Living on the edge, sailing through the cloud

Orchestrating Applications in the Edge to Cloud Computing Continuum

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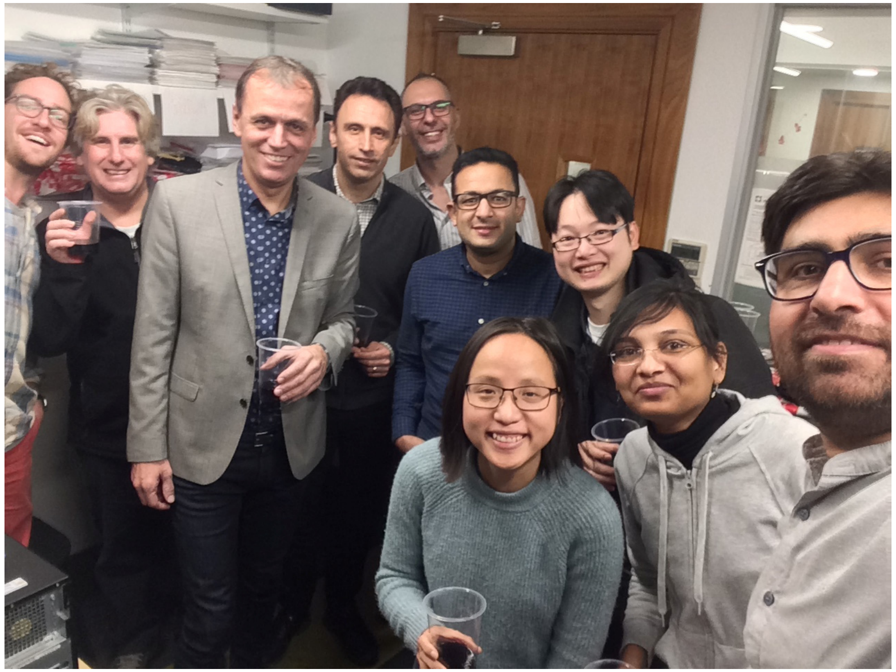
The Centre for Parallel Computing

Established in the 1990s

Focus on cloud/fog/edge computing

- Orchestration and autoscaling in the Cloud to Edge continuum
- Secure management of multi-cloud environments
- Cloud-native technologies – Docker, Kubernetes
- Standardised description of cloud-native applications - TOSCA
- Cloud/fog/edge based simulation environments for SMEs, research and the public sector
- Science/business gateways - user friendly interfaces for clouds and high performance computing



Main research outputs with impact in the past 6 years:

- MiCADO – application-level cloud to edge orchestrator - https://micado-scale.eu/
- emGORA workspace – a commercial digital marketplace for manufacturing simulation, data analytics and AI-based digital twins - https://www.emgora.eu/
- PITHIA e-Science Centre – Science Gateway for the space physics community - https://esc.pithia.eu/

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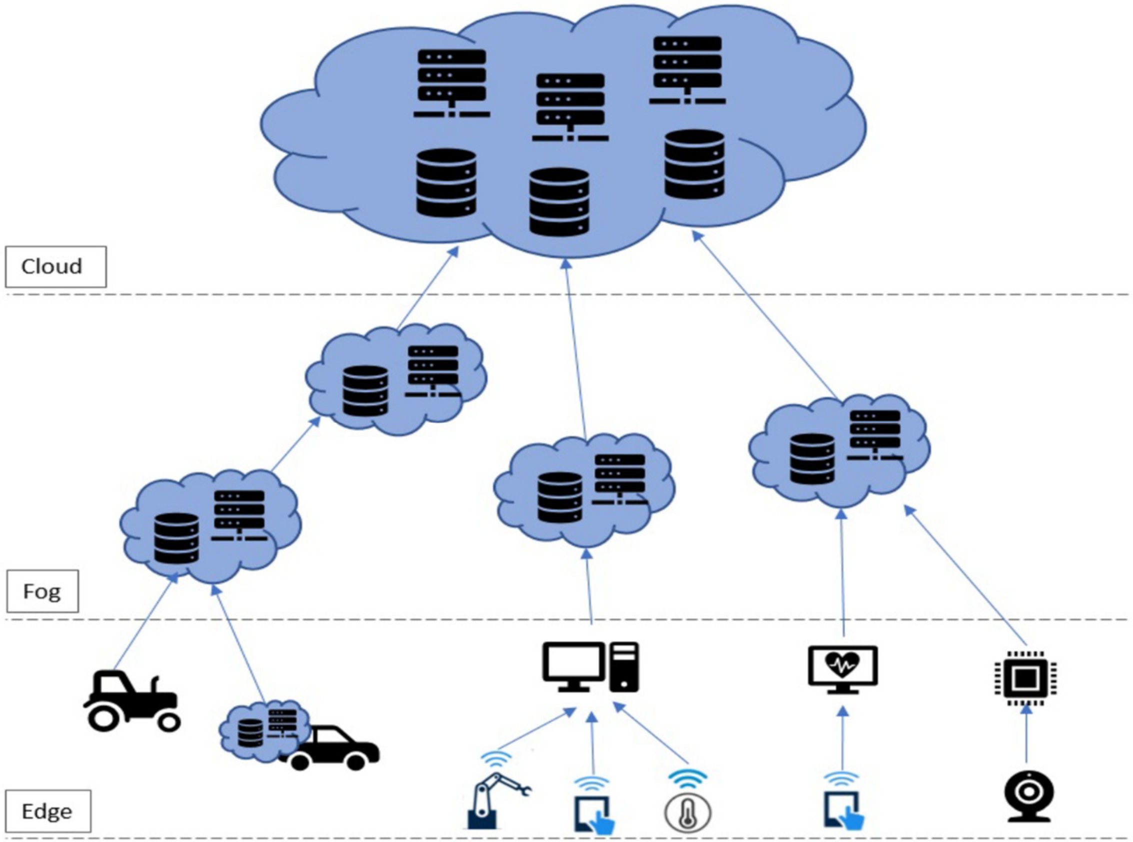
The Cloud-to-Edge Compute Continuum



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

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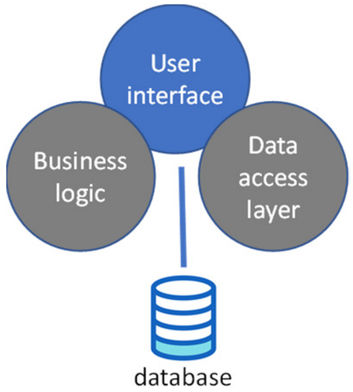
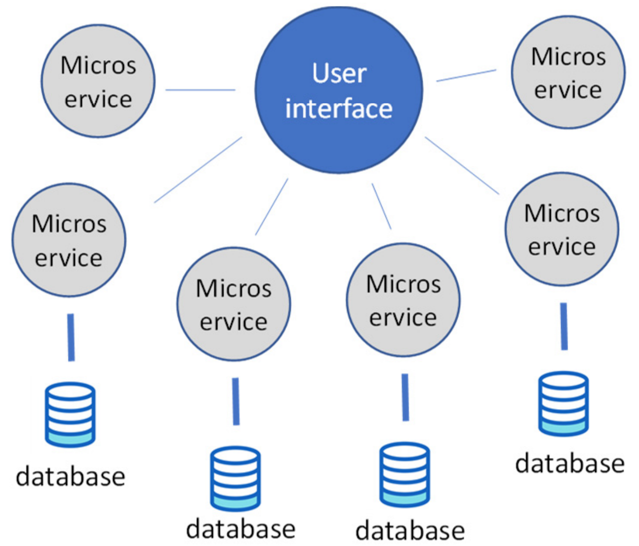
Monolithic vs Microservice architectures

- Monolithic
  - All application components together
    - Single host, single DB, single server



- Microservice
  - Each application component individual
    - Containers make it possible!
    - Individual hosts, databases and servers
    - All working together



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Cloud-native approach

- Cloud Native Computing Foundation - CNCF Cloud Native Definition v1.0: https://github.com/cncf/toc/blob/master/DEFINITION.md

- Cloud native technologies empower organizations to build and run scalable applications in modern, dynamic environments such as public, private, and hybrid clouds.

- Containers, service meshes, microservices, immutable infrastructure, and declarative APIs exemplify this approach.

CLOUD NATIVE
COMPUTING FOUNDATION

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Cloud-to-Edge orchestration

- **Orchestration** is the automated configuration, management, and coordination of computer systems, applications, and services.
- **Cloud orchestration** can be used to provision 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 beyond the cloud layer; e.g. offload tasks from fog/edge servers to the cloud

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What challenges are we addressing?

- Cloud computing is gaining more and more attention in **various industrial sectors**
- **Private** clouds have significant benefits in terms of security and integrability into the enterprise environment but **hybrid** and multi-clouds are also widespread.
- New solutions are needed to support **Internet of Things** (IoT) and **Big Data** application areas -> cloud-fog-edge computing is a new challenge
- Growing demand for **cloud ochestrators** and **brokering** tools.

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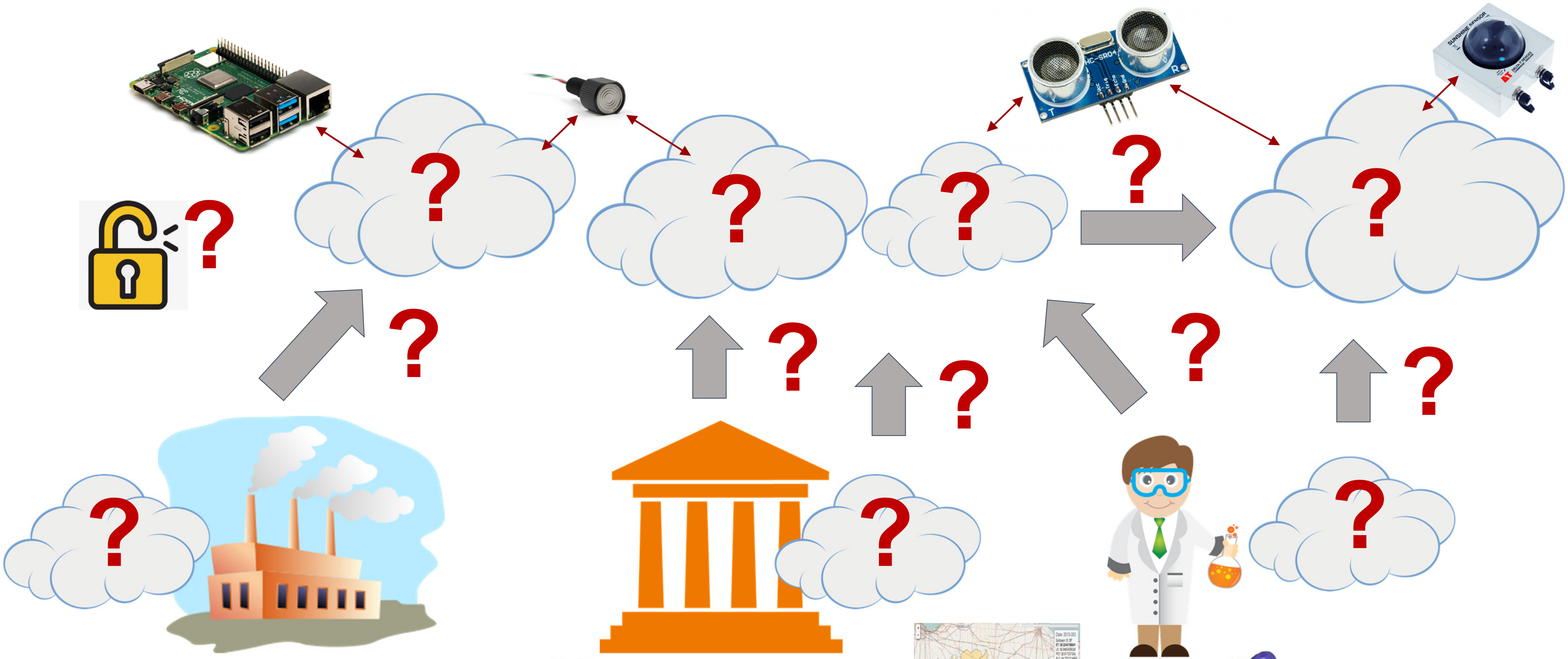
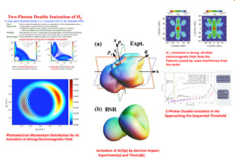
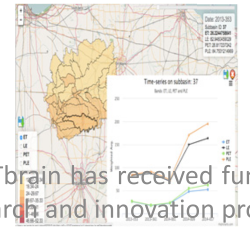
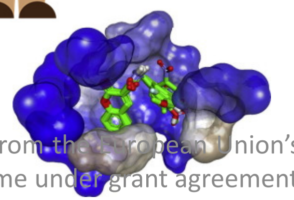
What challenges are we addressing?









