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MLSysOps

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Machine Learning for Autonomic System Operation in the Heterogeneous Edge-Cloud Continuum

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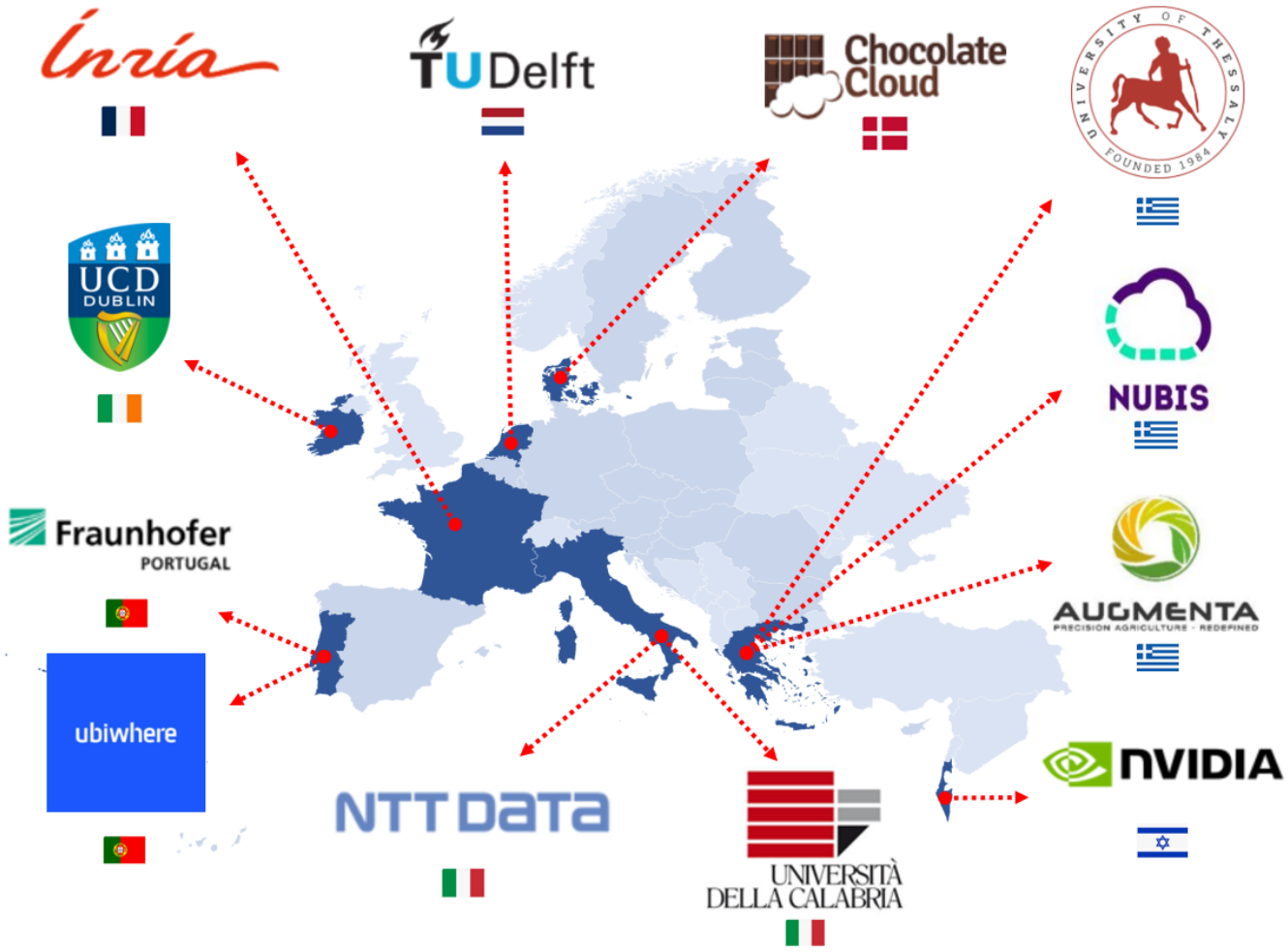


