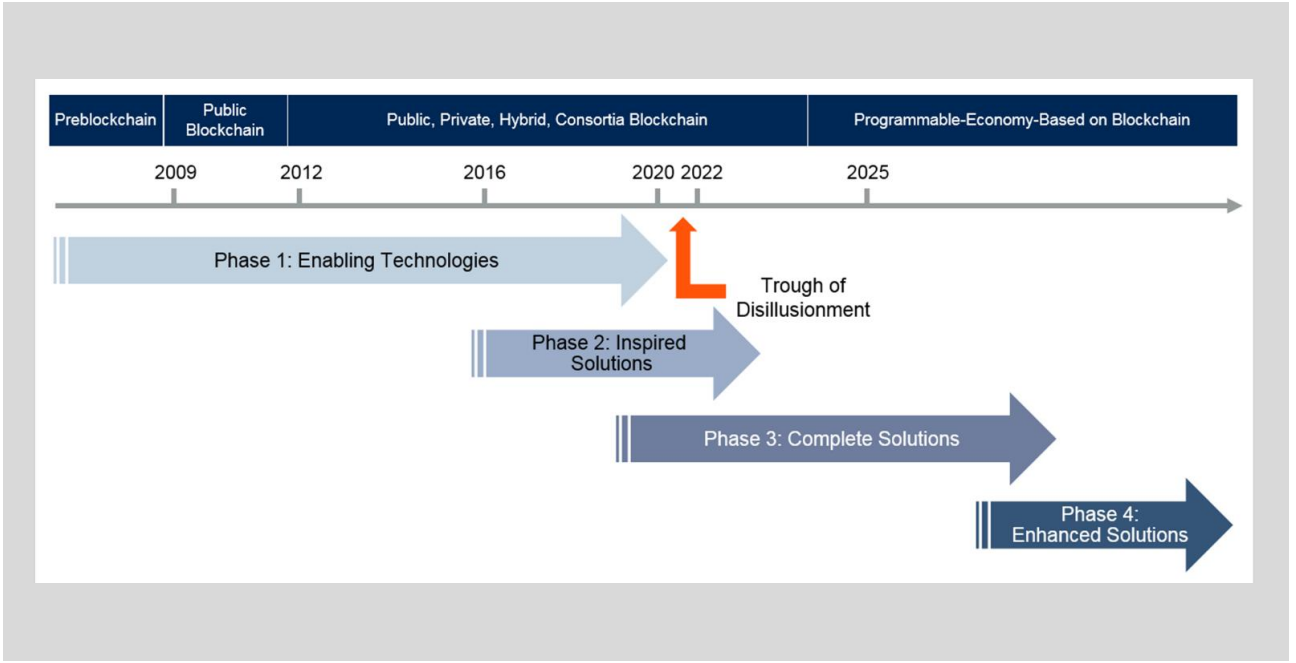
BLOCKCHAIN

Considering that the global blockchain market is experiencing a strong growth, with a predicted CAGR of 56.3% over the projection period of 2022-2029, the worldwide blockchain market is expected to increase from $7.18 billion in 2022 to $163.83 billion by 2029.

The growth of blockchain will be driven by all the **opportunities that it can bring to companies** streamlining daily operations, creating digital records (e.g., certificates, public registers), validating transactions, encrypt documentation etc. Currently the main obstacle to a full deployment for blockchain is represented by **strict government regulations**.

Drivers	*Description*	*contributions ($ billion)*	
		2025	2030
Provenance	Improve transparency in supply chain helping organisations in verifying the sources of their goods and tracking their movements.	231	962
Payments and Financial Instruments	It will work as a back-end technology and will help companies working in the financial services sector to create and manage assets more efficiently.	105	433
Identity	Increase cost efficiencies and avoid frauds and identity thefts safeguarding personal credentials online (e.g., driving license, professional certificates).	54	224
Contracts and Dispute Resolution	Streamline business agreement outlining any controversy showing a potential for resolving disputes and contract.	18	73
Customer Engagement	Improve customer engagement integrating blockchain into Customer Relationship Management (CRM) platforms and making them more user-friendly.	13	54



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PESTLE

Political

- **Lack of a common political agenda** for the adoption of edge to cloud solutions at EU level.
- Presence of **tax incentives** for the adoption of edge to cloud systems in EU Countries.
- Political choices regarding regulation have posed legal restrictions in several EU countries against the connection to renewable energy sources.

Economic

- **High investment costs** associated with the deployment of aerOS solution.
- **Positive impact on correlated market** and on the supply chain.
- Potential entry barriers to the market.
- Potential reluctances to the adoption of a solution derived from a EU funded project.
- Increase in **European competitiveness**.

Social

- Availability of **skilled professionals.**
- Social request for digital transformation.
- Improvement of **working conditions**.
- **Privacy and security** concerns.

Technological

- Strong **interrelation** with other technological solution and mutual enhancement.
- Difficulties to overcome **reluctances** and make disruptive technologies accepted.
- Marked improvement of current technologies.

Legal

- **Privacy and security** as increasing concerns for the edge to cloud computing.
- Lack of legal regulations related to cloud and edge computing.
- **Uncertainty regarding future ineluctable regulatory framework changes**.
- **Lack of homogeneity among EU** countries regarding regulation.

