



TRUSTWORTHY, COGNITIVE AND AI- DRIVEN COLLABORATIVE ASSOCIATIONS OF IOT DEVICES AND EDGE RESOURCES FOR DATA PROCESSING

Building the Association-Based Continuum: From Resource Isolation to Federation

Aristotelis Kretsis, Institute of Communication and Computer Systems (ICCS) / NTUA

International Conference on Engineering, Technology, and Innovation

Special Session: Cognitive Computing Continuum

Porto 2026

Cognitive Cloud Continuum Challenges

- ❑ Heterogeneous application requirements (cloud for scale vs. edge for proximity).
- ❑ Edge capacity is exploding, yet most of it is isolated.
- ❑ Individual sites are too small, too scattered, and too isolated to join any cloud or any market.
- ❑ The capacity is already out there; what is missing is a way to make it act together.



Fragmented

Capacity split across many small, independent administrative domains



Isolated

Edge islands that belong to no cloud and trade in no market



Underutilized

Sitting idle, below the critical mass needed to pool or trade



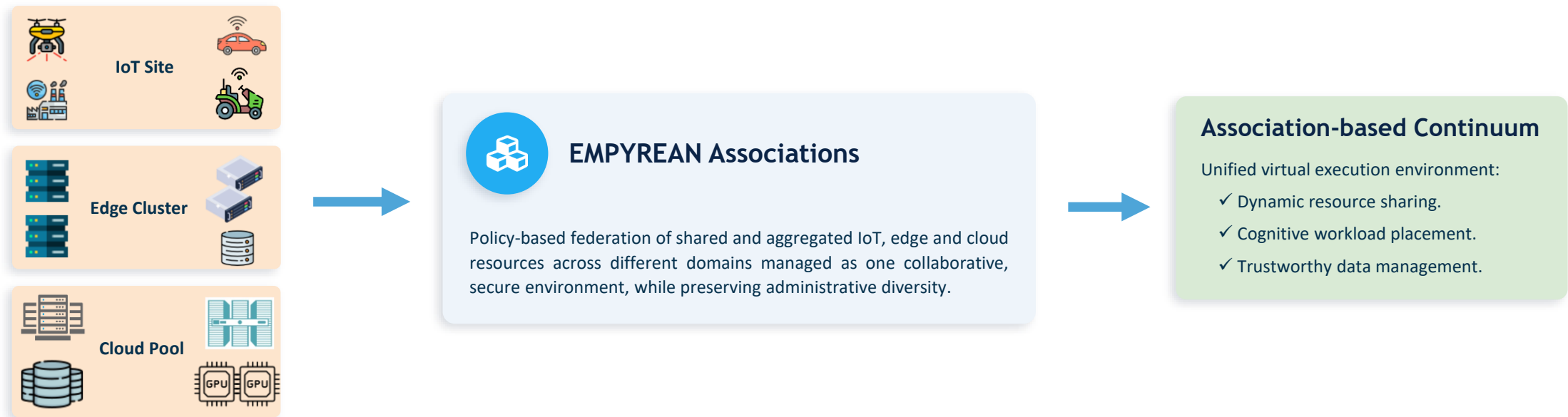
No incentive

Weak return on investment stalls new edge deployment and funding

EMPYREAN - Concept



- ❑ EMPYREAN envisions an autonomous computing ecosystem over heterogeneous resources.
- ❑ In agriculture, healthcare and industry, associations let independent members pool resources, share knowledge and act collectively, while each keeps full control of what it owns.
- ❑ It is one of the oldest and most resilient ways humans coordinate at scale.



Fragmented resources, local-only management,
limited collaboration



THE CORE IDEA

A governed, self-organising collective of shared IoT, edge and cloud resources, pooled across administrative domains into one secure, virtual execution environment.

Brownfield by design, it reorganises resources that already exist.



Heterogeneous & pooled

IoT, edge, and cloud resources combined into one virtual execution environment.