Trends

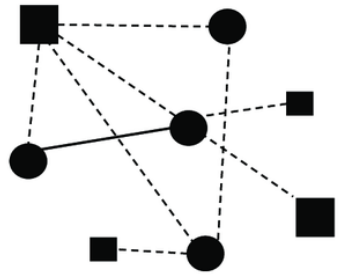
Applications have moved outside the cloud

- Involving nodes and resources toward or directly at the edge of the Internet…
- … and including powerful but also resource-constrained IoT devices

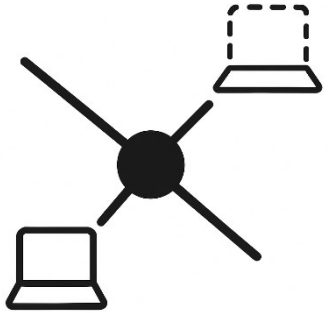
Impossible to monitor/manage large systems by rule-based approaches

Challenges

Scale



Heterogeneity

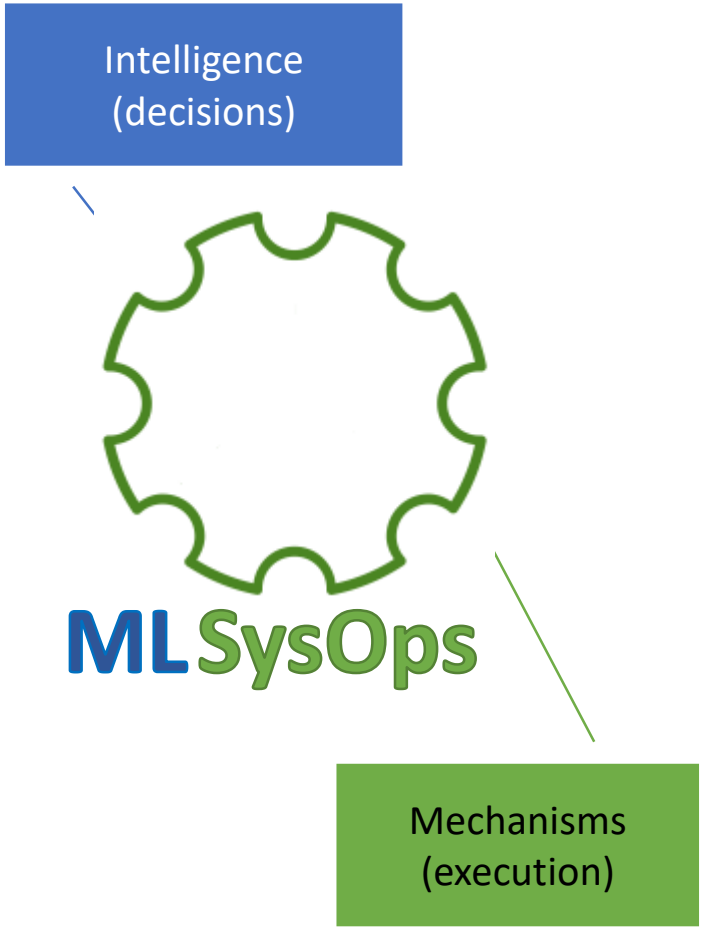


Volatility

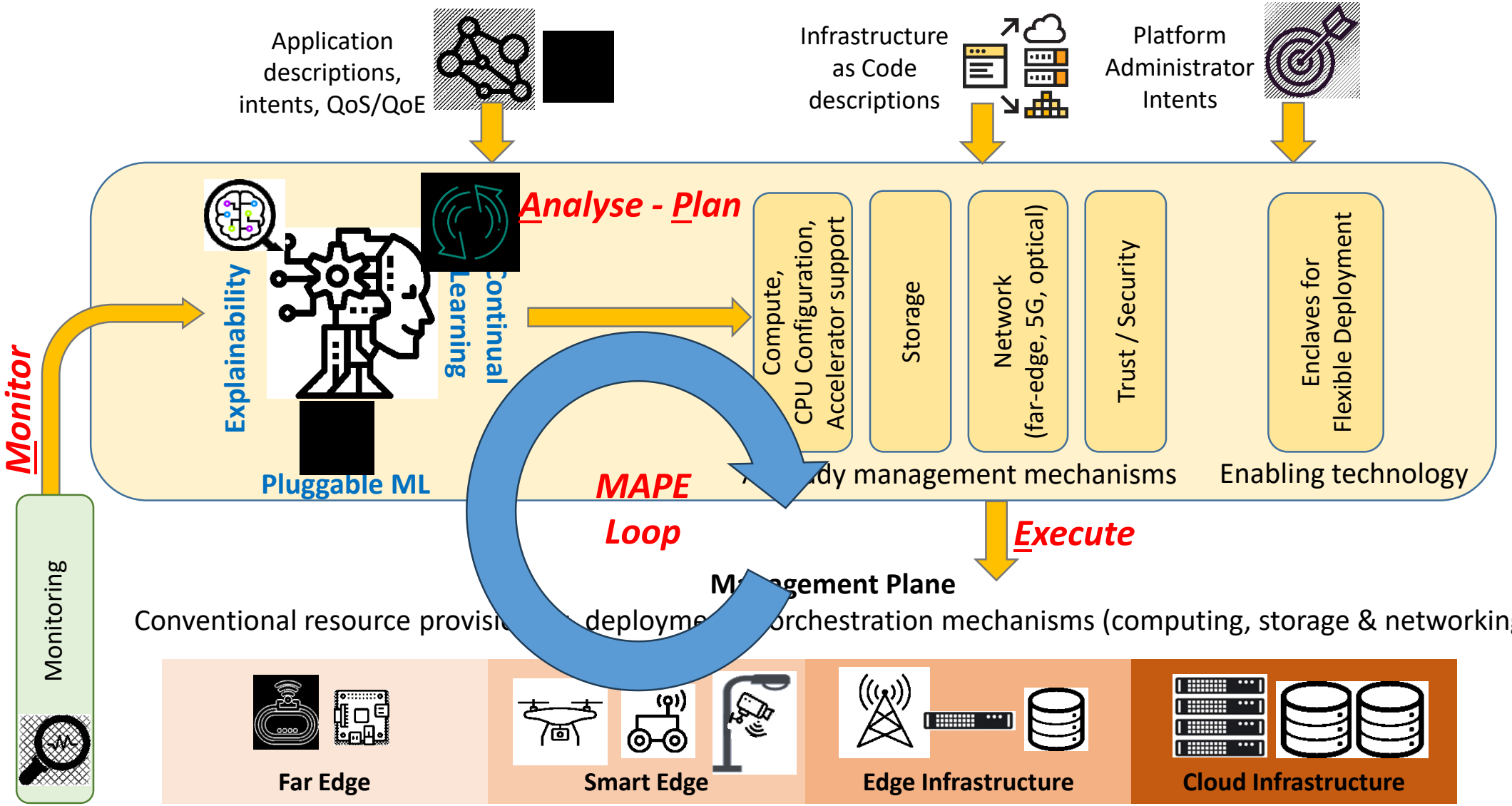
The MLSysOps project

*Autonomic system management and configuration in the **cloud-edge-IoT continuum** using **AI/ML methods***