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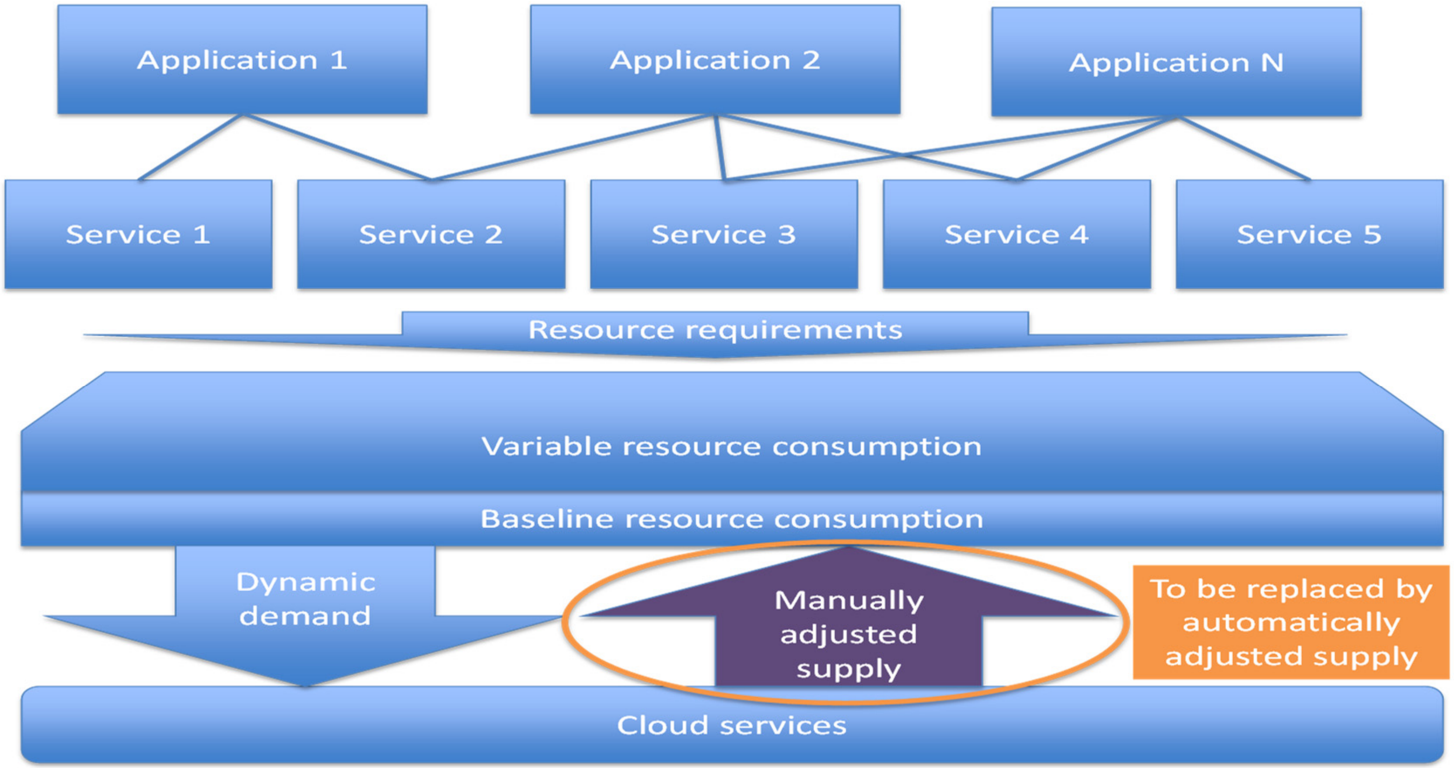
The beginnings – application-level cloud orchestration

- deploying complex sets of application microservices in a cloud agnostic way
- supporting a wide range of scaling policies and intelligent scaling decisions
- supporting cloud application developers
- providing advanced policy-based security solutions



COLA – Cloud Orchestration at the Level of Application
https://project-cola.eu/

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The COLA project

- EU H2020 project
- 1st January 2017 - 30th October 2019
- Funding: 4.2 million Euros
- 14 project partners from 6 European countries
- 10 companies and 4 academic/research institutions
- More information: https://project-cola.eu

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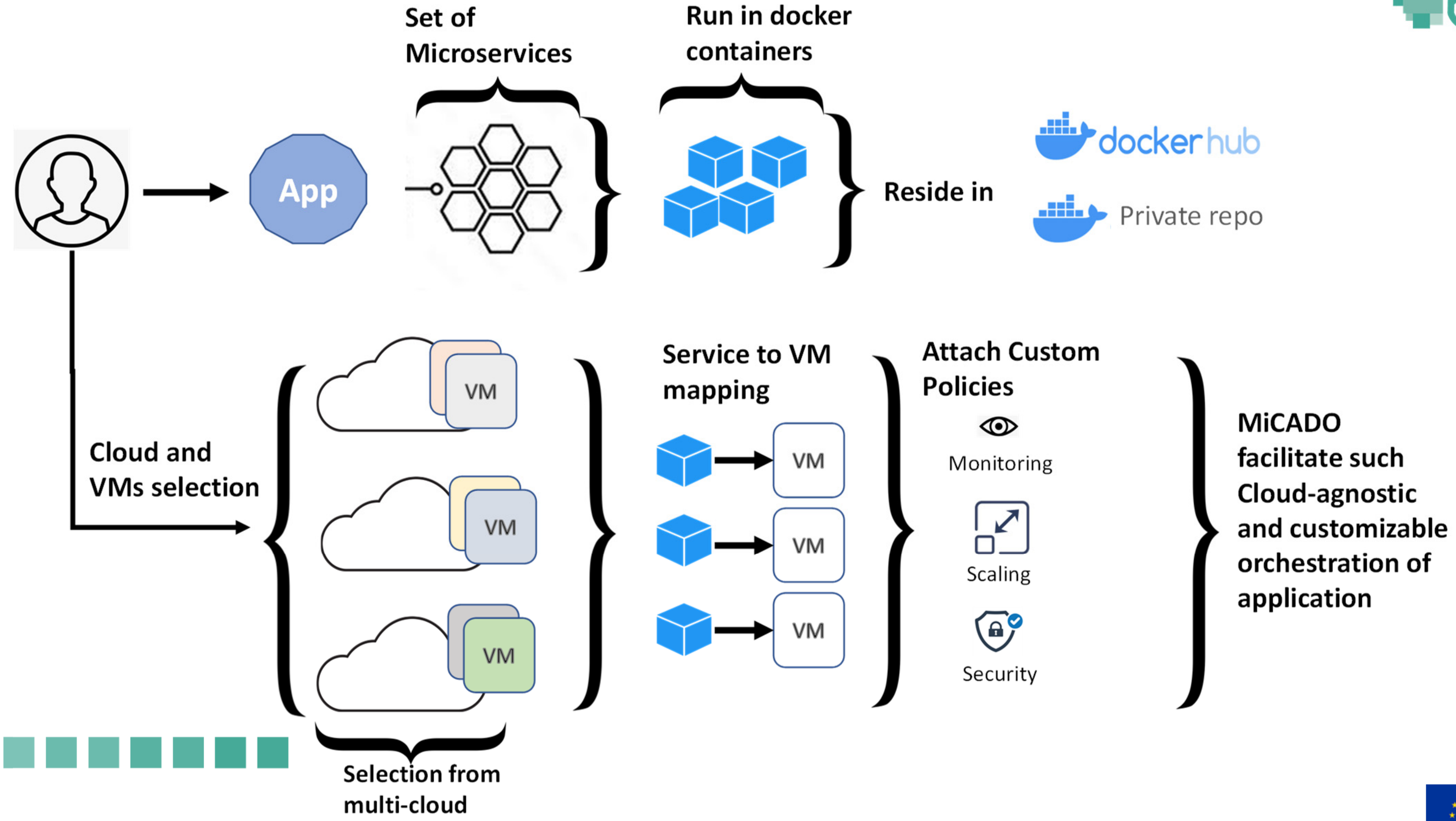
MiCADO – Microservices-based Cloud Application-level Dynamic Orchestrator

- Result of the **H2020 COLA** project
  - currently actively developed in the H2020 DIGITbrain project,
  - is/was used in ASCLEPIOS, PITHIA-NRF, CO-VERSATILE, Harpocrates and ARCAFF
- Automated application **deployment** based on TOSCA-based application description templates
- Automated **scaling** based on highly customisable scaling policies
  - scaling at both **container and virtual machine** levels
- **Multi-cloud** support – application portability
- Policy driven **security** settings
- Open source - https://micado-scale.eu/

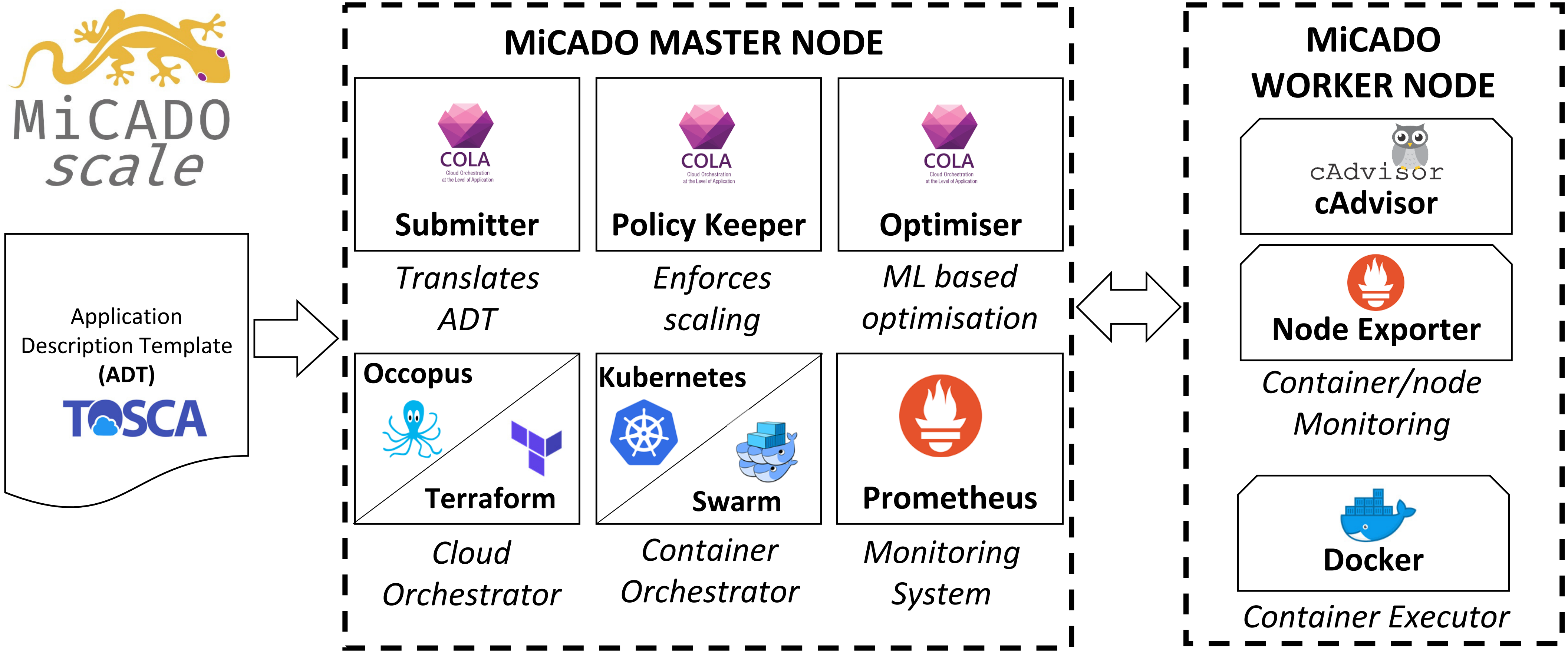
COLA
Cloud Orchestration at the Level of Application

MiCADO scale

The overall concept



MiCADO – Microservices-based Cloud Application-level Dynamic Orchestrator



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Application description in MiCADO

- Application Description Templates

- Written in Oasis Standard TOSCA
  - A cloud language in YAML
  - www.oasis-open.org/committees/tosca/

- Authored by developers
  - Understand application, metrics and scalable components

- Finalised by application operators
  - Provide Compute details for a Cloud Service Provider