Environmental

- Data centres are extremely **energy-intensive.**
- **Environmental factors are increasingly relevant** in executives and customers decisions.
- The growth of the edge and cloud computing market, coupled with the growth of the correlative markets (e.g. IoT) will require an higher number of data centres and infrastructure.

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aerOS

EUROPEAN IOT-EDGE-CLOUD

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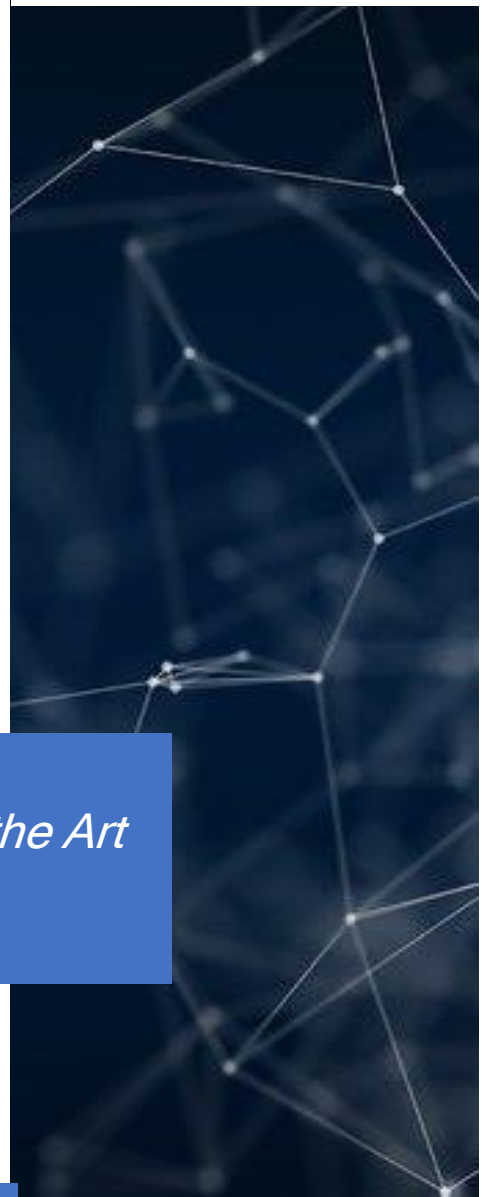

aerOS Interviews with Coordinators and Technical Leaders

Workshop on State of the Art and Market Analysis

General methodology

ORAL INTERVIEWS

WHO

Project Coordinator
Technical Coordinator
Technical Leaders

WHY

In-depth discussions with the promoter of the project, the technical leader and those responsible for the development of the technologies that will be applied during the implementation of the pilots, on key aerOS issues, mainly from the point of view of:

- market context and
- state-of-the-art and technological trends

HOW

11 questions to stimulate the discussion and deepen the following factors that affect aerOS:

- General factors
- Economical factors
- Technological factors

WRITTEN INTERVIEWS

WHO

Targeted partners

WHY

Written interview to deepen specific aspects, complicated to be addressed in oral interviews, related to Legal, Political and Environmental factors that can affect aerOS

HOW

7 written questions to deepen the following factors:

- Legal factors
- Political factors
- Environmental factors

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General aspects

Interest towards aerOS

- Cloud continuum domain
- Integration with current 5G systems
- Optimization of resources and services
- Data protection processing in Industry 4.0
- Big data management perspective
- Attention on interoperability and open-source trends

aerOS potential impact in enterprises

- Tech transfer contracts with the private sector
- Creation of spin-offs and start-ups
- Cloud services and/or fog and edge computing will enable more efficiency in big data analytics and remote data management, and will help deploying advanced orchestration methods to be combined with their current connectivity and cloud solutions
- Prediction of potential accidents
- Better protection from economic crimes, having not to wait for the management delays of the cloud and permitting as a response fast and decisive actions.
- Performance optimization
- aerOS platform will provide value added services like smart control, active monitoring, energy efficiency, remote configuration and continuous Technical Support assistance

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Economical factors

Market trends

- Compatibility with already existing cloud operating systems
- More distributed network connected infrastructure
- Common layer in services and topologies
- Data security, data reliability and protection-oriented solutions
- Positive environmental impact

Competitors and comparables

- **GAIA-X**: a project promoted by the EU for the development of an open source-based European data infrastructure.
- **ZeroNet**: a Hungarian decentralised web-like network of peer-to-peer users.
- **Huawei Open Source**
- **NEC Electronics GmbH** open-source implementation solution included in the work of firmware.
- **Arrowhead** open-source service-oriented architecture and tools that allow the orchestration of microservices in a safe way
- **ROS** - robot operating system, specifically focused on robot management.