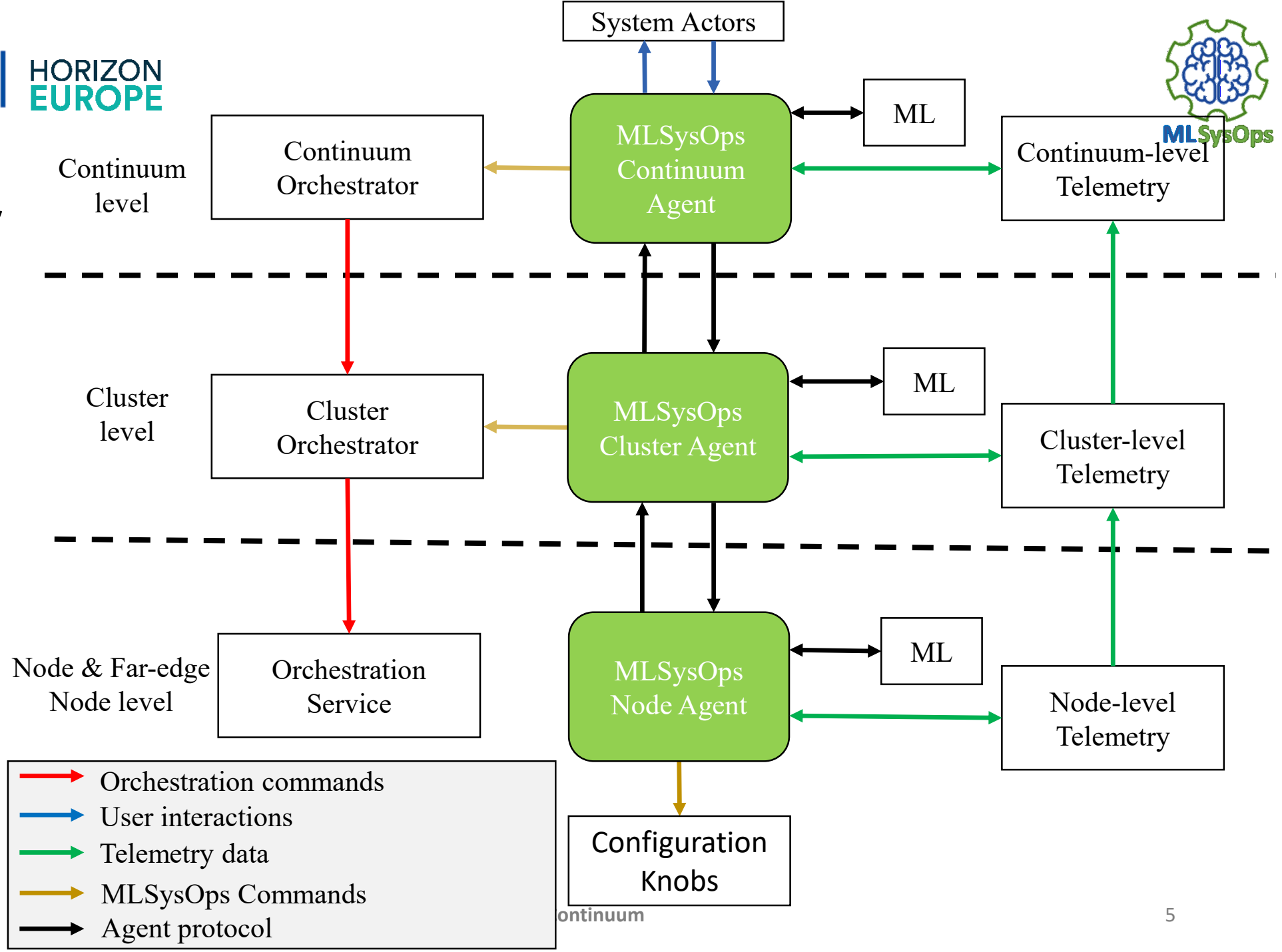
- Focus on modular, distributed applications
  - Comprised out of independently executable components (containers)
- Explore different management aspects
  - Deployment, computing, storage, communication/networking, trust
- Disassociate management from control
  - Develop AI/ML-ready (policy-neutral) mechanisms
  - Take decisions using suitable ML models
- Key AI/ML properties
  - Distributed / hierarchical approach
  - Continual learning / efficient model retraining
  - Explainability
- Extensive data generation evaluation via real-world application testbeds, research testbeds and simulators