Across administrative domains

Many independent owners and clusters, yet each keeps control of what it contributes.



Secure & autonomous

Self-organising and policy-governed; trustworthy and resilient by default.



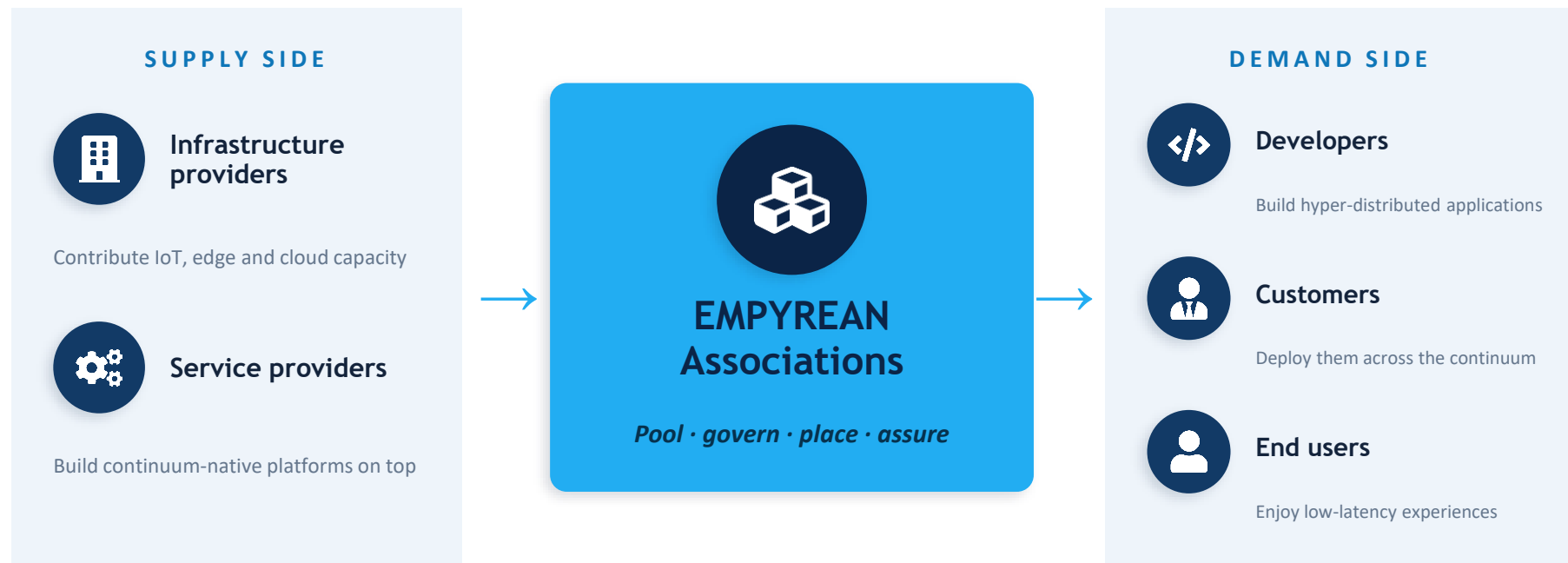
A unit that can federate

The building block that also cooperates with other Associations across the continuum.

EMPYREAN Ecosystem: From Supply to Demand



- ❑ A bridge between supply and demand across the continuum.
- ❑ The Association becomes the common space where resources, services, and applications operate under common rules.



Organizations can act as both providers and users, strengthening the ecosystem as it grows.

EMPYREAN's Association – Design Drivers



- ❑ Five capabilities that shape every architectural choice in the platform, distilled from functional requirements.
- ❑ Realization requires a complete management fabric with orchestration, data, trust, monitoring and lifecycle control.