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Economical factors

Alternative solutions for data management/ processing/ analysis

Communication protocols	• OPC Unified Architecture • Zenoh (Zero Overhead Network Protocol).
Commercial cloud-based services	• Google Cloud • Microsoft Azure
Open-source data management solutions	• Elastic search • MongoDB
Industrial IoT solutions	• Mind Sphere
Industrial Engineering solutions	• Dassault Système

Entry barriers

- Ethical and legal issue
- The reluctance to share information and data (privacy and security)
- Technological lock-in of digital solutions
- User understanding and acceptance
- potential lock of connection

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Economical factors

aerOS unique selling points

- aerOS will build a new Operating System for managing the cloud computing environment
- aerOS is a proper and complete open-source interoperable Edge continuum solution
- aerOS will expand the notion of the Operating System from a single hardware to a network and it will make it more user-friendly
- Different perspectives and needs will be incorporated in a Meta Operating System across the Continuum
- aerOS solution will adapt to different use cases while still providing inter-compatibility to all the existing users, offering flexibility and scalability for different sectors

Barriers in the adoption of an EU funded project solution

Market reluctance against products or services delivered from European projects, based on concerns about the feasibility, functionality and applicability of the solutions beyond the limited and controlled pilots where they were tested and developed
The prototypes from funded R&D projects are usually matured for sale after the project within 3-7 years. Further investments and time needed to advance the prototypes to a product level, and rapidly changing customer requirements

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Technical Factors

Tech trends

- Edge Computing and hybrid cloud **orchestration**
- **Digital Twin** technologies
- **Data Spaces** technologies
- **Modular and scalable** in-vehicle platforms and modules
- **Big Data,** in the meaning of data-driven preventive and predictive maintenance

How companies work with unstructured data and where data are stored

- Experience with **natural language processing** and different techniques used in it
- Processing of **images**, that is to say preparing a model and also pre-processing images
- **Standardisation** efforts
- Usually, **the information is not maintained by a single system**, and, in some cases, not even by the same entity, so to have mechanisms to effectively exchange or share that information is a significant issue they have to deal with

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Technical Factors

How companies work with IoT ecosystems

- End-to-end IoT system, offering an on-machine gateway, connectivity service and cloud back-end in a single turn-key solution
- Interoperability of IoT platforms on different levels
- Software to philtre data
- Remote control and remote management and remote recording, to gather the metrics and combine them for results-based decision-making
- IoT hub where to collect all the information from the sensors, to philtre and to pre-process the data in the edge before sending to the cloud

Main benefits of edge cloud continuum system in EU

- Too significant opportunity for European Countries to stay **competitive** if they reach the goal on time
- The Edge to Cloud continuum system is pivotal for **European non-dependence**, sovereignty, and for a stronger position of European industry in the global market
- It is really important for Europe to introduce the cloud continuum in order to optimize either the performance of existing services and products or to be the triggering point that will help the developers to introduce into the market innovative solutions, new services and new products

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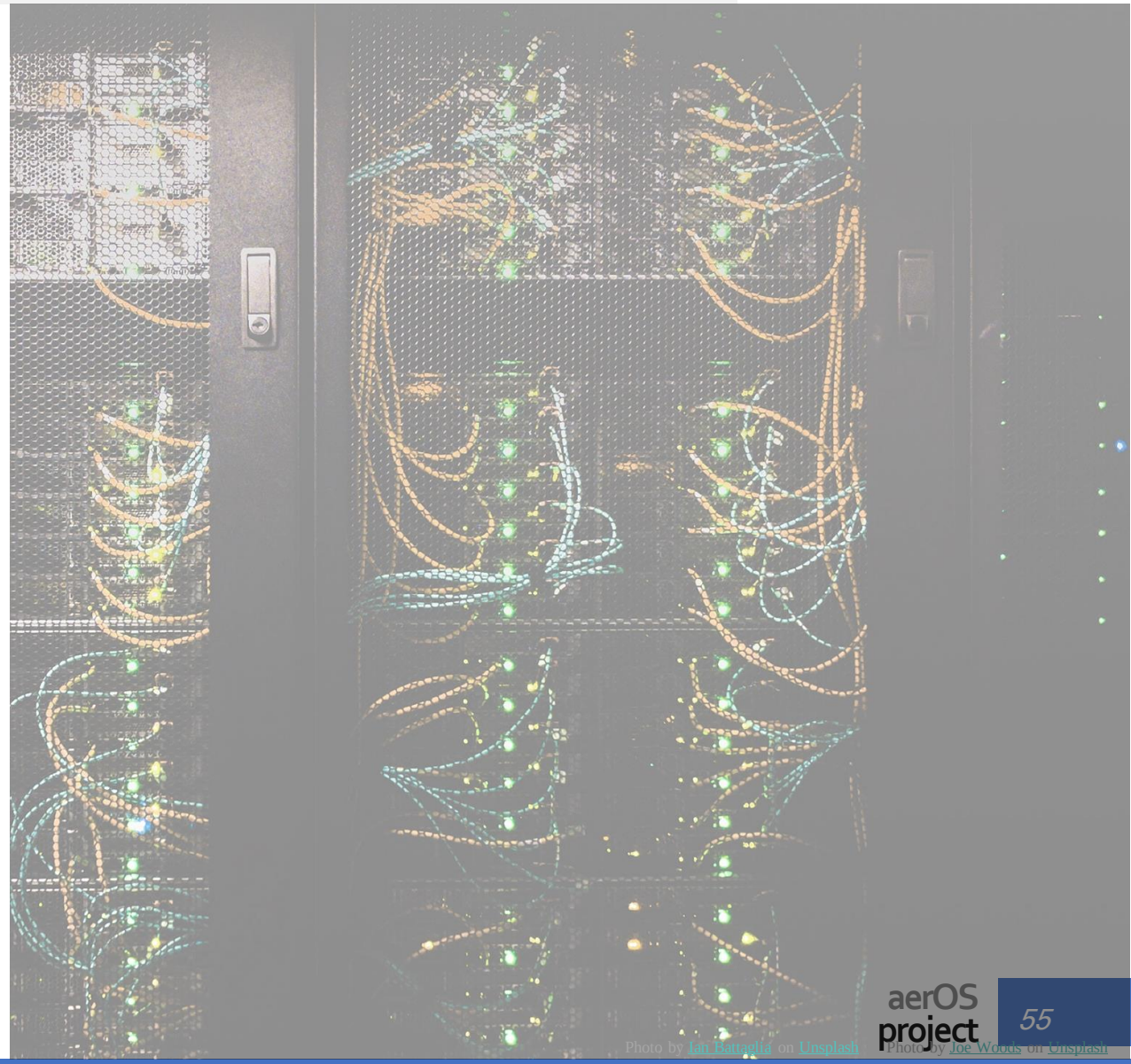
Economical factors

