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Energy-optimisation techniques for complex workloads from the Swarmchestrate project

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EGI2024, 01/10/2024, Lecce, Italy

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Application-level Swarm-based Orchestration Across the Cloud-to-Edge Continuum

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- http://swarmchestrate.eu
- Budget: ~ EUR 5.5 Million
- Co-funded by EU Horizon Europe, UKRI and South Korea
- Duration: 3 years (1 January 2024 – 31 December 2026)
- 14 project partners from 10 countries across Europe and South Korea
- Combination of academic and industry partners
- Project coordinator: Dr Robert Lovas (HUN-REN SZTAKI / Institute for Computer Science and Control, Hungary)
- Project Scientific Coordinator: Prof. Tamas Kiss (University of Westminster, UK)

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Partners and their expertise

#	PARTNER		COUNTRY	TYPE	EXPERTISE
1.	SZTAKI	HUN-REN Szamitastechnikai es Automatizalasi Kutatointezet	HU	RO	cloud and edge related application, service and resource orchestration system integration project management
2.	TUB	Technische Universität Berlin	GER	UNI	swarm computing, distributed intelligence
3.	ICCS	Institute of Communication and Computer Systems	GR	UNI	cloud orchestration, distributed monitoring and application/resource specification and management TOSCA standard
4.	TUNI	Tampere University	FIN	UNI	end-to-end security and identity management data privacy
5.	UL	University of Ljubljana	SL	UNI	Cloud-to-Edge continuum, decentralised blockchain-based edge and fog technologies computing platforms end-to-end security and identity management
6.	FUEL	Fuelics Idiotiki Kefalaiouxiki Etaireia	GR	SME	energy optimisation smart city sensors D1-Wastewater Manhole Management in Athens Metropolitan Sewage Netork D2-Magnetometer threshold recalibration
7.	SUITE5	SUITE5 Data Intelligence Solutions	CY	SME	distributed AI methods communication, dissemination and sustainabilty
8.	FEA	FrontEndArt Software Limited	HU	SME	analysis and validation fog simulator framework
9.	FBK	Fondazione Bruno Kessler	IT	RO	distributed AI methods
10.	UST	UST Global España	ESP	SME	digital twins, virtual environments blockchain D-A metaverse digital twin of a natural habitat
11.	InnoRenew	InnoRenew CoE	SL	SME	sensor development application migration from cloud to edge assessing scalability D- Microphones and cameras in Koper, CO2 emission monitoring
12.	ENU	Edinburgh Napier University	UK	UNI	edge and fog computing, security
13.	SNU	Seoul National University	KOR	UNI	energy efficiency (analysis and optimisation of the orchestration) distributed AI methods
14.	UOW	University of Westminster	UK	UNI	cloud and edge related application, service and resource orchestration project management TOSCA standard distributed AI methods

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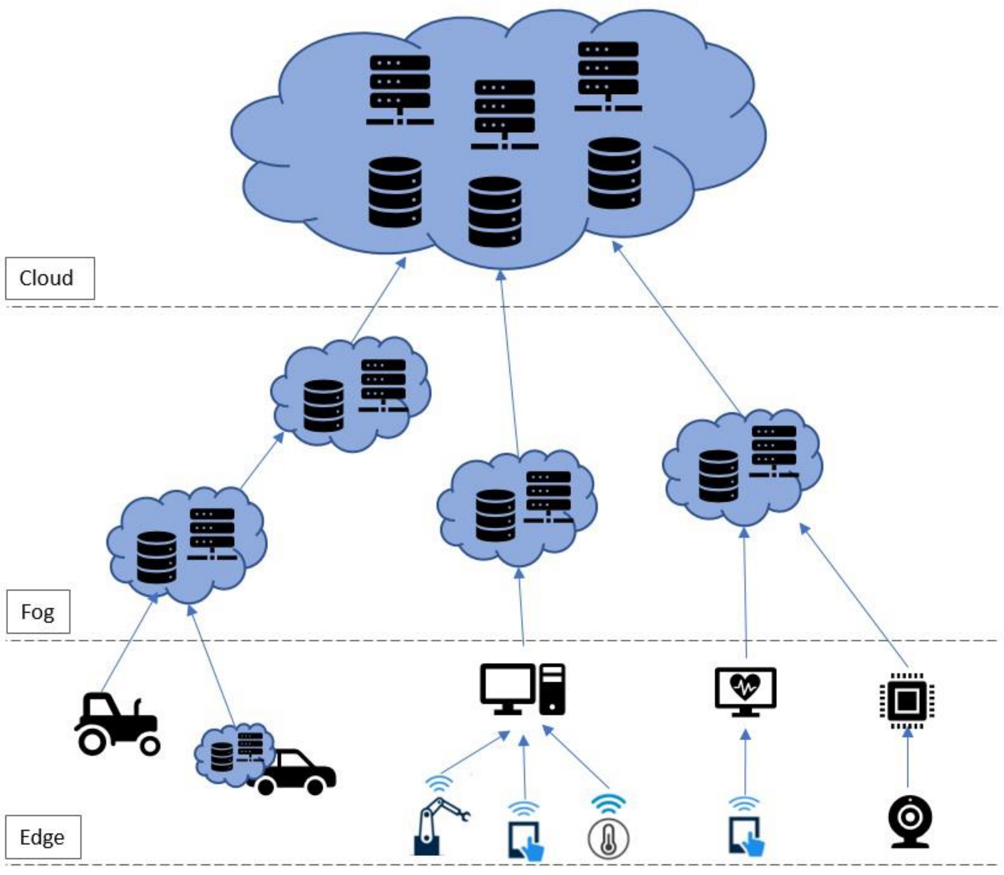
Cloud-to-Edge Continuum