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Application description

- Three sections
  - Container Infrastructure
    - Containers, volumes, configurations
  - Cloud Infrastructure
    - Instance size, SSH keys, opened ports, VM image
  - Monitoring & Scaling Policy
    - Metric collection
    - Queries, alerts, thresholds, scaling logic


```yaml
stressng:
  type: tosca.nodes.MiCADO.Container.Application.Docker.Deployment
  properties:
    image: lorel/docker-stress-ng
    args: ['--cpu', '0', '--cpu-method', 'pi', '-l', '20']
    resources:
      requests:
        cpu: "900m"

  worker-node:
    type: tosca.nodes.MiCADO.CloudSigma.Compute.Occo.small
    properties:
      vnc_password: secret
      libdrive_id: ADD_LIBRARY_DRIVE_ID (e.g. 0d2dc532-39f5
      public_key_id: ADD_PUBLIC_KEY_ID (e.g. d7c0f1ee-40df-
      nics:
      - firewall_policy: ADD_FIREWALL_POLICY_ID (e.g. fd97e
        ip_v4_conf:
          conf: dhcp
```


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Monitoring and autoscaling in MiCADO

- Highly customizable monitoring subsystem
  - Monitored metrics are collected by dynamically attachable data collectors (Prometheus exporters)
- Highly customizable scaling logic
  - Scaling logic is fully programmable (using Python)
- Many different scaling policies are supported
  - Application types (job execution, web applications, …)
  - Different metrics (cpu, network, number of jobs, …)
  - Various strategies (load-based, deadline-based, event-based, …)
- Scaling of containers and virtual machines are supported
  - Container-only and VM-only scaling
  - Scaling at both levels in parallel, independently or cooperatively
  - Possible to use predefined scaling policy or own-developed

```yaml
policies:
  - monitoring:
      type: tosca.policies.Monitoring.MiCADO
      properties:
        enable_container_metrics: true
        enable_node_metrics: true
  - scalability:
      type: tosca.policies.Scaling.MiCADO.Container.CPU
      targets: [ stressng ]
      properties:
        constants:
          SERVICE_NAME: 'stressng'
          SERVICE_TH_MAX: '60'
          SERVICE_TH_MIN: '25'
        min_instances: 1
        max_instances: 3
```


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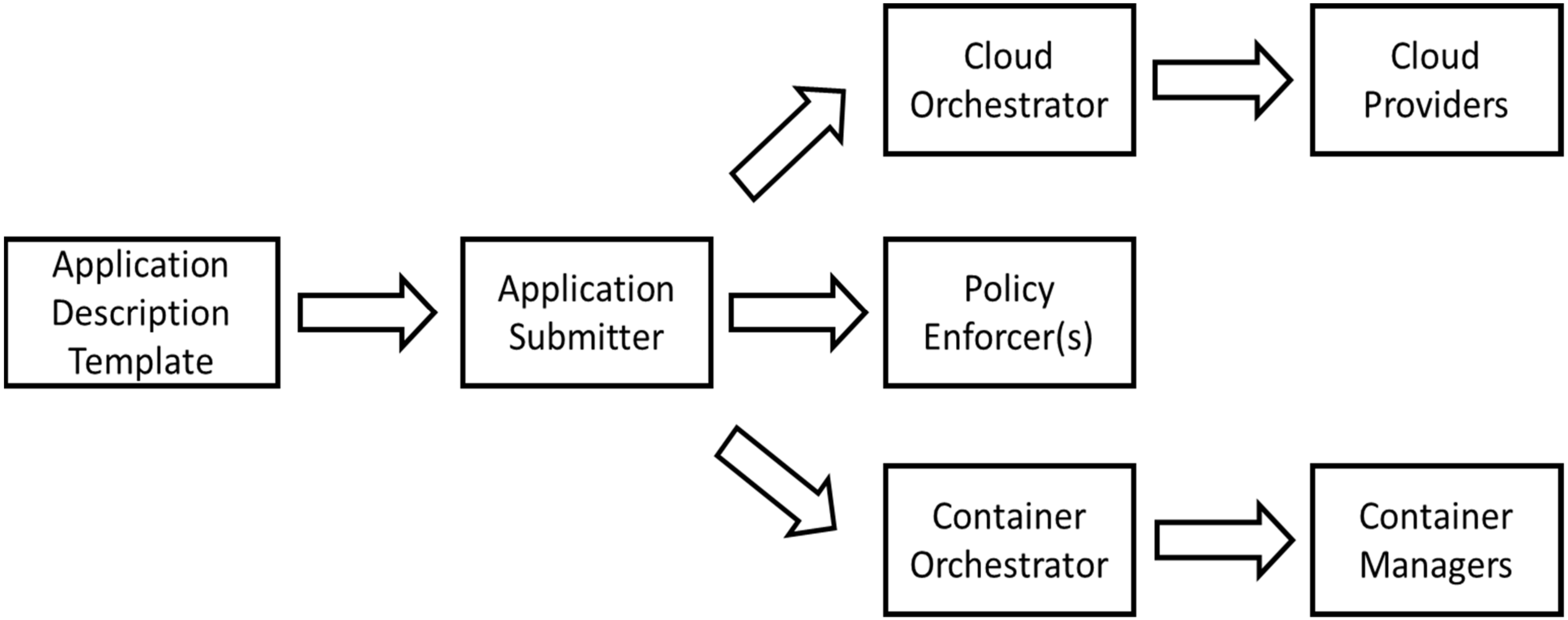
How does MiCADO work?



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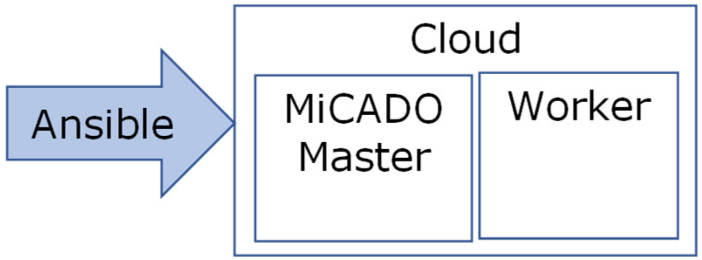
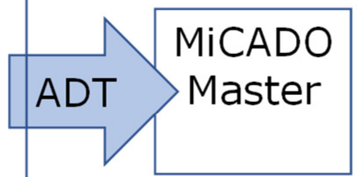
How to use MiCADO?

1. Deploy MiCADO by customizing Ansible configuration files
2. Describe your application (for e.g. virtual machine, scaling policy, etc.) by creating/ customizing TOSCA-based ADT file (Application Description Templates)
3. Submit your ADT file visa REST API call
4. Tracking MiCADO master and worker nodes in Dashboard during run-time




```
topology_template:
  inputs:
    app_image:
      type: string
      description: Docker image
to run for the application
      required: yes
      ...
```



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Supports a large variety of clouds

amazon web services

Azure

ORACLE

openstack.

Google Cloud

egi

CloudBroker

CloudSigma

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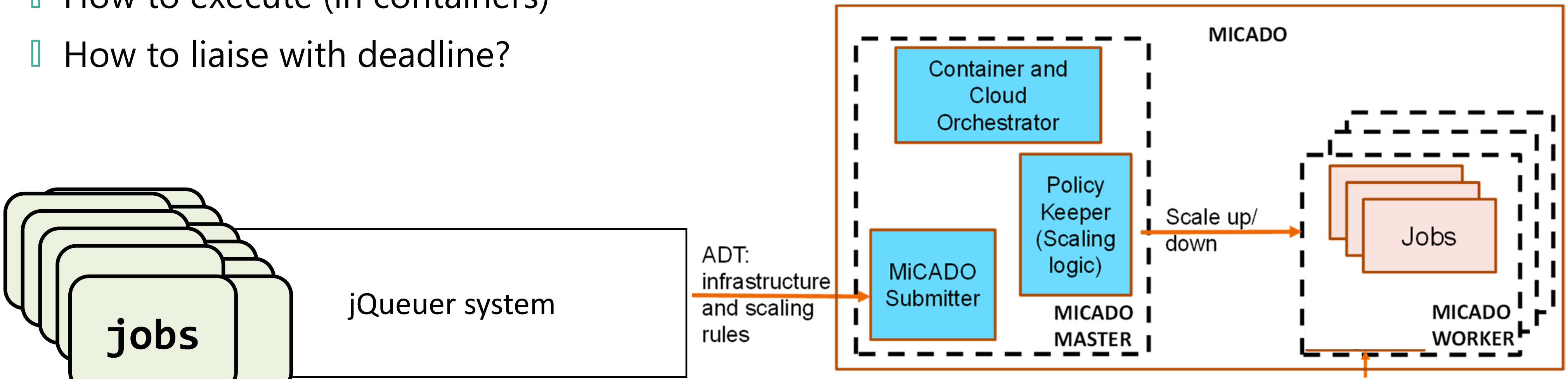
MiCADO and job execution

- Large number of jobs results in significant overall execution time
- Usually Restricted to complete all jobs by a deadline
  - Where to put the jobs?
  - How to distribute?
  - How to execute (in containers)
  - How to liaise with deadline?



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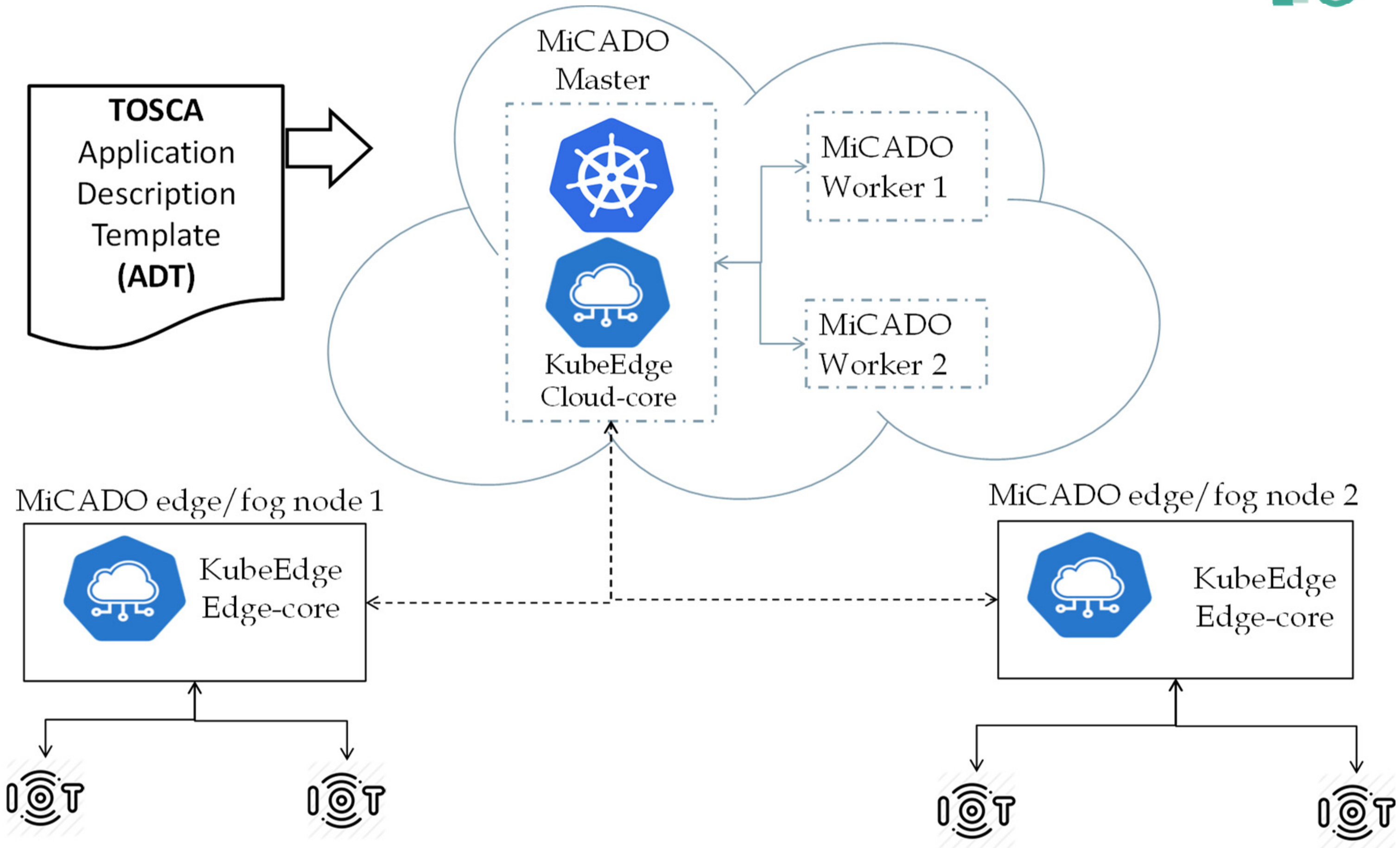
How to extend orchestration to the Edge

- Solution using KubeEdge
- Automated deployment of microservices extended to edge nodes
- Monitoring information collected from edge workers
- Scaling/reconfiguration policies extended towards edge