Use of external cloud infrastructure_Potential internal barriers

- The initial hurdle due to the compliance with internal IT policies for any cloud solution.
- For Universities and Research Entities, the main potential hurdle could be represented by internal policies about opening networks to the WAN.
- More than one partner recognised that there is the need to add some rules inside the firewall for the data coming from external sources, with all the relative costs.
- Migrating operational activities to the cloud would require training of personnel, digitalisation of records kept in physical form, and a particular care towards privacy of sensitive identifiable Information.
- Insufficient national internet infrastructure.



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Legal Factors

Ethical and legal barriers for the adoption of cloud and edge systems

- Data handling
- The transmission of sensitive information to the cloud
- Possible unauthorised access
- Data corruption
- Infrastructure failure
- Trustworthiness, transparency to the cloud user functionalities is pivotal
- GDPR compliance and compliance with National legal legislation
- IPR, confidentiality and privacy issue, security measures, security certification
- Although some extra EU Countries are GDPR compliant others are not, and legal issues could arise if the cloud servers are located there

Potential ethical and legal solutions to the aforementioned barriers

- Anonymisation and pseudonymisation policies
- GDPR compliance
- Privacy Impact Assessment and development of a single data EU market
- The need of pooling European data in key sectors

Legal Factors

Legal differences in the adoption of cloud or on premises systems

- The current legal scenario does not regulate the data sovereignty issues that act as barriers to adopt external cloud-based solutions

Different views:

- There are no obvious differences between on-premises and cloud system
- the apparent absence of differences is the reason behind the fact that Teaching Factories are important entities to foster the testing and adoption of cloud/edge and AI systems
- The adoption of a cloud based system is legally easier.

Current regulation in the adoption of cloud/edge and AI systems

- Different geographies have different regulations and different approaches to the topic “Privacy vs. Innovation”
- From a European Union perspective, those regulations have been reported: European Data Strategy; Data Governance Act; EU Cybersecurity Act; Proposal for a Regulation laying down harmonised rules on artificial intelligence; Coordinated Plan on Artificial Intelligence (2021)
- It has been pointed out that sometime is better to decide only to use cloud servers within the EU because of the lack of regulation outside the EU borders

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Political Factors

Presence of tax incentives for the adoption of edge to cloud systems in EU Countries

Below national incentives for the adoption of IT solutions:

- In Latvia, it has been reported the presence of an Industry 4.0 initiative to incentivise the adoption of Edge to Cloud solutions.
- In Italy, it has been reported the general aim of national tax credit at supporting the adoption of 4.0 solutions for manufacturing companies including edge to cloud system. In addition, R&D grants support the adoption and development of Industrial 4.0 technologies.
- In Romania, there are limited tax incentives that apply for IT and RND projects.

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Environmental Factors

Environmental positive impacts related to the adoption of edge to cloud systems

- Better work processes enabled by edge to cloud systems (and in general, by new levels of automation) lead to more optimized usage of input materials and lower environmental impact. The partners agreed on the fact that the introduction of a new cutting-edge technology could improve the whole system making it more efficient.
- Cloud is more environmentally friendly as unused processing power is usually diverted to other instances, whereas on-premises is exclusively utilized for internal processes.
- The limitation of physical records (paper, and so on) and the use of hardware resources on site (servers, server rooms, climate control, and so on) reduce the Carbon Footprint.
- The ability for staff, encouraged and facilitated by the solution, to remote working reduces the need to commute.