Application areas

- Smart manufacturing/Industry 4.0
- Smart cities
- Precision agriculture
- Self-driving cars
- Augmented reality
- Etc.

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Orchestration

- **Orchestration** is the automated configuration, management and coordination of computer systems, applications and services (by RedHat)
- **Cloud Orchestration** can be used to provide or deploy servers, assign storage capacity, create virtual machines, manage networking, deploy complex microservice architectures, auto-scale applications at run-time, etc.
- **Cloud-to-Edge Orchestration** extends this concept beyond the cloud layer; e.g., offload tasks from fog/edge servers to the cloud

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Centralised vs. Decentralised Orchestration

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Centralised

- All current orchestrators have a central component
- Single point of failure
- Performance bottleneck
- Central point for an attack
- Does not fit the decentralised Cloud-to-Edge continuum

Decentralised

- **Self-organisation** without central component
- **Fast reaction and fast adaptation** to changes in local environment
- Fits well to the **decentralised nature** of the Cloud-to-Edge continuum
- Main technical principles: **swarm computing, distributed AI, blockchain, decentralised identity management**

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Swarmchestrate Project Objectives

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- Develop an **application-level decentralised orchestration framework**, utilising Swarm-based distributed intelligence
- Dynamically create and manage **a set of interconnected Swarms** across the distributed Cloud-to-Edge infrastructure
- Develop **matchmaking algorithms using decentralised AI** methods to optimise energy efficiency and effectiveness
- Develop trusted, reliable, secure and transparent **knowledge management**
- Develop a **simulation environment** based on the novel decentralised orchestration concept of the project
- Implement **real-life application demonstrators** utilising Swarmchestrate services in realistic scenarios