Combine the heterogeneous

Federate IoT, edge and cloud from different owners into one unified virtual environment



Trust by design

Secure onboarding, decentralised identities, verifiable credentials and trusted execution



Operate autonomously

Self-configuration, self-optimisation and resilient re-allocation under change



Low, predictable latency

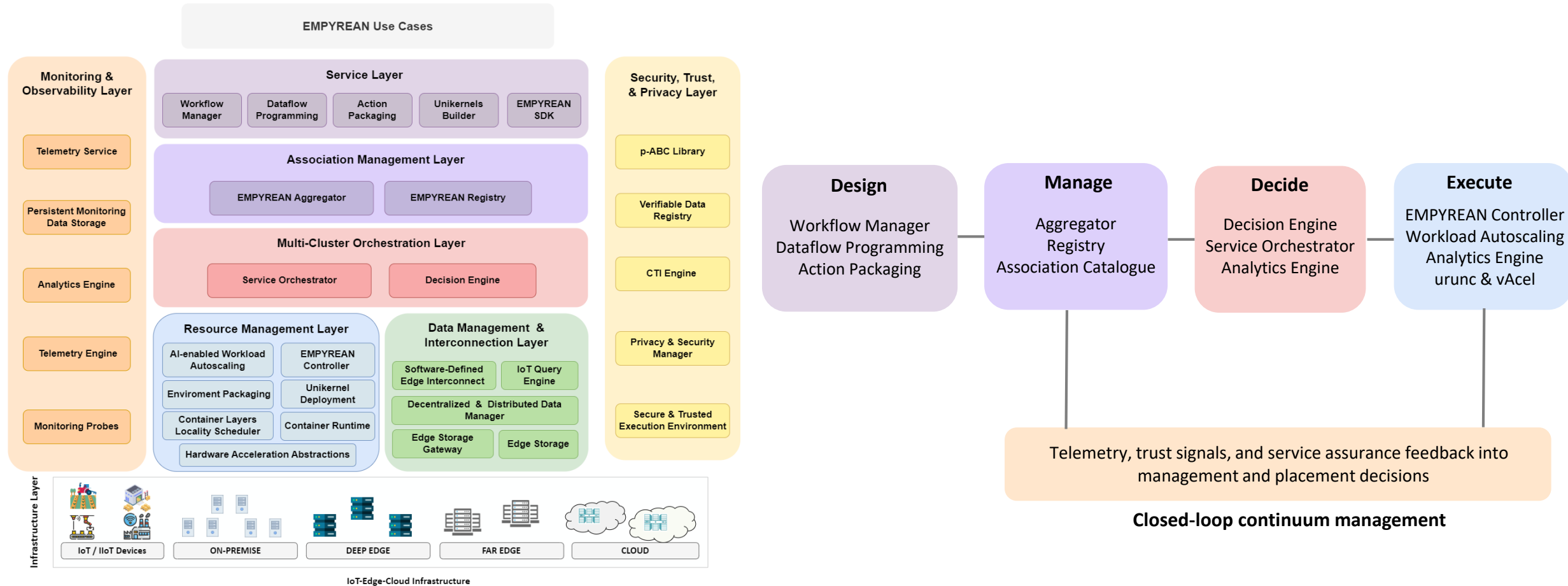
Locality-aware placement plus decentralised, message-centric data movement



Know & federate

A catalogue and live state per Association; exchange data, events and policies across them