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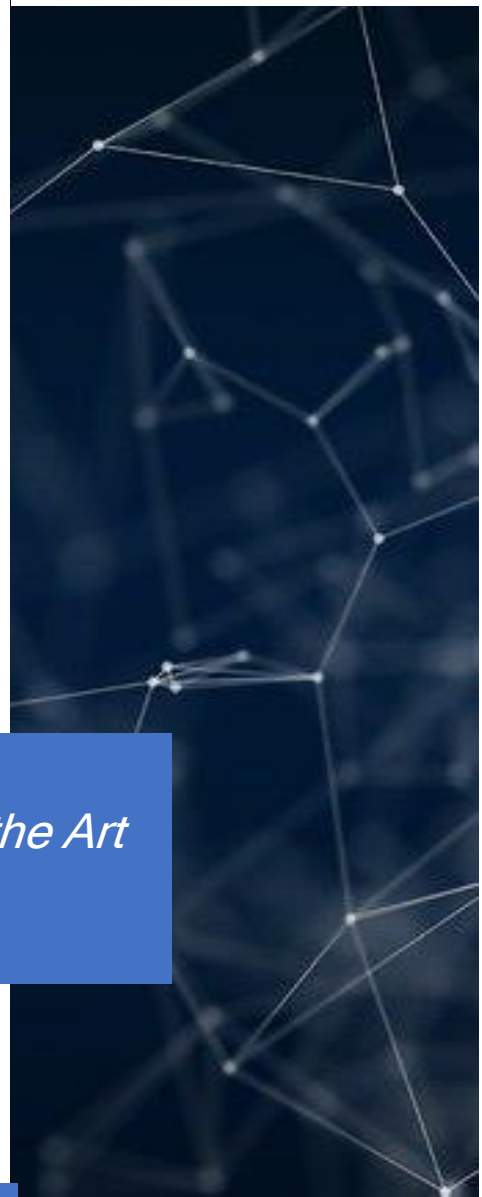

aerOS Focus Groups results

Workshop on State of the Art and Market Analysis

General methodology

WHO

Pilot partners involved in one of the following pilots:


Manufacturing-production


Renewable energy sources


Port Continuum


Smart building


Machinery of agriculture, forestry and construction

WHY

Explore with end-user partners expectations and issues mainly related to economic and technological factors that will influence the execution of the pilots.

The focus groups represented the first moment in which the partners of each pilots had the opportunity to exchange views

HOW

12 questions to stimulate the discussion and deepen the following factors that affect aerOS:

- General factors
- Economical factors
- Technological factors

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General aspects

Interest towards aerOS

- All partners agreed on the fact that aerOS represent a unique solution
- aerOS solution allow a better distributed data processing on edge cloud
- Work optimization through the deployment of intelligence in mobile machines
- Opportunity to exploit investments in 5G
- Strong attention on User Experience
- Opportunity to boost the research on Edge Cloud

aerOS potential impact in enterprises

- aerOS improves companies' value propositions
- aerOS will strongly support the digital transformation and will allow partners to be versatile towards new environments
- aerOS will allow the optimization of timing and costs
- Improvement in data collection, data storage and data analysis

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Economical factors

Market trends

- Energy efficiency and sustainability
- Edge Cloud Processing
- AI technologies and Machine Learning techniques in all the processes, business and applications
- Digitalization and automation
- Standards for connectivity
- Cloud computing

Market features

- **High demand** of the Edge processing
- Lack of **Intelligence management**
- The **absence of comprehensive** online Edge processing **solutions**
- **Interoperable system** that allows customers not to change their data structures and data formats
- Need for an **orchestration of data and machines**
- **Data security, data privacy and data resilience** with elastic and flexible solutions

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Economical factors

Competitors and comparables

Projects

- ICOS (IoT to Cloud Operating System)
- NEMO (Data processing and communication platform)
- FLUIDOS (Flexible, scaLable secUre and decentralIseD Operating System)
- TwinSIM
- NaLamKI
- DEMETER

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Barriers

Entry barriers

- Data privacy, data security and data handling
- Legal restrictions
- Lack of interoperability and user friendliness
- Reluctance against digital solutions
- Lack of heterogeneity of data
- Lack of technical abilities of the team in dealing with new disruptive technologies

Barriers in a solution coming from EU funded project

It has been reported that solutions developed in a controlled environment (as in EU Projects) is less attractive than a solution tested in a relevant commercial environment. The European funded solution are typically tested in laboratory.
In any case, it seems to be a non-general barrier, as some partners have reported that they have not encountered any obstacles for commercialization.

Economical factors

aerOS unique selling points

SMART BUILDING

aerOS foresees an autonomous handling of smart buildings while at the same time maximizing the resources and the profits

RENEWABLE ENERGY SOURCES

aerOS solution direct connection to the energy source will allow to avoid some costs for energy transferring, making the energy price lower

MANUFACTURING AND PRODUCTION

The ability to intercommunicate and interoperate between different machines and different types of information
aerOS comes as a European Standard

PORT CONTINUUM

aerOS will facilitate and simplify the development of applications that go across Cloud, Edge and Far Edge
aerOS will be tested in several use case scenarios becoming a customised solution for several different sectors.