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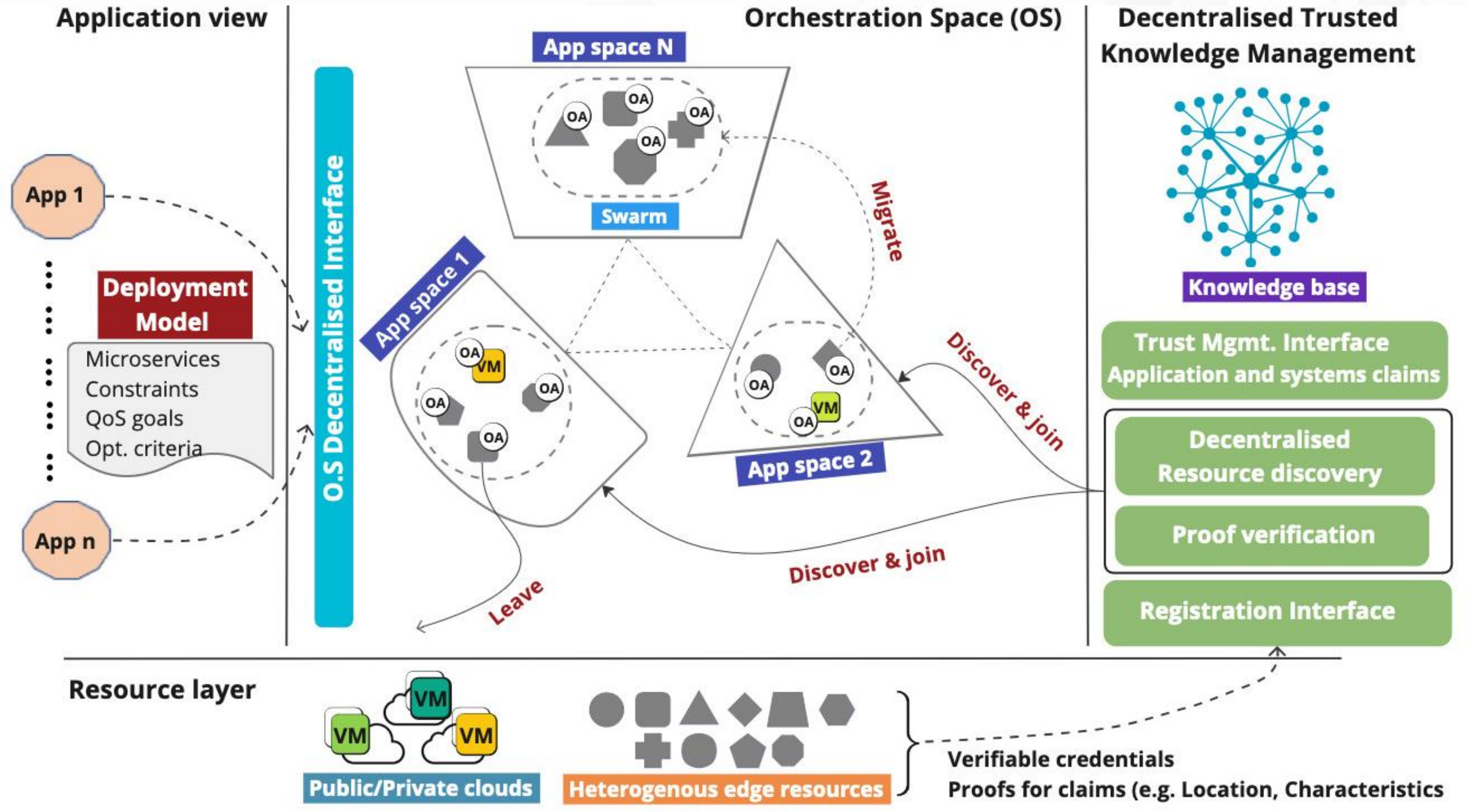
Swarmchestrate Concept



Main Swarmchestrate Components

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Video scene analytics

Digital twin of nature

Waste water management

Parking space management

Context-aware Semantics for Application Specification

Decentralised Orchestration Framework

AI-Driven Decentralised Intelligence

Swarms Management

Simulation and Digital Twin Modelling

Energy Optimisation

Secure computing and Privacy

Decentralised Trusted Knowledge Management

Computational and Data resources

Cloud

Edge

IoT

Demonstrator1: Flood Prevention

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- This demonstrator will focus on a **network of** ultrasound **water-level measurement sensors** used for the **early flood warning** in the Athens metropolitan area
- Use Swarmchestrate to **dynamically reconfigure** a large network of sensors (~100), using data **from external sources like weather forecast and weather databases**, to optimise the measurement and connection interval of each sensor, extending battery life
- Additionally, make use of external data to dynamically create Swarms of application components in the Cloud-to-Edge Continuum that will combine the measurements and use the upstream data **to forecast a possible flood event before it actually occurs** and gets detected by the physical sensors

Read more: swarmchestrate.eu/flood-prevention/

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Demonstrator2: Parking Space Management

- This demonstrator will be based on the FUELICS **parking occupancy, battery-operated sensor** that offers parking and anti-parking roadside services
- Use Swarmchestrate to **combine the magnetic flux data of multiple sensors**, and in the case of abnormal behavior, to will trigger the auto-calibration and reconfiguration of the sensors in an automated way
- Additionally, create a **network of sensors that spawn globally** across countries in very different longitudes/latitudes and attempt **to depict changes of the earth's magnetic field over time at planetary scale**, as well as, using smaller localised sensor networks to study possible effects of local phenomena (e.g., an earthquake) at a particular location

Read more: swarmchestrate.eu/parking-space-management/

Demonstrator3: Digital Twin of Natural Habitat

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- Getting and **processing data collected from the physical environment** cost-effectively is a fundamental issue for Cloud-to-Edge systems
- Use Swarmchestrate for **edge processing and swarming** between on-location devices which can preprocess data and **reduce overall storage, transmission and processing costs**
- Additionally, **prepare** the ground **for full scale digital twins** that harness the localised digital resources to inform of **real time changes** to be made to virtual environments enjoyed by many **remote users**

Read more: swarmchestrate.eu/digital-twin-of-natural-habitat/

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Energy optimisation goals, tasks