EMPYREAN Architecture



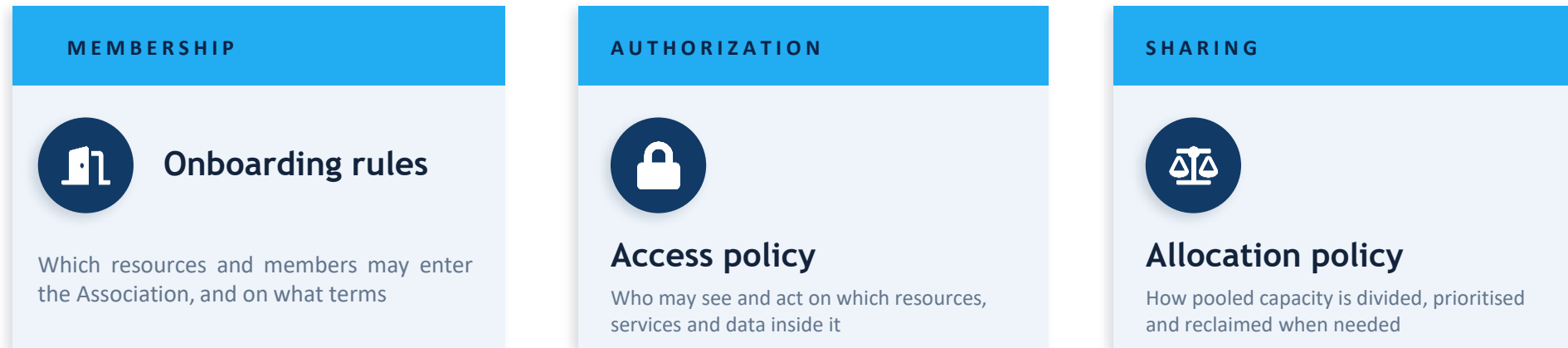
Association Lifecycle

- An Association lifecycle: from empty to governed to active.
- Associations are secure by default and open only through explicit, auditable policies.



Association Policies

- ❑ Every Association has to answer three questions before sharing anything.
- ❑ Governed sharing: three policies.
- ❑ The Registry turns “who can do what” into explicit, machine-checked policy, declared once and exposed through one consistent REST interface.
- ❑ Policies are stored in the Registry, not scattered in code and identity stays cryptographic.



EMPYREAN Aggregator



- ❑ The Aggregator: the management fabric
- ❑ The Aggregator gives an Association logic, it forms it, runs it, and connects it outward to peers.



Forms & coordinates

Creates Associations and orchestrates the resources within them.



Spans the continuum

Let IoT, edge and cloud across clusters act as one.



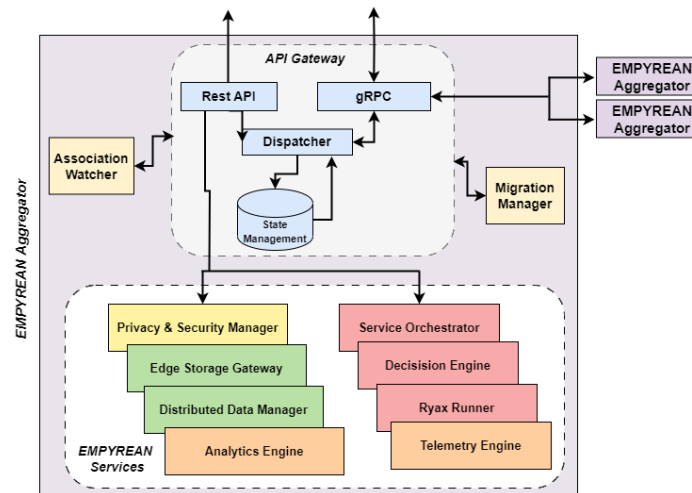
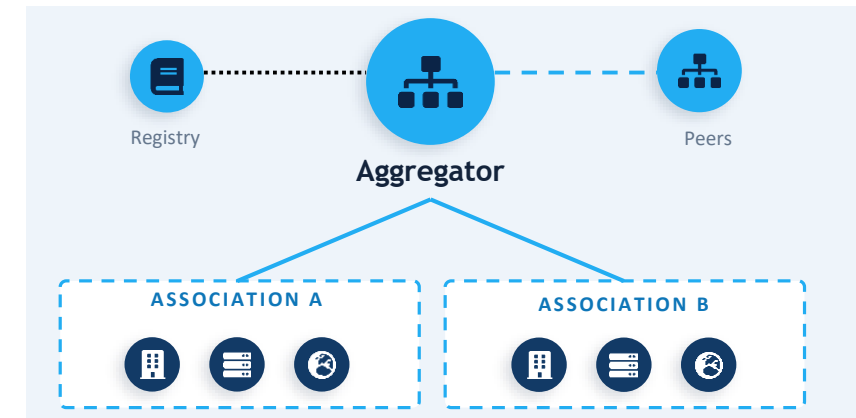
Connects outward

Interfaces with other Aggregators and cloud providers.