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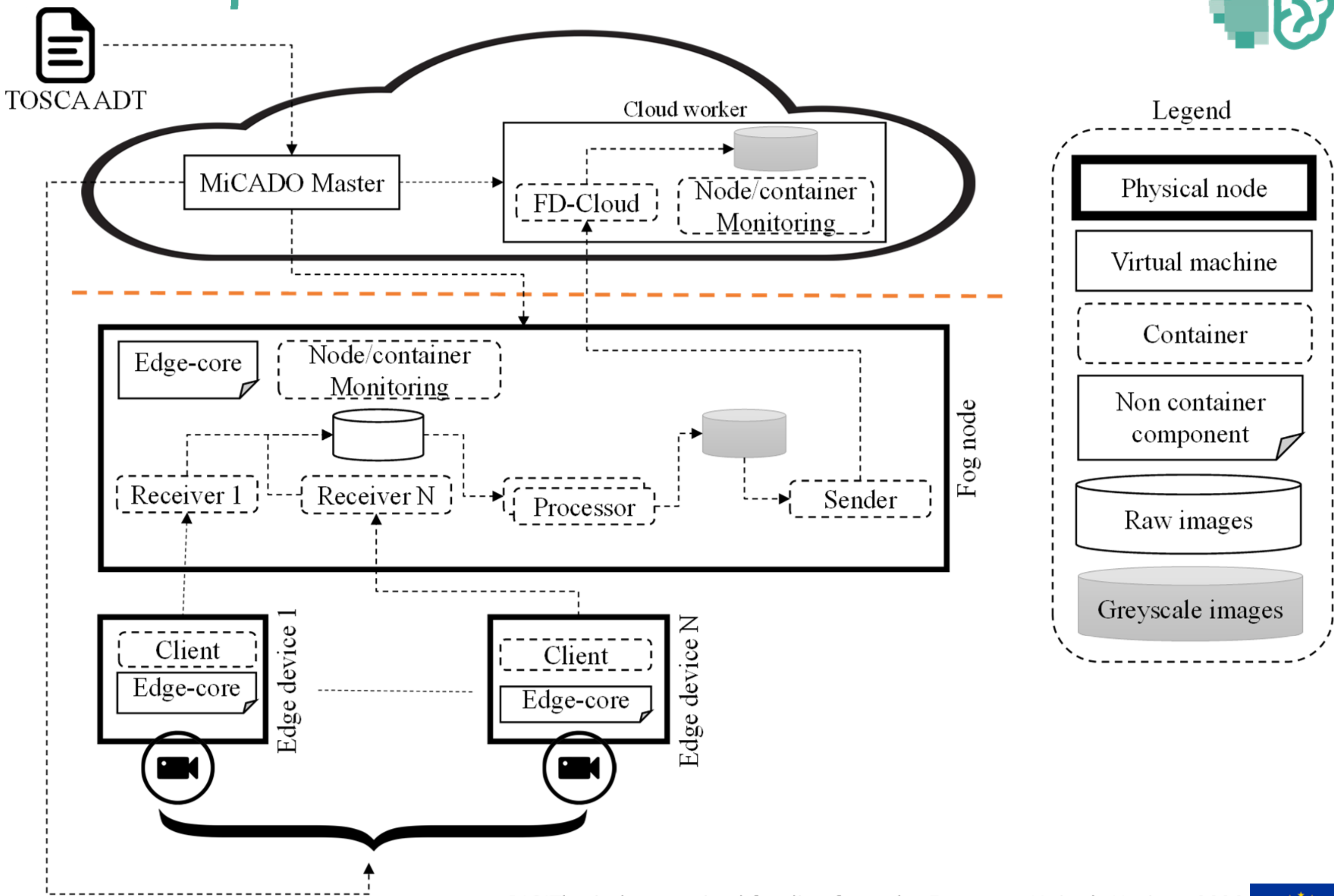
Face detection example

- Edge device captures video stream
- Fog node recognises faces in images
- Cloud server stores images with faces



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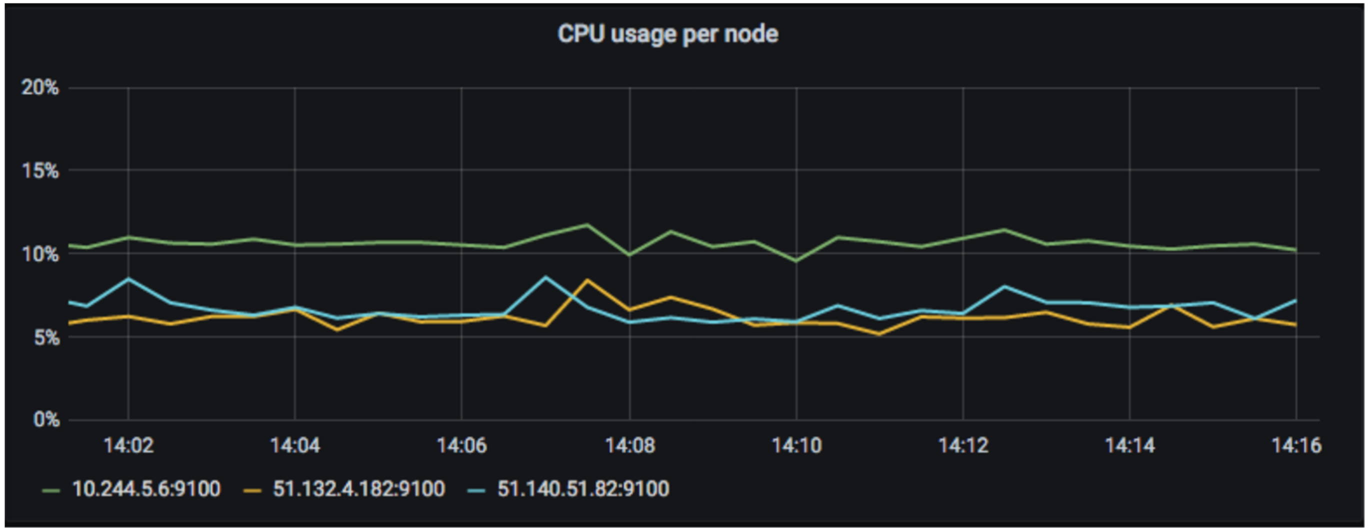
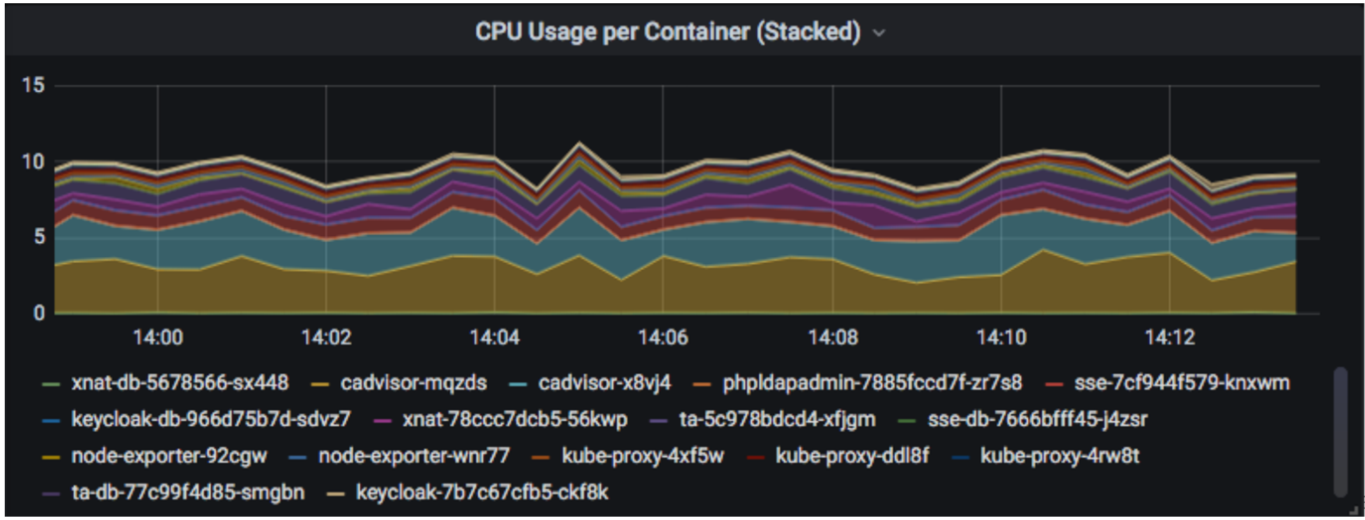
Face detection example MiCADO dashboard





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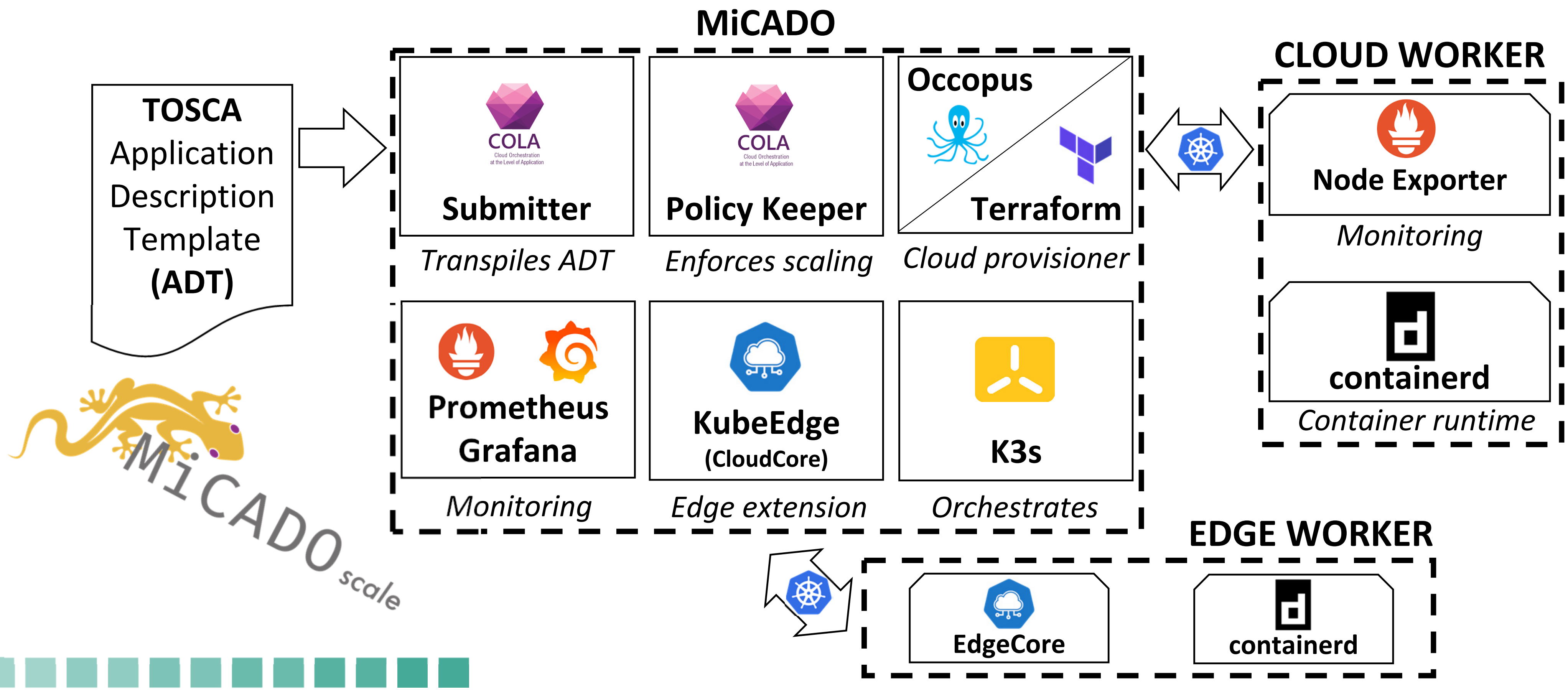
Latest MiCADO architecture with Edge extension



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MiCADO in the DIGITbrain project