How? Concept

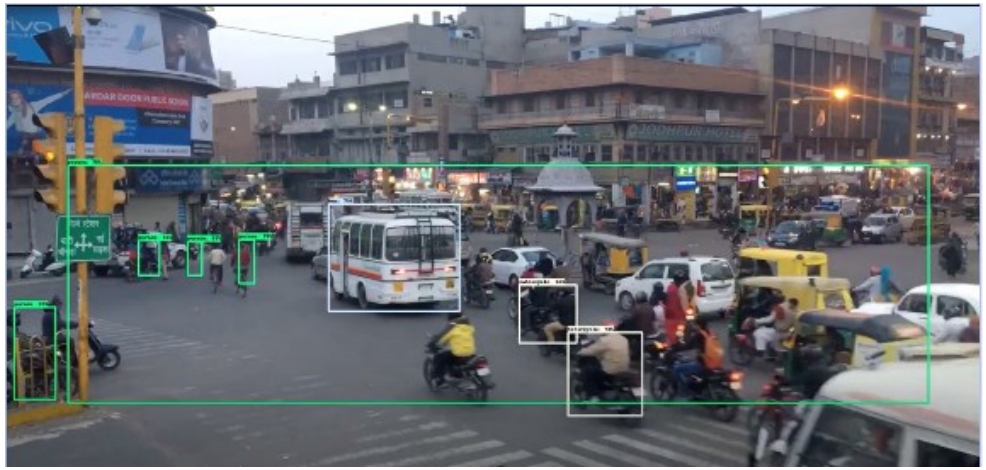

Application descriptions, intents, QoS/QoE
Infrastructure as Code descriptions
Platform Administrator Intents
Analyse - Plan
Explainability
Continual Learning
Pluggable ML
Monitor
Monitoring
MAPE Loop
Compute, CPU Configuration, Accelerator support
Storage
Network (far-edge, 5G, optical)
Trust / Security
Enclaves for Flexible Deployment
dy management mechanisms
Enabling technology
Execute
gement Plane
Conventional resource provisi deployme orchestration mechanisms (computing, storage & networking)
Far Edge
Smart Edge
Edge Infrastructure
Cloud Infrastructure

How? Hierarchy



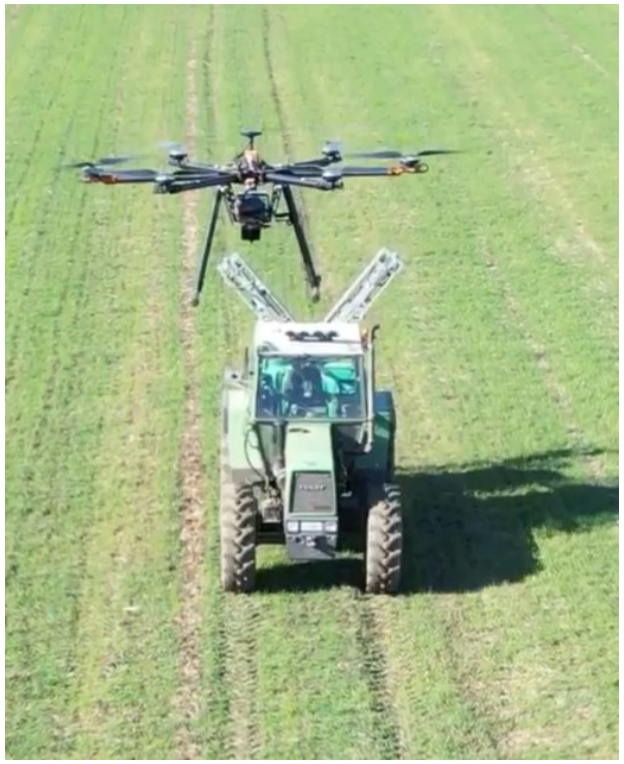
Two real-world application use cases

Smart Cities



Improve existing system via AI/ML-driven control to manage/configure application modules that can be deployed on smart lampposts and/or to datacenters.