Resilient by design

Many Aggregators form one self-managing control plane.



EMPYREAN Registry



- ❑ The Registry: one unified view.
- ❑ The Registry gives an Association a memory, one place that knows every resource, service and asset within it.



Registers everything

IoT, edge and cloud resources as they join the Association.



Catalogues assets

Services, ML models and datasets, all in one place.



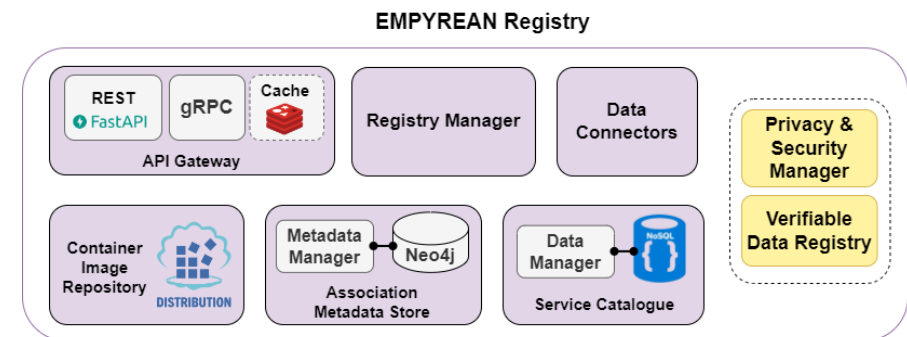
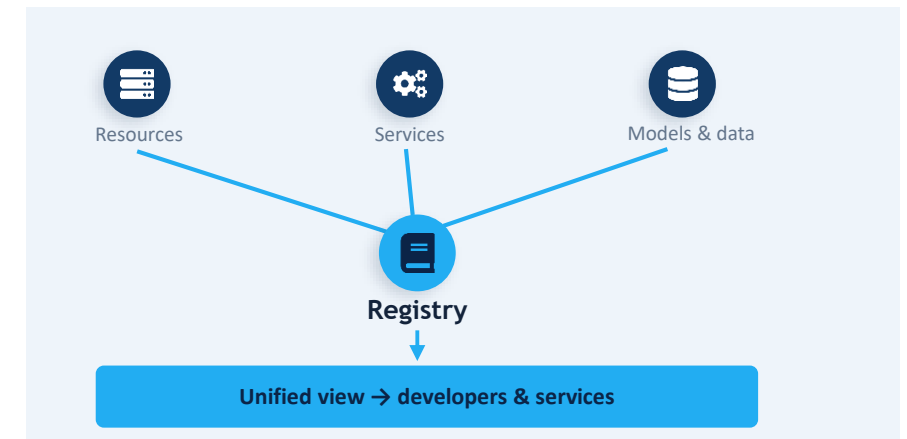
One unified view

A single, consistent view for developers and services.