- Start date: 1st July 2020 - Duration: 42 months - Number of partners: 36

Core technical and administrative partners

Experiment partners

Network of DIHs

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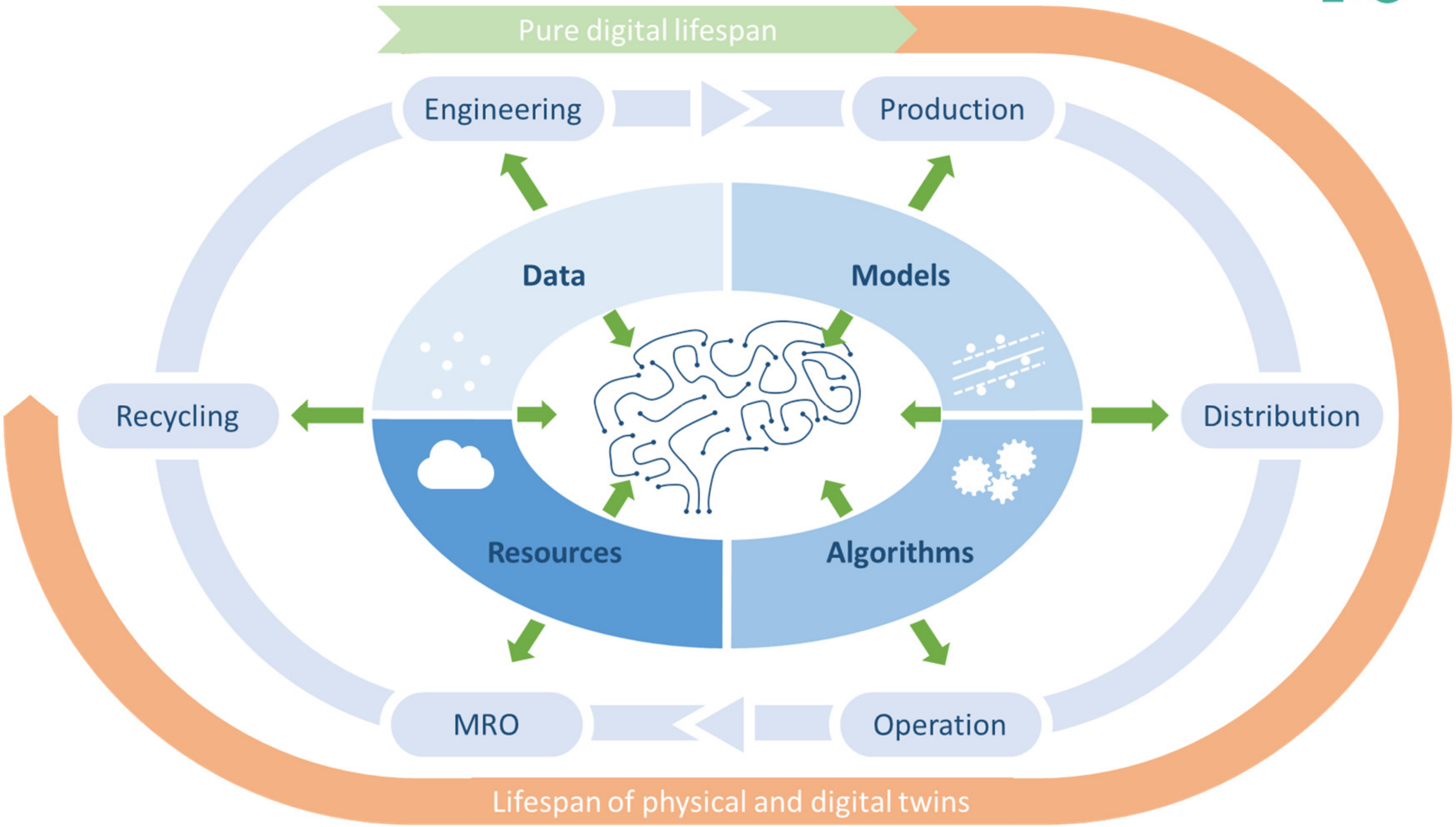
MiCADO in the DIGITbrain project

- Compose Digital Twins from their basic building blocks (Data, Model, Algorithm)
- Execute Digital Twins in the Cloud-to-Edge continuum
- Collect, store and analyse data related to events in the Digital Product Brain



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Key DIGITbrain concepts

- **Industrial Products:** Mechatronic systems (or components) that are operated by manufacturing companies to support the production of other products (e.g. a manufacturing line).
- **Digital Twin:** Represented by static and dynamic models that can evaluate historical and actual data to assess the condition and to simulate the behaviour of the industrial product.
- **Digital Product Brain:** Guides the behaviour and performance of the industrial product by coalescing its physical and digital dimensions and by memorising the occurred (physical and digital) events over a significant part of its lifecycle.

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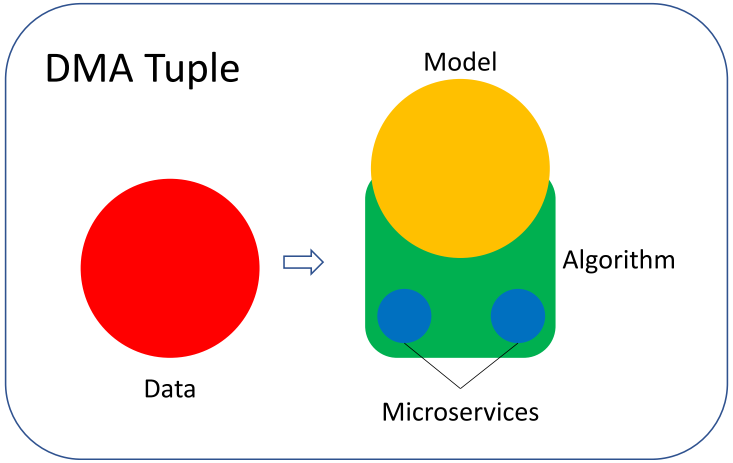
Data – Model – Algorithm – Microservices

- **Data:** Refers to data sources in the form of files, streams or databases; data sources are considered to be external to the Db Platform (typically residing at the factory)
- **Model:** A Model is a description of a certain behaviour of/for an Industrial Product according to the given characteristics and operation conditions. A model is typically a file.
- **Microservice:** Encapsulates an executable procedure in a containerized form, e.g. in a Docker container.
- **Algorithm:** An Algorithm consists of one or more Microservice(s) and evaluate a model. Algorithms (its microservices) can be deployed into different resources (e.g. edge, cloud, HPC) to be executed, depending on the needs of the Model.



- Digital Twin: a DMA tuple

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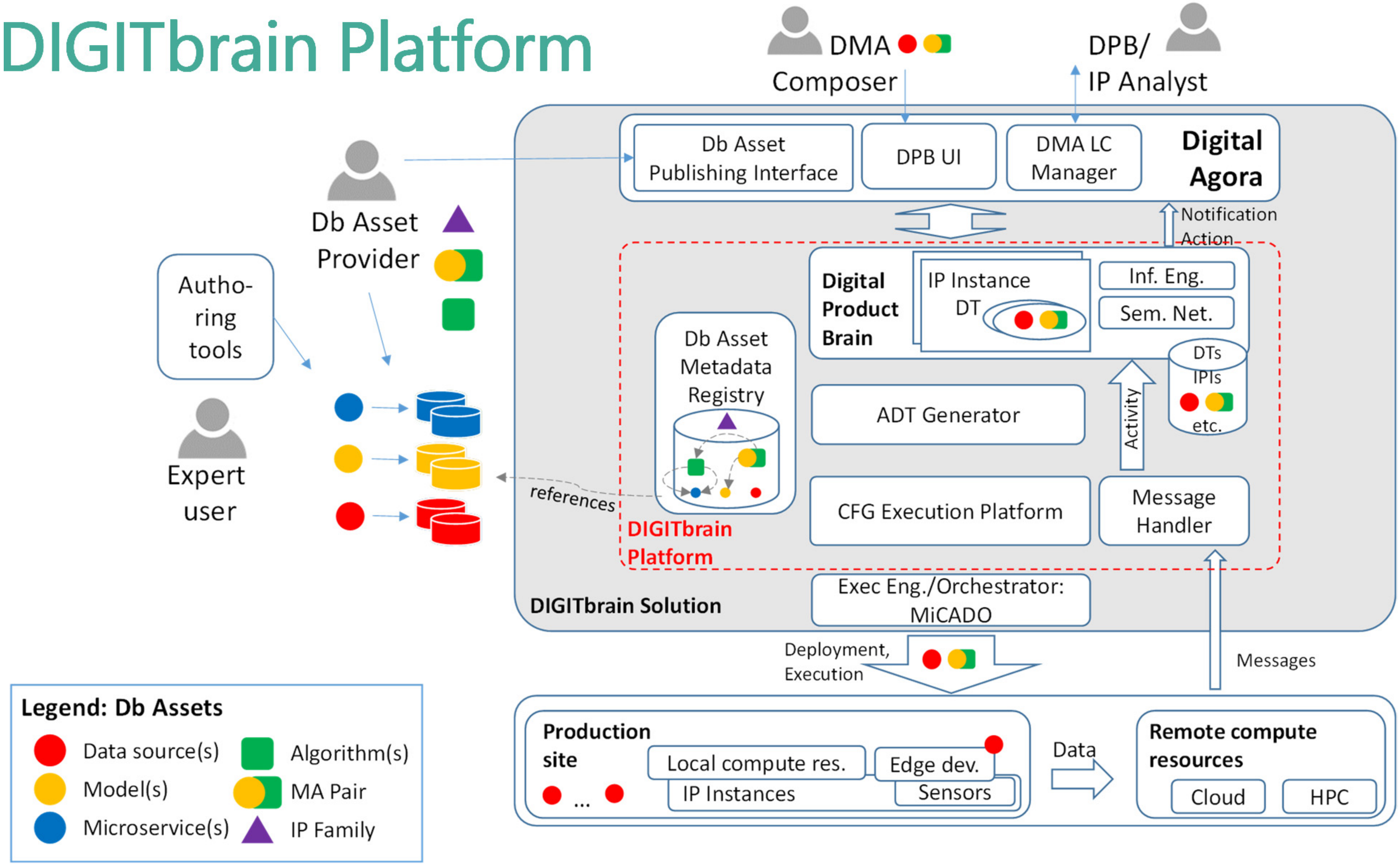
The DIGITbrain Platform



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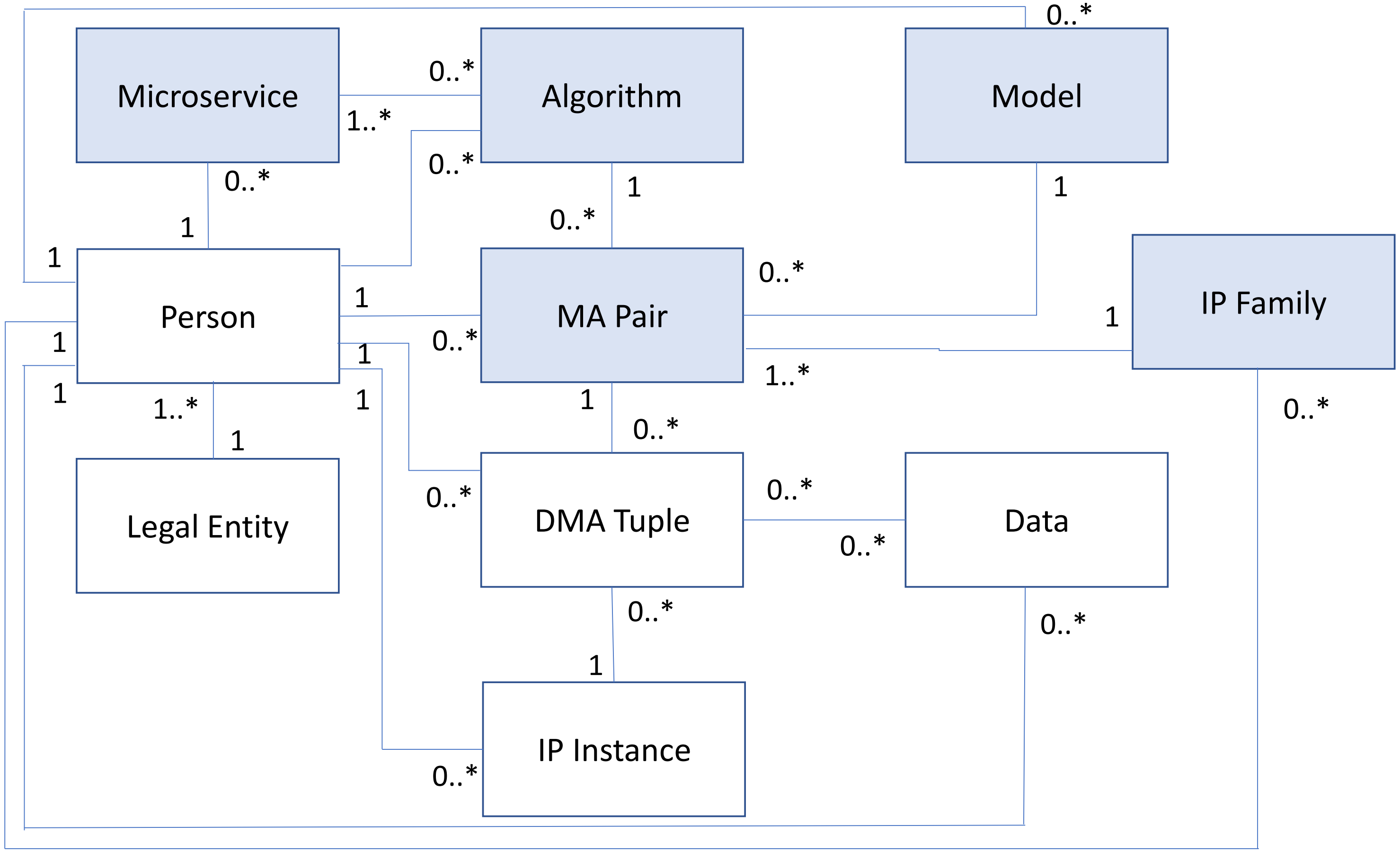
DIGITbrain Metadata



https://digitbrain.github.io/

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DIGITbrain Metadata

Microservice

Back to top

This page has been auto-generated based on an OpenAPI Specification
Most users will prefer this view which may include examples and additional info