MACHINERY FOR AGRICULTURE, FORESTRY AND CONSTRUCTION

aerOS care about sustainability of resources

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Technical Factors

Tech trends

- **Edge computing** involved in the delivery of **5G technologies**, in the **data transfer** and **digital transformation** of companies
- **Cloud solutions vs on-premises solutions**
- **Common platform** for suppliers and for end-users
- **Flexibility** in machine-to-machine data communication
- **Standards** for connectivity

How companies manage data

- Strict procedures to be followed to be compliant with **GDPR**, as data pseudonymisation/ anonymization.
- Use of **huge databases and servers**
- Data safeguarded through **maintenance services and surveillance center**
- Several **commercial cloud** solutions are used

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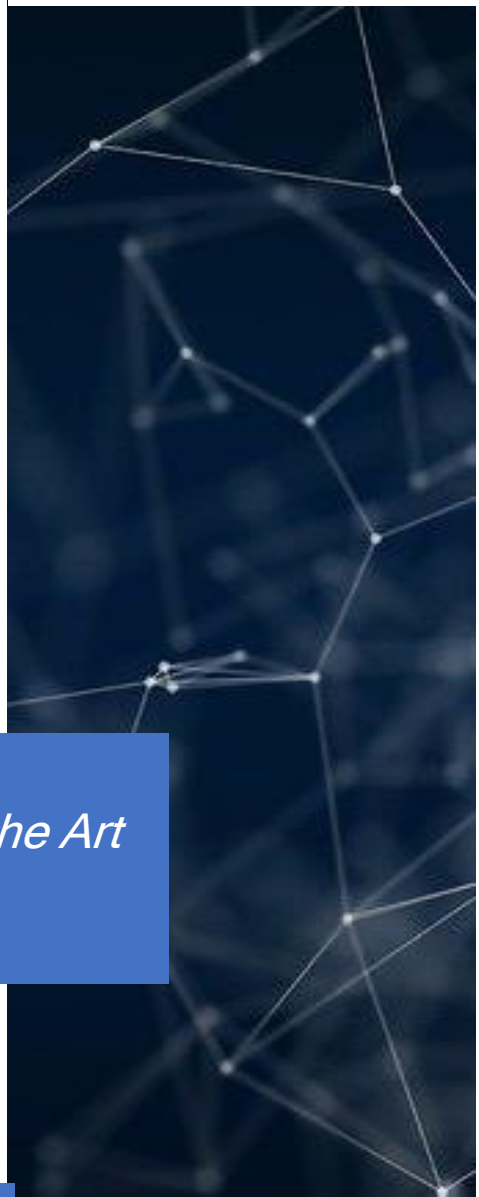


Survey

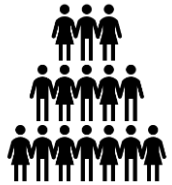
Workshop on State of the Art and Market Analysis

AEROS SURVEY

Gathering relevant and diverse **feedback** from major stakeholders, regarding the **core topics** which will be object of deep and careful research during the whole project lifespan

Assess specifically **the current adoption level and actual needs required for any further adoption of Edge-to-Cloud technologies**

From October the 31st 2022 until November the 24th 2022



The survey has been filled in by a total amount of **129 participants**, of which **51 answered to the whole questionnaire** while 78 responded only to their applicable targeted questions

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AEROS SURVEY - QUESTIONS

The questionnaire has been divided into **six groups**: besides the general category, the remaining five have been dedicated to the PESTLE factors, that is to say Political, Economic, Social, Technological, Legal and Environmental, yet following a logical order of correlation among questions.

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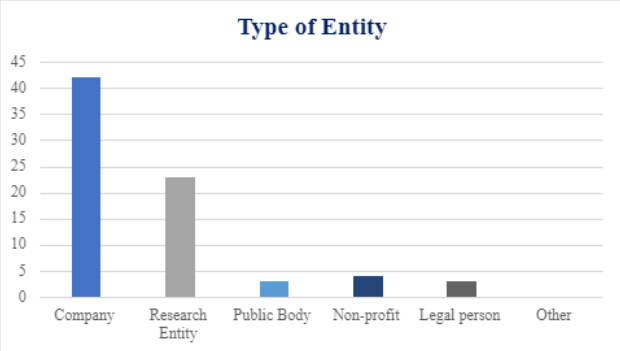
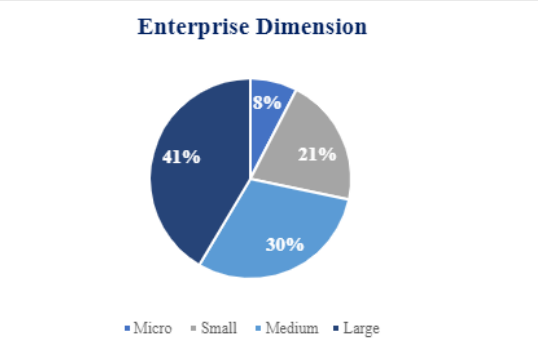
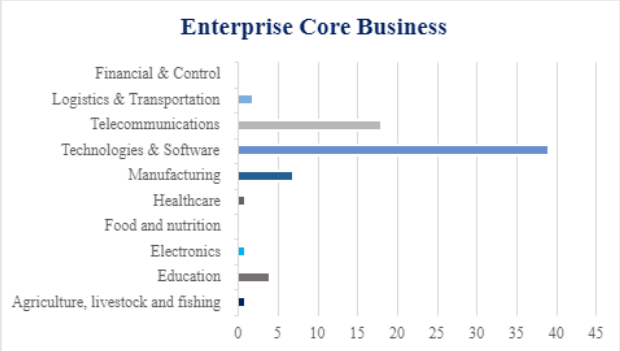
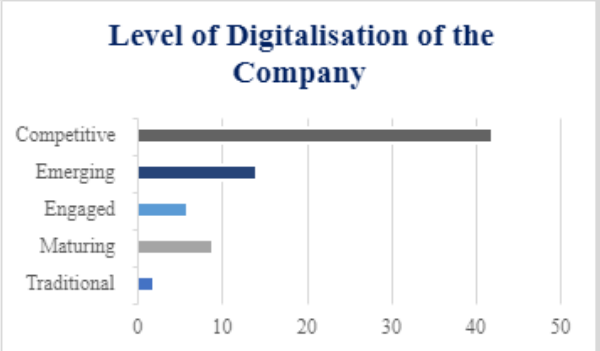
AEROS SURVEY - PARTICIPANTS GENERAL CHARACTERISTICS

The majority of them works in **companies** (mostly large and medium sized) and Research Entities (including Universities). Most of the Companies happened to be in the **Technologies & Software, Telecommunications and Manufacturing Businesses**, and revealed to be mostly **technological competitive**.