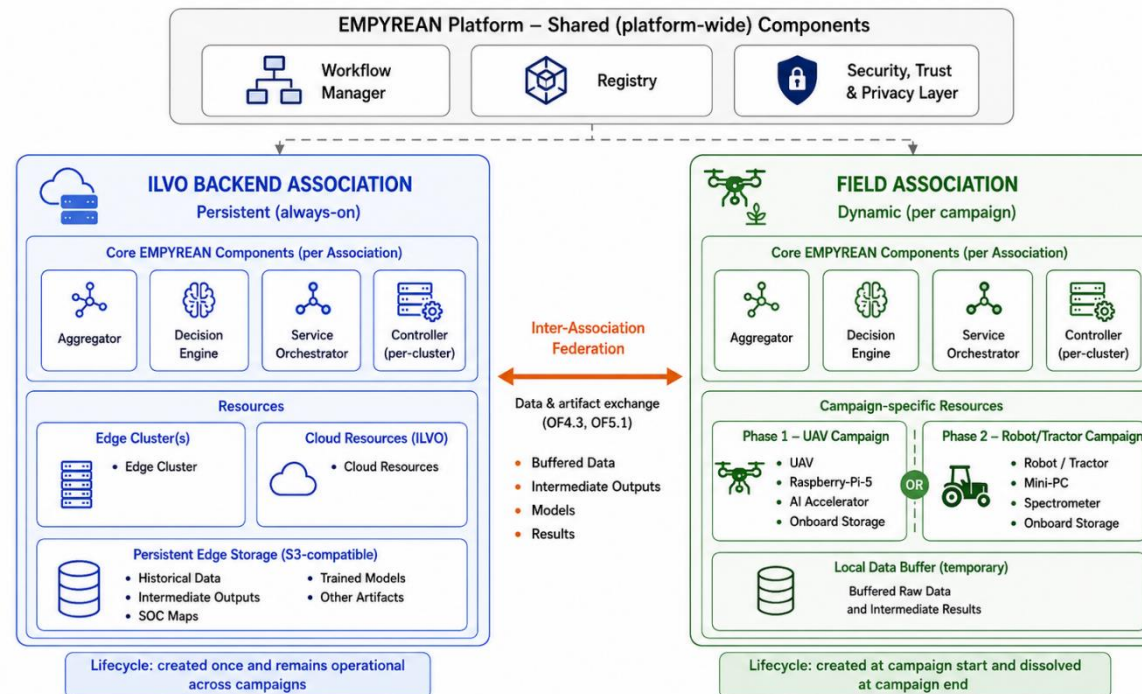
Speeds delivery

Simplifies discovery, development and deployment.



From Isolation to Federation

- ❑ Associations don't just pool inward, they cooperate outward.
- ❑ Each Aggregator acts as a gateway, exchanging data, events, policies, workloads and local views with its peers, so capacity can flow to where it is needed.
- ❑ Continuous operation despite heterogeneity, distributed ownership, and dynamic edge conditions.



Why It Matters



Brownfield, not greenfield

Reorganise resources that already exist, components and algorithms are reusable and adaptable, lowering the barrier to adoption.



A path to RoI

By making sub-critical edge resources poolable and tradable, EMPYREAN supplies the incentive that was missing to deploy and invest.



Trustworthy by construction

Decentralised trust, verifiable identity and default-deny governance make cross-domain sharing safe enough to be commercial, not just experimental.



Easy management

A practical, deployable management framework for the federated orchestration of emerging edge-cloud technologies.

Strategic Impact



EMPYREAN does more than federate resources. It advances Europe's vision of trustworthy, AI-driven IoT-edge-cloud continuum.



An open ecosystem of Associations

Committed to software interoperability and portability, provides an open EMPYREAN ecosystem across providers, not vendor lock-in.



Cognitive, trustworthy AI

Decentralised, AI-driven orchestration from edge to cloud, the “cognitive cloud” vision made operational.



Digital sovereignty by design

Federating EU edge with decentralised identity reduces reliance on non-European hyperscalers, keeping data in Europe.



Green & inclusive growth

Reclaimed capacity and sustainability-aware placement; continuum access opened to SMEs and regions.



Europe's digital & industry targets

Unique technological advances, proven in key sectors such as manufacturing and agriculture, advancing Europe's digital and industry goals.



Thank you!

Kretsis Aristotelis (akretsis@mail.ntua.gr),
ICCS - NTUA

Visit our site & follow us on social

The research leading to these results has received funding from the EU HORIZON EUROPE under grant agreement n° 101136024



<https://empyrean-horizon.eu>



https://twitter.com/empyrean_he



<https://www.linkedin.com/company/empyrean-project/>