Name	Type	Details
name	string character varying	description: human readable short, yet descriptive name of the Microservice.
version	string character varying	description: version as defined by the user.
description	string character varying	description: human readable short description of the Microservice's capabilities.
classification_schema	string public.classification_schema	enum: ['Simulation', 'ML', 'others'] description: fine-granular classification of the Microservice
type	string ARRAY	description: detailed type of the microservice, list of keywords
deployment_format	string public.deployment_format	enum: ['docker-compose', 'kubernetes-manifest'] description: identifier of the deployment environment required to deploy the Microservice's container
deployment_data	string json	description: JSON of docker-compose or kubernetes manifest required to run the container
configuration_data	string ARRAY	description: List of objects specifying configuration file(s) content required by the service

Algorithm

This page has been auto-generated based on an OpenAPI Specification
Most users will prefer this view which may include examples and additional info

Name	Type	Details
name	string character varying	description: a human-readable name to ease identification and discoverability for human users
description	string character varying	description: a short, human-readable description of the Algorithm to aid a human user in analysing the Algorithm's capabilities and its applicability to a certain problem
classification_schema	string public.classification_schema	enum: ['Simulation', 'ML', 'others'] description: the classification of the Algorithm, to describe the specialization area
type	string ARRAY	description: a detailed list of attributes to describe the Algorithm's field of application
version	string character varying	description: the version, as defined by the provider
list_of_microservices	string ARRAY	description: a list of Microservice Asset IDs, which are contained in the algorithm
deployment_mapping	string json	description: a mapping specifying which microservice should run on which host. By default each microservice is assigned a respective host, but this behaviour is not always ideal (eg. when two or more Microservices may need to run on the same host)

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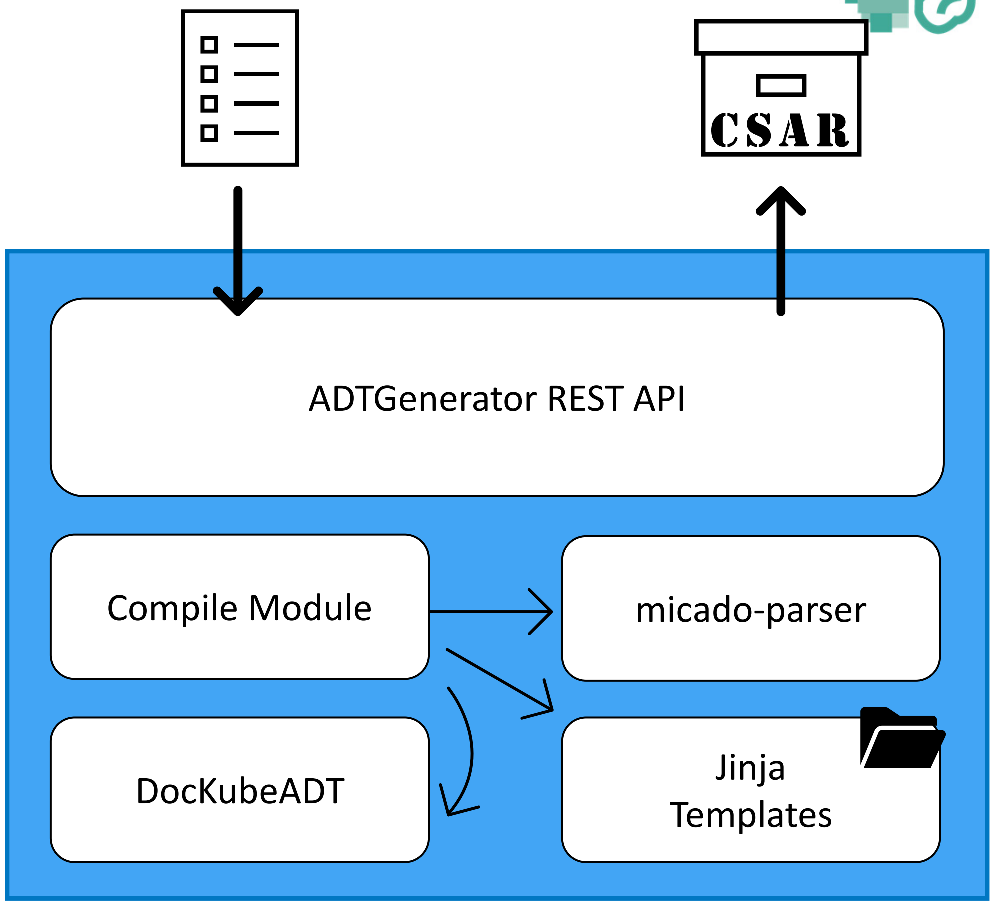
The ADT Generator

- Aim:
  - Translate metadata key/value pairs into a TOSCA application descriptor
  - Compose various metadata (Ms, D, M, A, MA, DMA) into a single descriptor file
- Challenge:
  - all created by different authors at different phases



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ADT generation in multiple steps

- 1. prepare
  - 1.1 save inputs
  - 1.2 validate inputs
- 2. generate deployments
  - 2.1 compile deployment
  - 2.2 save deployment
- 3. generate algorithm
  - 3.1 compile algorithm
  - 3.2 save algorithm
- 4. generate microservices
  - 4.1 substitute data asset references
  - 4.2 substitute model asset references
  - 4.3 checking unresolved references
  - 4.4 compile microservice
  - 4.5 save microservice
- 5. pack
  - 5.1 insert micado type imports
  - 5.2 create csar
  - 5.3 validate csar
- 6. store
  - 6.1 uplodad to s3

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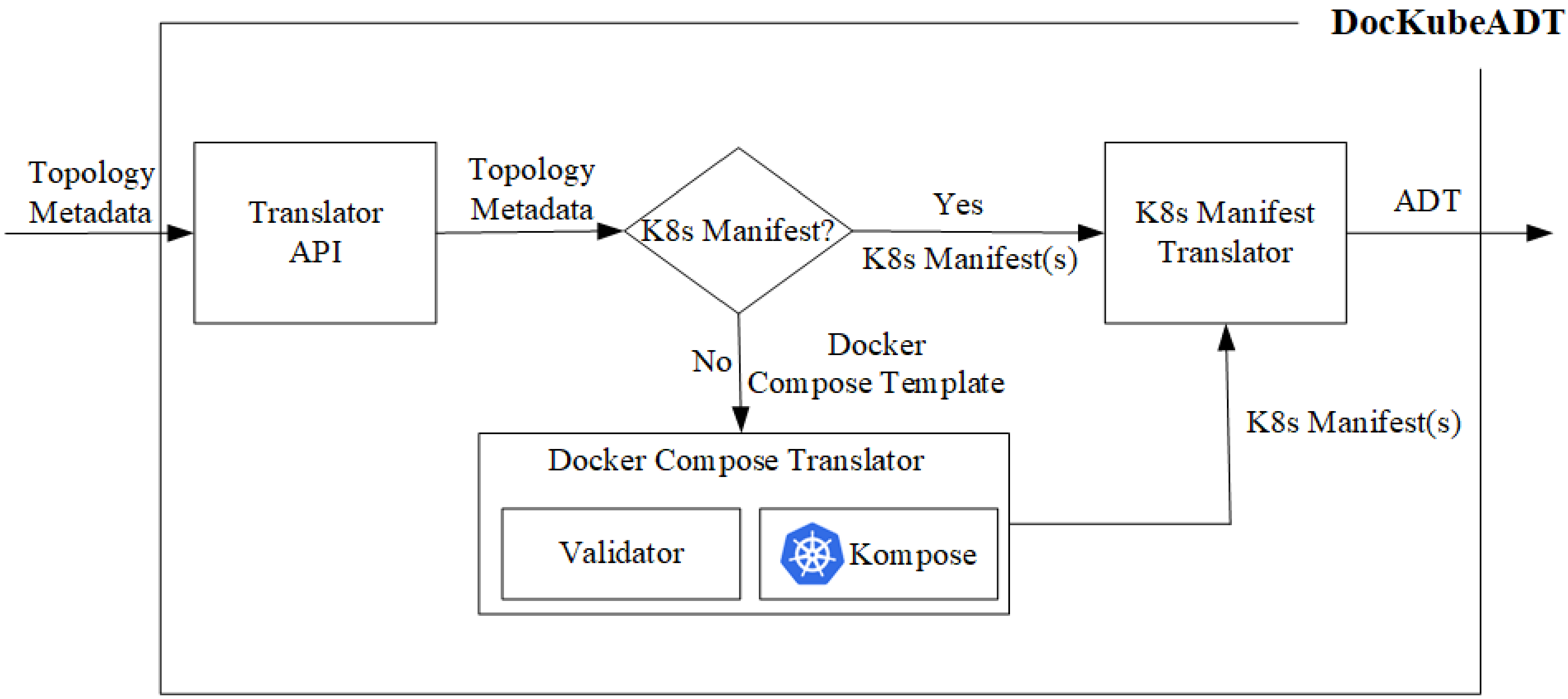
DocubeADT



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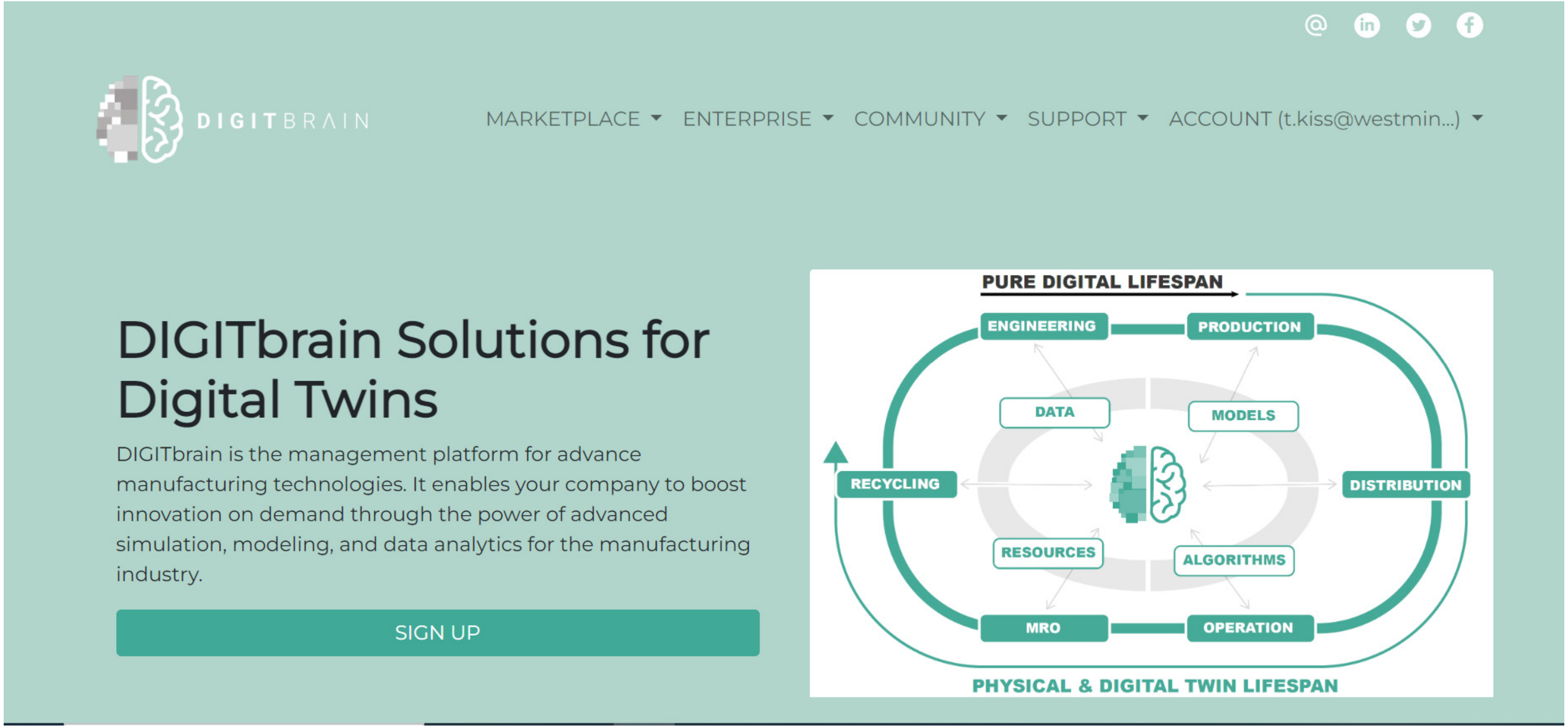
How does it all work?