In conclusion of the general part of the survey, it has been reconfirmed the expectation according to which the three **business areas that could benefit the most** from a complete and functional solution such as aerOS are Technology & Innovation, Research & Development and Engineering Business Units.

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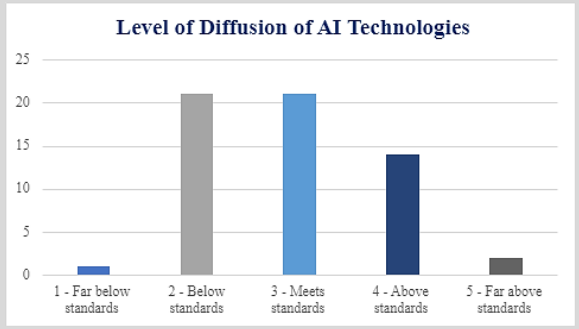
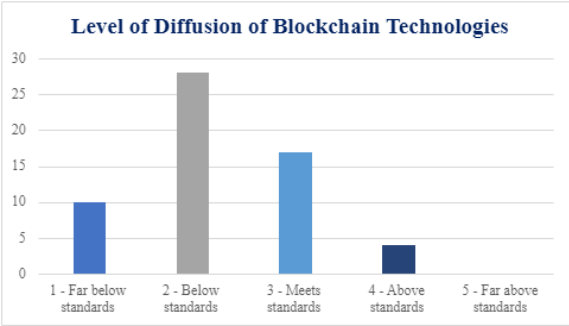
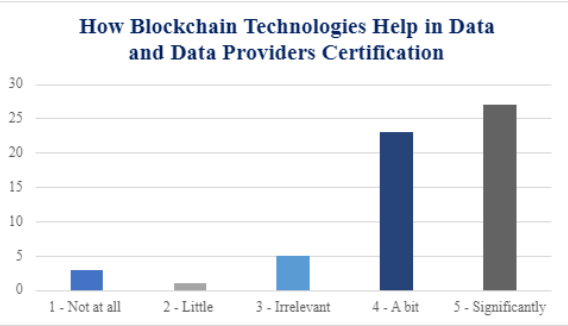
AEROS SURVEY - ECONOMIC ASPECTS

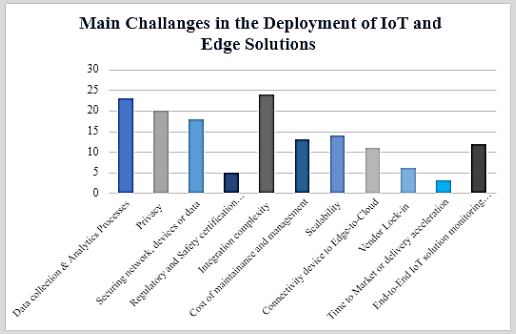


The perception of the level of diffusion of Artificial Intelligence technologies throughout the countries and/or business realities of the participants has given **mixed results**. As it has been perceived as equally meeting and below the standards from the majority, immediately followed by above standards.

The diffusion of **blockchain technologies resulted to be below the standards** for the largest part it resulted, with a few cases of far below and meeting standards, while just a handful of far above the average. Despite these results, blockchain technologies are significantly **perceived as pivotal** in the certification of both data and data providers.







The survey registered that the **main concerns and challenges usually experienced by companies in the deployment of both IoT and Edge solutions** are referred to the **complexity for devices integration**, **data collection and analysis, privacy**, security issues, scalability, but some mentions went to vendor lock-in and maintenance costs.