Smart Agriculture



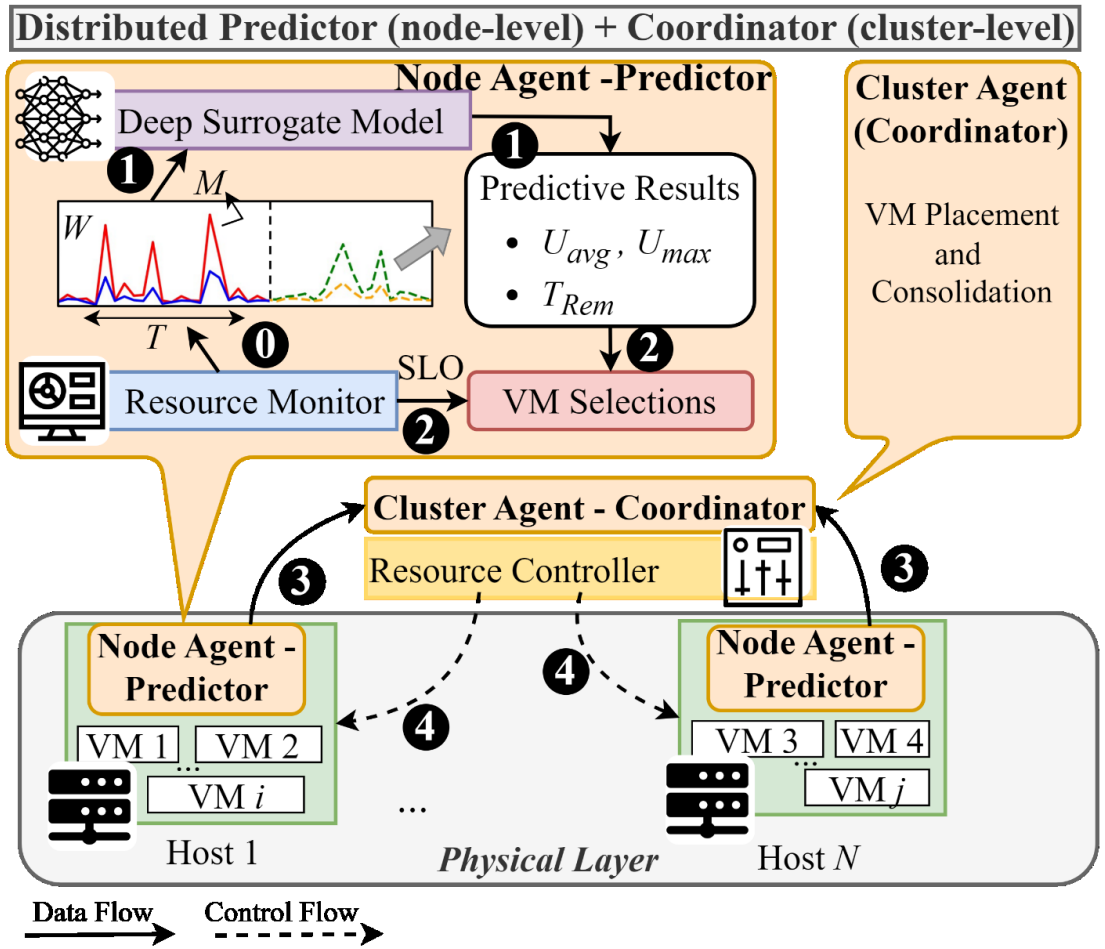
Improve existing system via AI/ML-driven control to jointly manage/configure the image processing application pipeline on a tractor and a companion drone.

One of the many outcomes

Can we do better with ML-based resource management for the Cloud?

Solution Overview

- Node-level ML model
  - Runs locally on each node
  - Predicts future CPU utilization and VM lifetime
  - Drives VM management decisions
- Cluster agent
  - Receives predictor output
  - Applies a heuristic to globally optimize cluster resources



Results

- Migration counts
  - **Decrease of 41.33%** compared with SoTA conventional (non-ML) policy
  - Only 7.5% over oracle (Ground Truth)
- SLO violations
  - **Lower by 34.98%** compared with SoTA conventional policy
  - A mere 1.1% more than oracle (Ground Truth)

Coming soon…

- Workshop organization
  - 2nd ML4ECS @ HiPEAC 2026 (Jan. 26, 2026)
  - In collaboration with other projects of the cluster

  https://ml4ecs.e-ce.uth.gr/

- Hackathlon organization
  - University of Calabria, Rende, Italy (Sep. 26-27, 2025)
  - Familiarize developers with the MLSysOps framework
  - Foster application & ML models development

Open-Source Release

Open-source components of the MLSysOps framework

https://github.com/mlsysops-eu/mlsysops-framework

Core Components

- Hierarchical Agent Architecture: Interfaces with orchestration/control systems and exposes an ML-model API for plug-and-play explainable/re-trainable models.
- Telemetry & Control Knobs: Collects metrics across the continuum and adjusts configuration (e.g., compute, network, storage, accelerator usage) dynamically.
- Distributed FaaS-style Executor: Enables function offloading across tiers to optimize latency, energy, and performance.
- Explainable ML & Reinforcement Learning Module: Offers transparent decisions, highlighting input factors influencing agent actions.
- Use-cases: Includes real applications focusing on smart cities and agriculture.

https://mlsysops.eu

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