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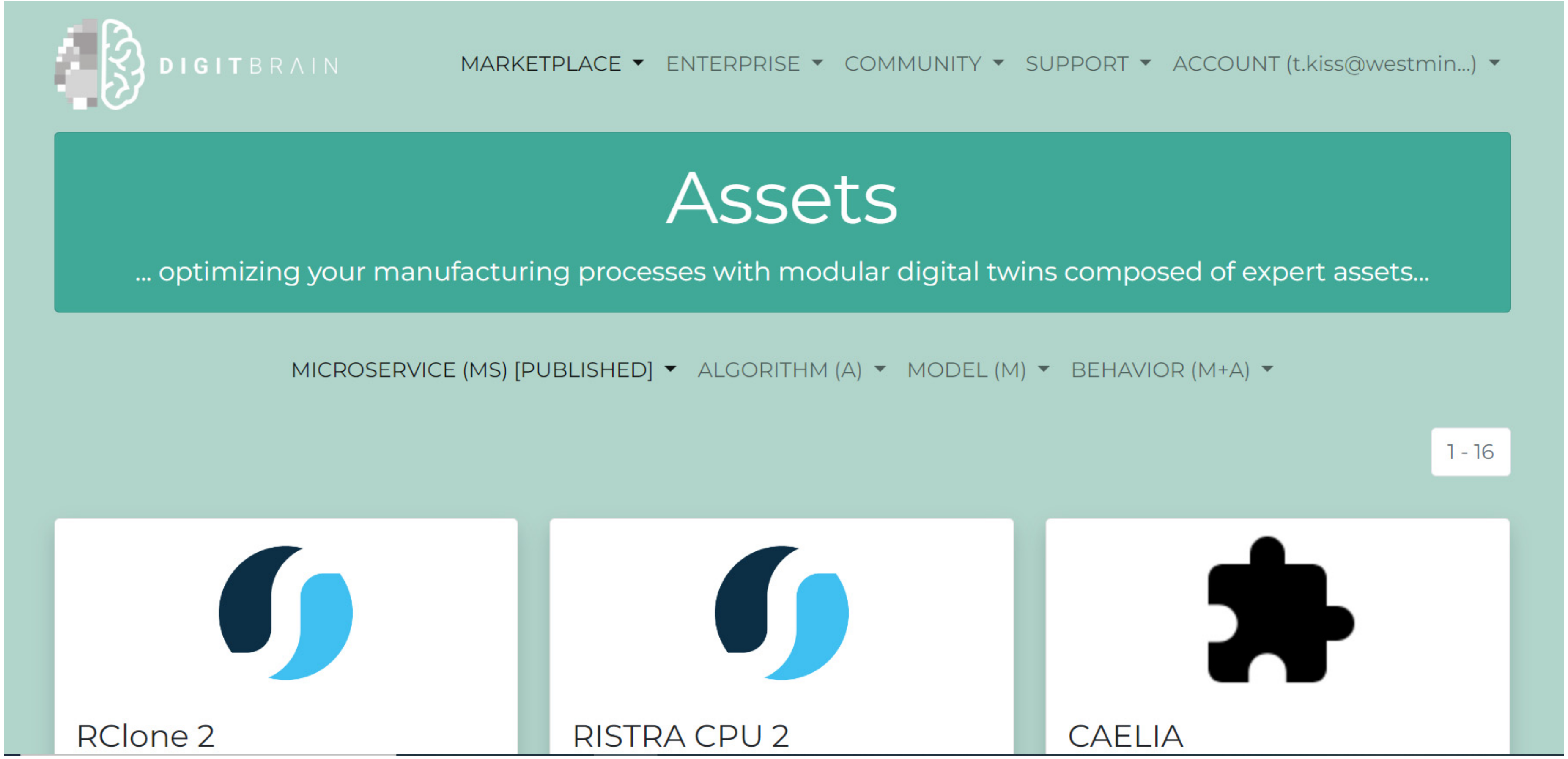
Publish assets, build and execute DMA tuples



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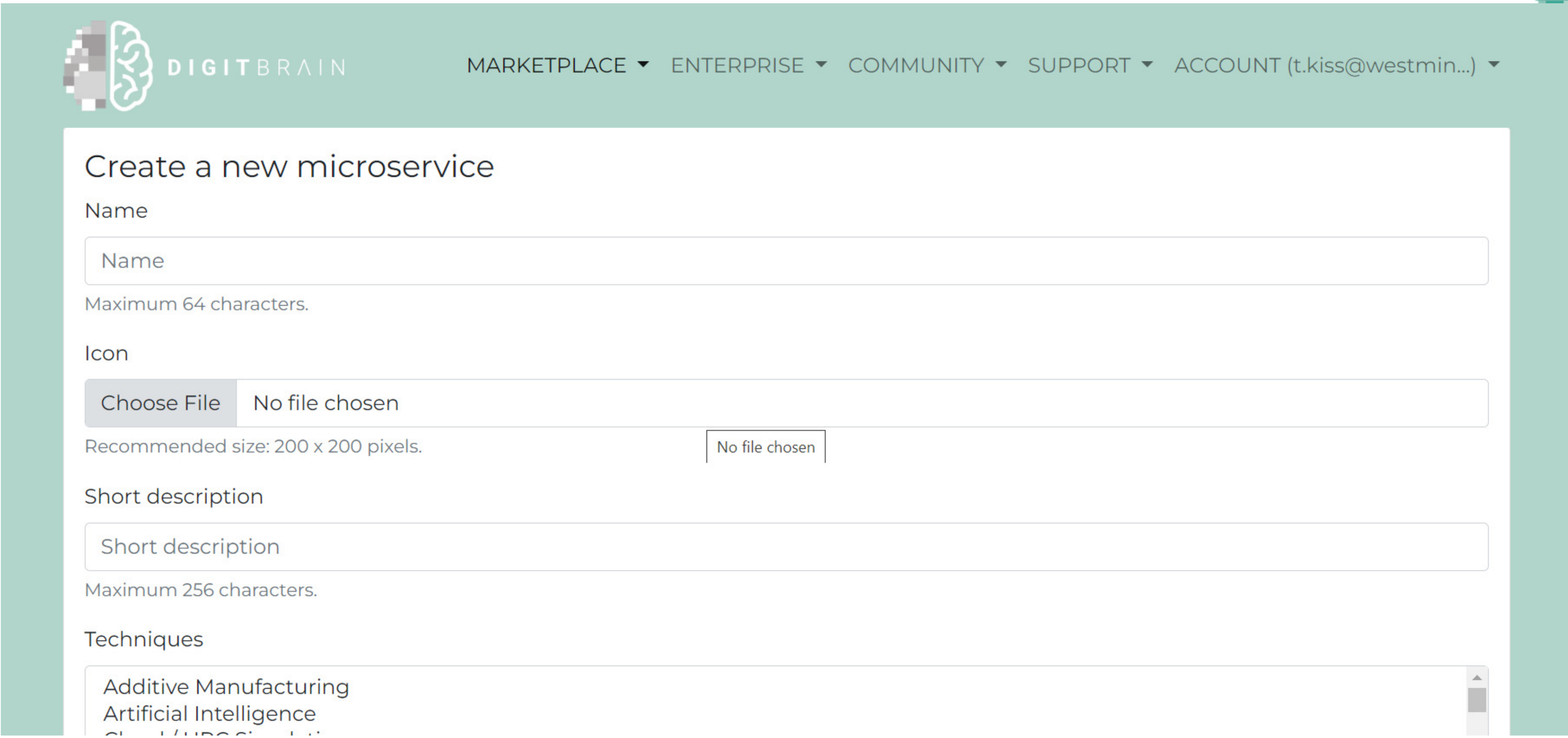

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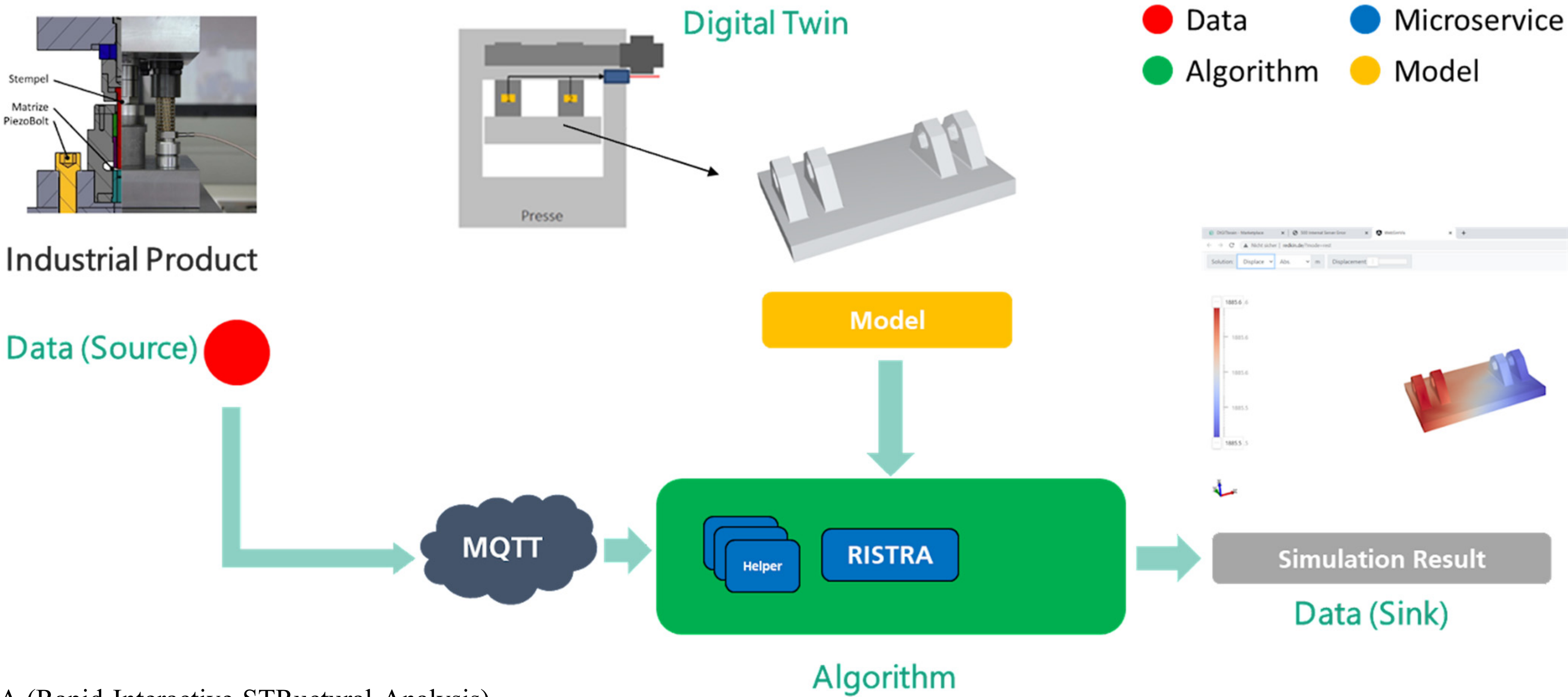
Example: Digital Twin of a Punching Machine



RISTRA (Rapid Interactive STRuctural Analysis),
a software library for fast structural analysis.