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- Goal:
  - **Optimising energy efficiency** and ecological sustainability of applications
- Task(s):
  - **design and implement an energy optimisation solution** for resource allocation within the envisioned Cloud-to-Edge ecosystem, under the constraints of the applications executed and the devices available.
  - **consider** cross-layer technical **input about hardware, software, and networking**
  - **consider** economics-related **input about application-specific needs (e.g., urgency of results, budget constraints, and other user objectives**).
  - to calculate a resource allocation solution for the very large amount of devices, besides **heuristics for multi-objective optimization**
  - also use **advanced machine learning algorithms** (e.g., deep learning and reinforcement learning)

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Multi-Object Optimisation Algorithm

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- Inputs
  - Parameters of feasible Swarm resource
    - Energy consumption
    - Cost of service placement
    - CPU speed of resource (e.g., VM instances)
    - Memory size of resource
    - Network latency and bandwidth
    - Availability of overall system
    - ...
  - Constraints
    - Task parameters (performance constraints, resources, location)
    - ...
  - User preferences
    - Performance vs Cost vs Locality vs …
    - ...
- Output
  - Resource assignment (placement plan)

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Genetic Algorihtms

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- Investigating Genetic Algorithms
- Example:
  - Solution expressed as a chromosome
  - Different characteristics of a solution encoded as genes
  - Evaluation function to rank different solutions
  - Iterative approach
    - Generation 0: initial random population
    - Evolutionary approach:
      - Rank population using evaluation function
      - Generate next generation by selecting X% top performers, Y% random, remaining obtained through mutation and crossover
  - Evolve until time is up or an acceptable solution is found

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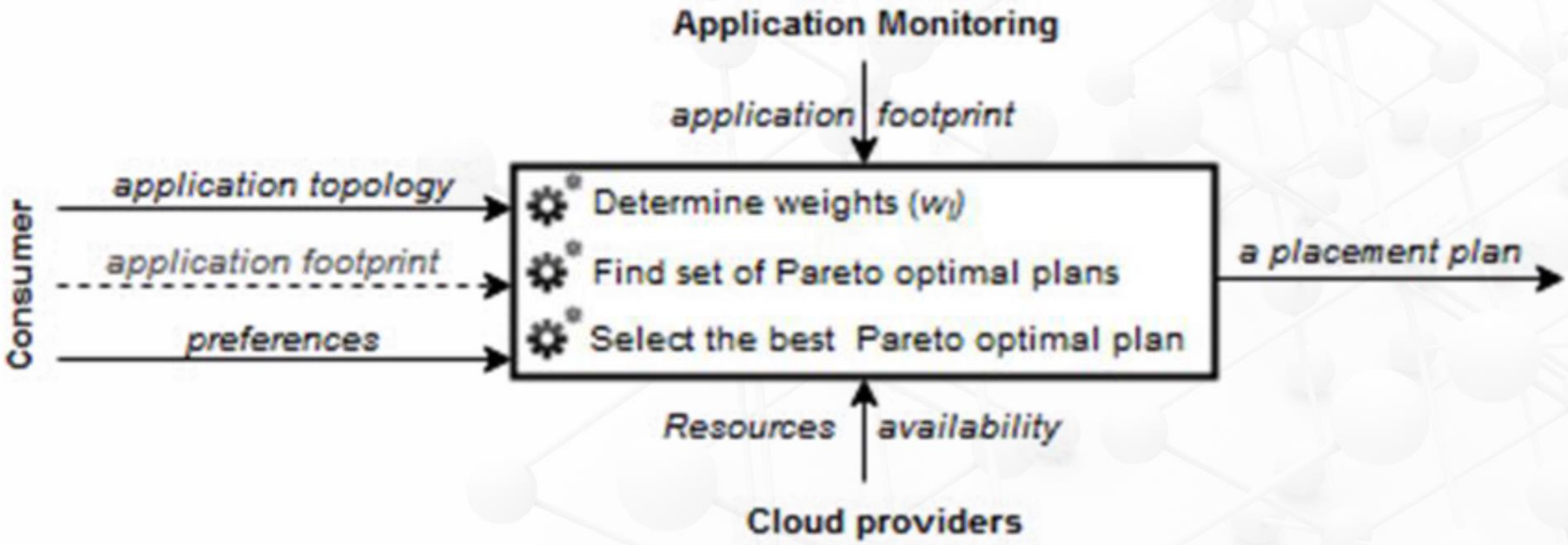
Contents by Jorn Altmann and Bernhard Egger, Seoul National University

Basic decision mechanism for energy efficiency



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Thank you for your attention!

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on behalf of the SwarmChestrate consortium

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Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

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This work was co-funded by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee (grant numbers 10101169 and 10102651).

This work was supported by Seoul National University (Institute of Engineering Research) and through grant NRF-RS-2023-00302083 by the National Research Foundation of Korea (NRF), which is funded by the Korea government, Ministry of Science and ICT (MSIT).

PARTNERS

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