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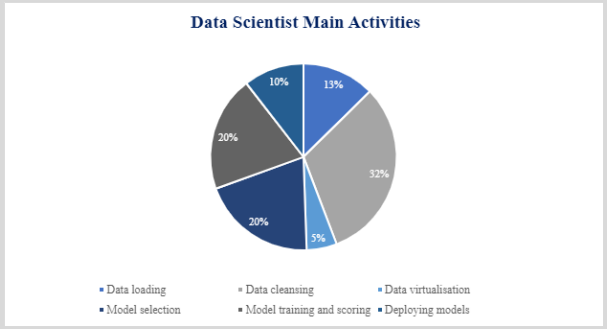
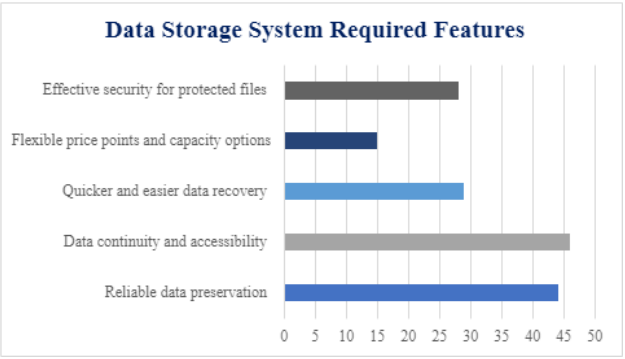
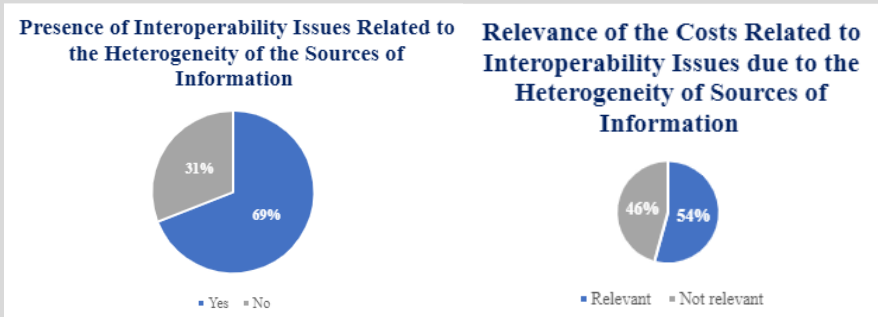
AEROS SURVEY - TECHNOLOGICAL (1/2)



Data scientists spend the majority of their working time especially **data cleansing, data loading, and model selection.**

As for the perception of how should be the main characteristics of an ideal data storage system, all the features provided as possibility by the aerOS consortium have been judged as particularly relevant, with a special mention for **data continuity and accessibility, effectiveness of the security, reliability of data preservation and quick recovery of lost material.**





Almost the whole group of participants has to liaise with many different **heterogeneous sources of information** (often and sometimes have been the most frequent answers to the specific question on the temporal occurrence), it must be noticed how this particular phenomenon is directly connected with **interoperability issues**, experienced by almost the 70% of the survey fillers and with relevant costs as a consequence for the 54%.

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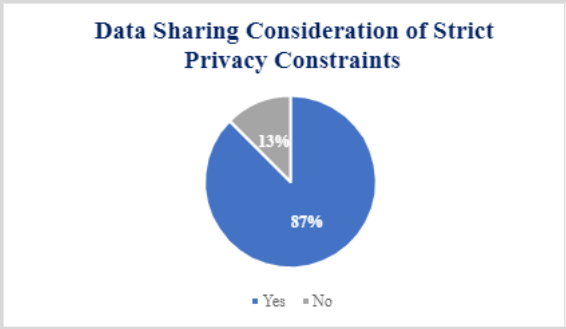
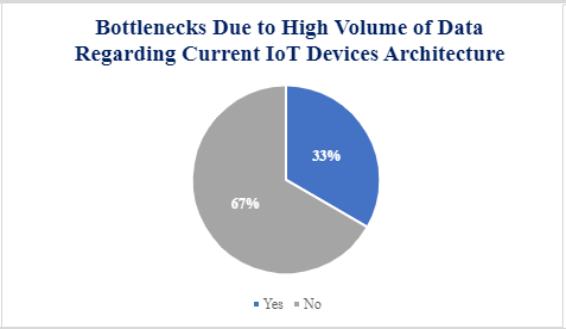
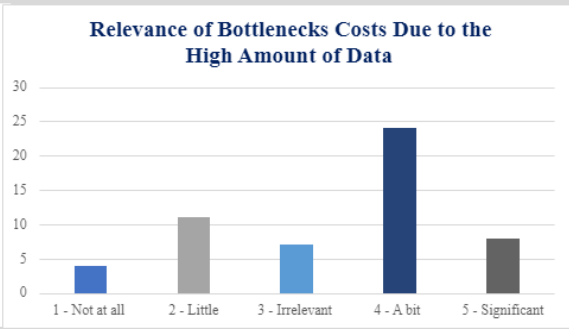
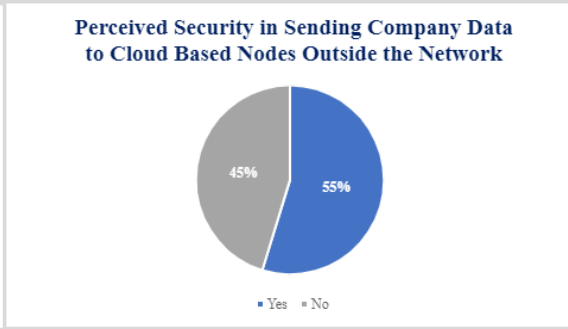
AEROS SURVEY - TECHNOLOGICAL (2/2)

As easily predictable, the aerOS survey participants recognised the **importance of very strict privacy concerns for data sharing**, at the same time pointing out that, for the **67% high volumes of data do not necessary bring to bottlenecks for currents IoT devices architectures**, and, even in the case of their occurrences, the cost is not perceived as too significant in general terms. Yet, regarding the security in letting company data travel throughout cloud-based nodes outside their respective networks, that is an argument that has divided the participants almost in half.









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EUROPEAN IOT-EDGE-CLOUD

THANK YOU!

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