Example provided Fraunhofer IGD – Andre Stork, Daniel Weber, Johannes Mueller-Roemer, Lars Lotter, Maxim Redkin

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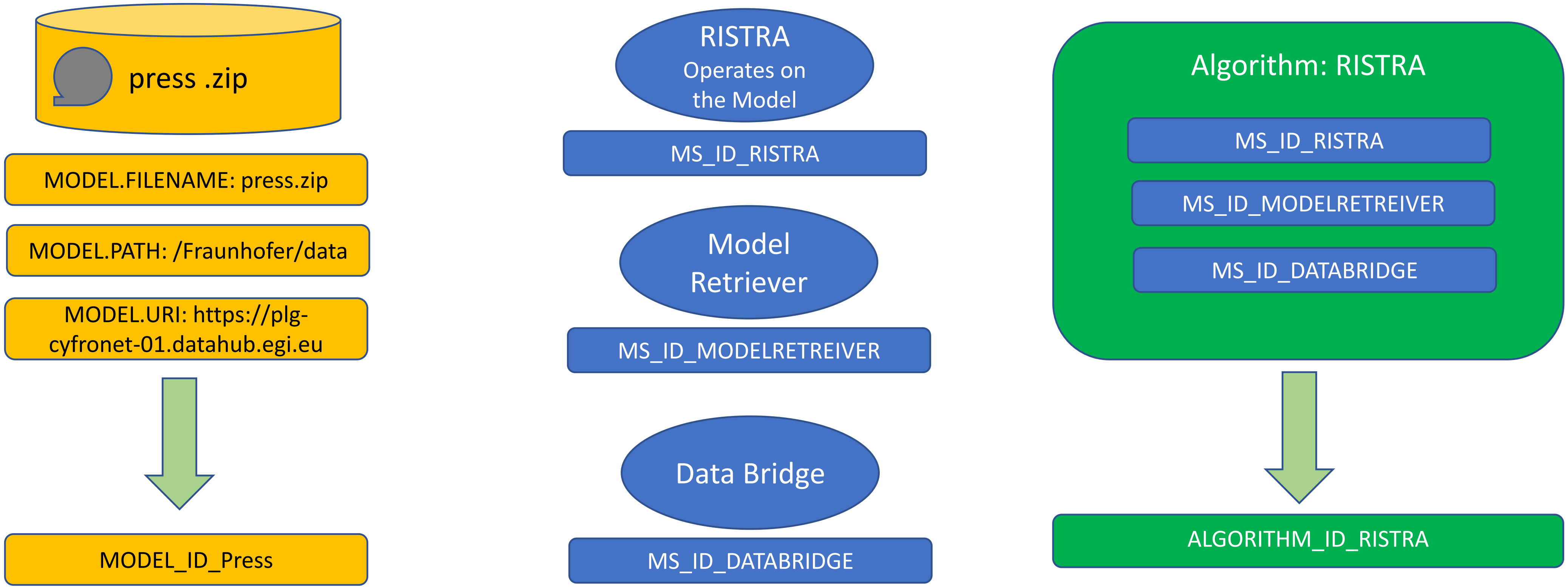
How to build the DMA Tuple?

Model: Created with RISTRA using a CAD model

Microservices: Core and additional functionality

Algorithm: Includes three Microservices



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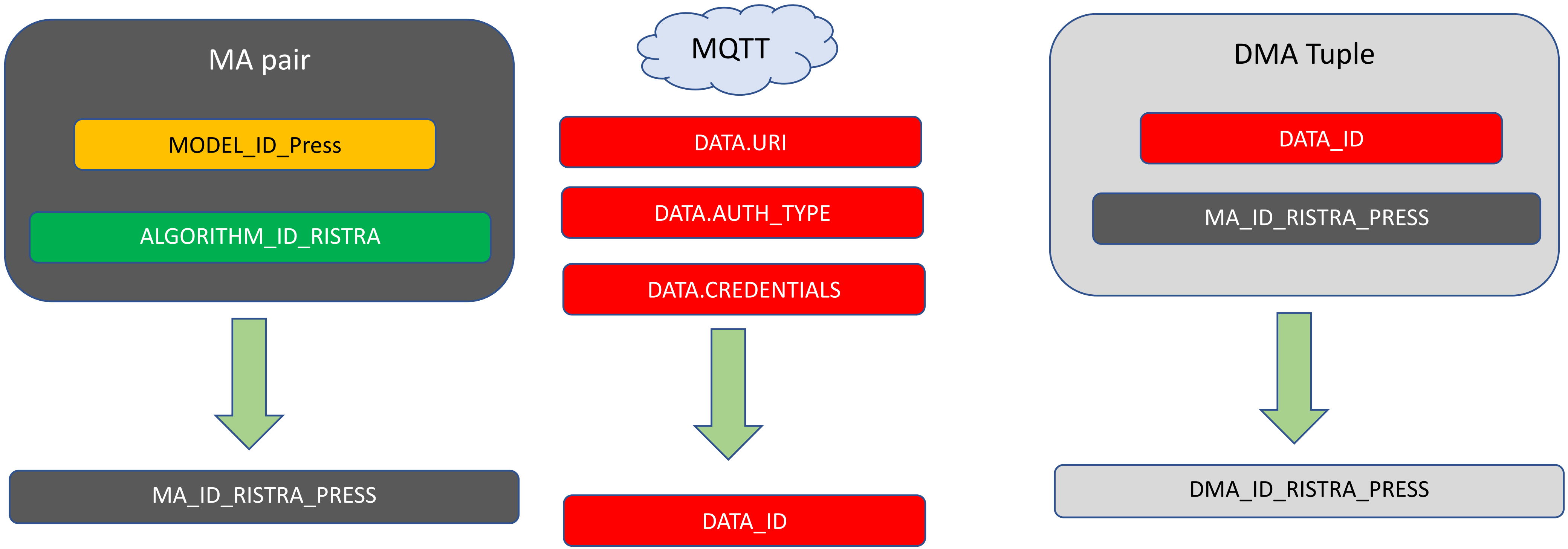
How to build the DMA Tuple?

MA Pair: Describes the behaviour of an IP Family

Data source: From IoT sensors via MQTT

DMA Tuple: The executable Digital Twin



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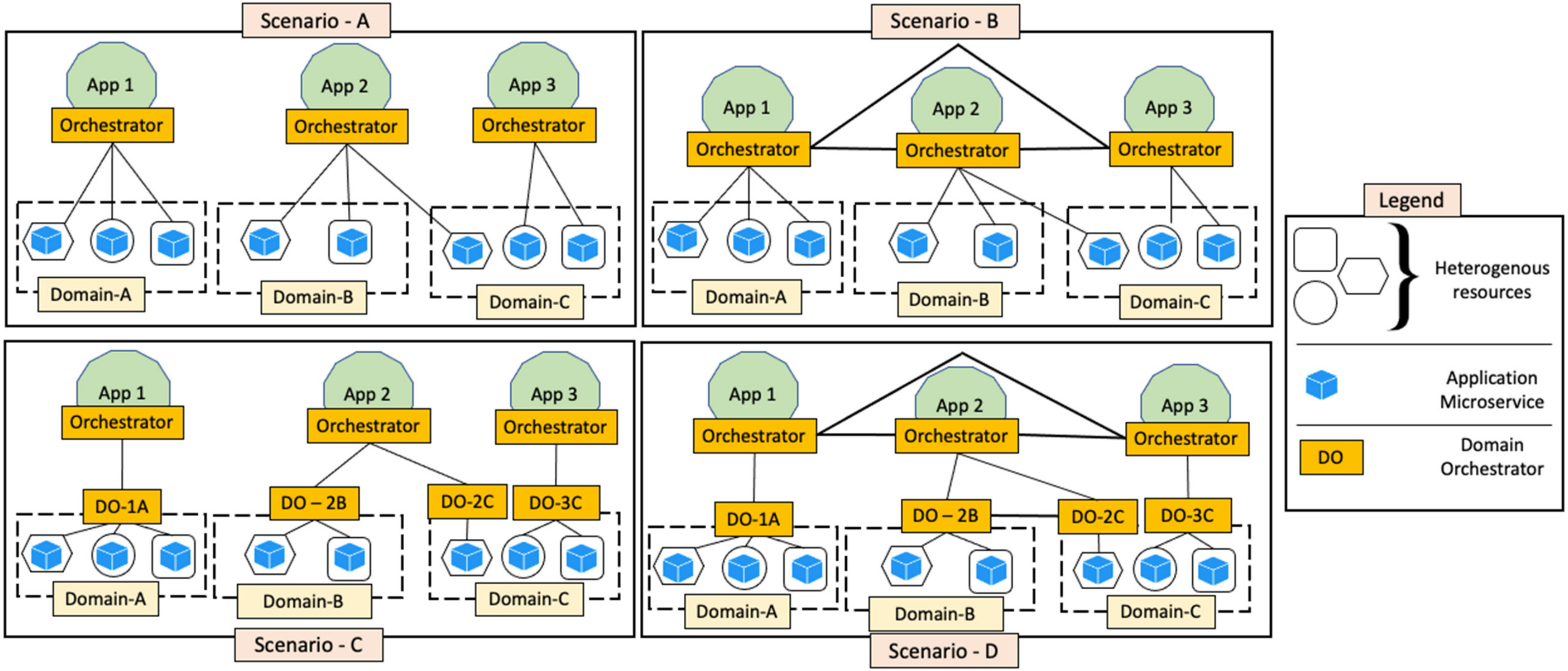
How to execute the DMA Tuple?

- Once DMA Tuple is built ADT generator can create TOSCA ADT for execution
- Copy of MiCADO is deployed by the platform
- ADT is passed to MiCADO to execute
- Resources are allocated based on ADT - RISTRA core simulation executes on edge

DIGITbrain has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952071

Where to go next? – Decentralised orchestration



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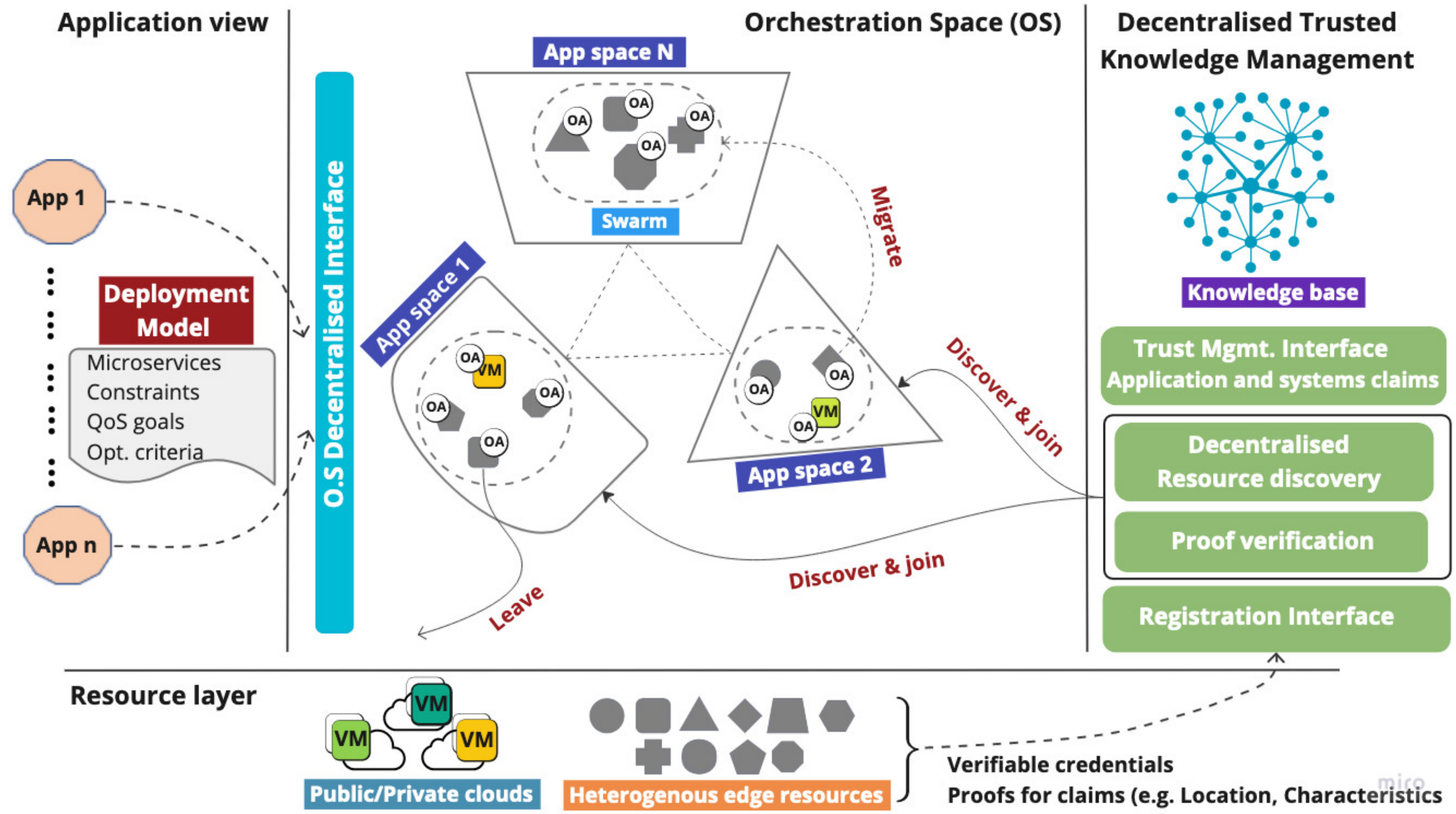
Where to go next? - AI-Driven Swarm-based orchestration



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The current CPC team behind all of this

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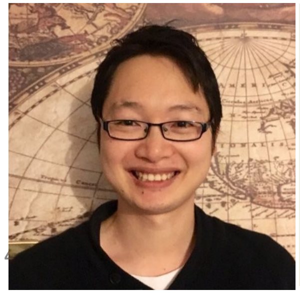

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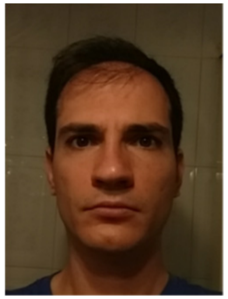

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Thank you for your attention!

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