



# nephele

An open-source IoT software stack and meta-orchestration platform  
for the computing continuum

Research Meets Open Source - Breaking barriers with Eclipse Thingweb and NEPHELE  
Eclipse Foundation Event

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# Main Challenges for the Computing Continuum



- need for **convergence of IoT technologies** based on novel architectural approaches, able to guarantee continuous and seamless openness and interoperability of the existing and emerging solutions.
- need for the provision of an **integrated meta-orchestration environment for hyper-distributed applications**, where a **synergy** between cloud and edge computing orchestration platforms takes place



Eclipse Foundation, From DevOps to EdgeOps: A Vision for Edge Computing, White paper, 2021

# Main Innovations in NEPHELE



- an **IoT and edge computing software stack** for leveraging virtualization of IoT devices at the edge part of the infrastructure and supporting openness and interoperability aspects in a device-independent way.
- a **synergetic meta-orchestration framework** for managing the coordination between cloud and edge computing orchestration platforms, through high-level scheduling supervision and definition, based on the adoption of a “system of systems” approach.

*Implementations for both innovations are made available as **open-source** under the **GitLab repository of Eclipse Research Labs**.*



# NEPHELE Open Source Ecosystem



Eclipse Research Labs GitLab

## Goals:

- prepare NEPHELE open-source results for up-take by developers (open calls, OS communities, Meta-OS cluster, etc.) by implementing open-source best practices.
- create and maintain an open-source community (sustainability of the produced software artifacts).
- close interaction with standardization initiatives and working groups.
- examine exploitation pathways and increase impact.

Eclipse Research Labs / NEPHELE Project

## NEPHELE Project

A lightweight software stack and synergetic meta-orchestration framework for the next generation compute continuum.

Recent activity Last 30 days: 6 Merge requests created, 0 Issues created, 0 Members added

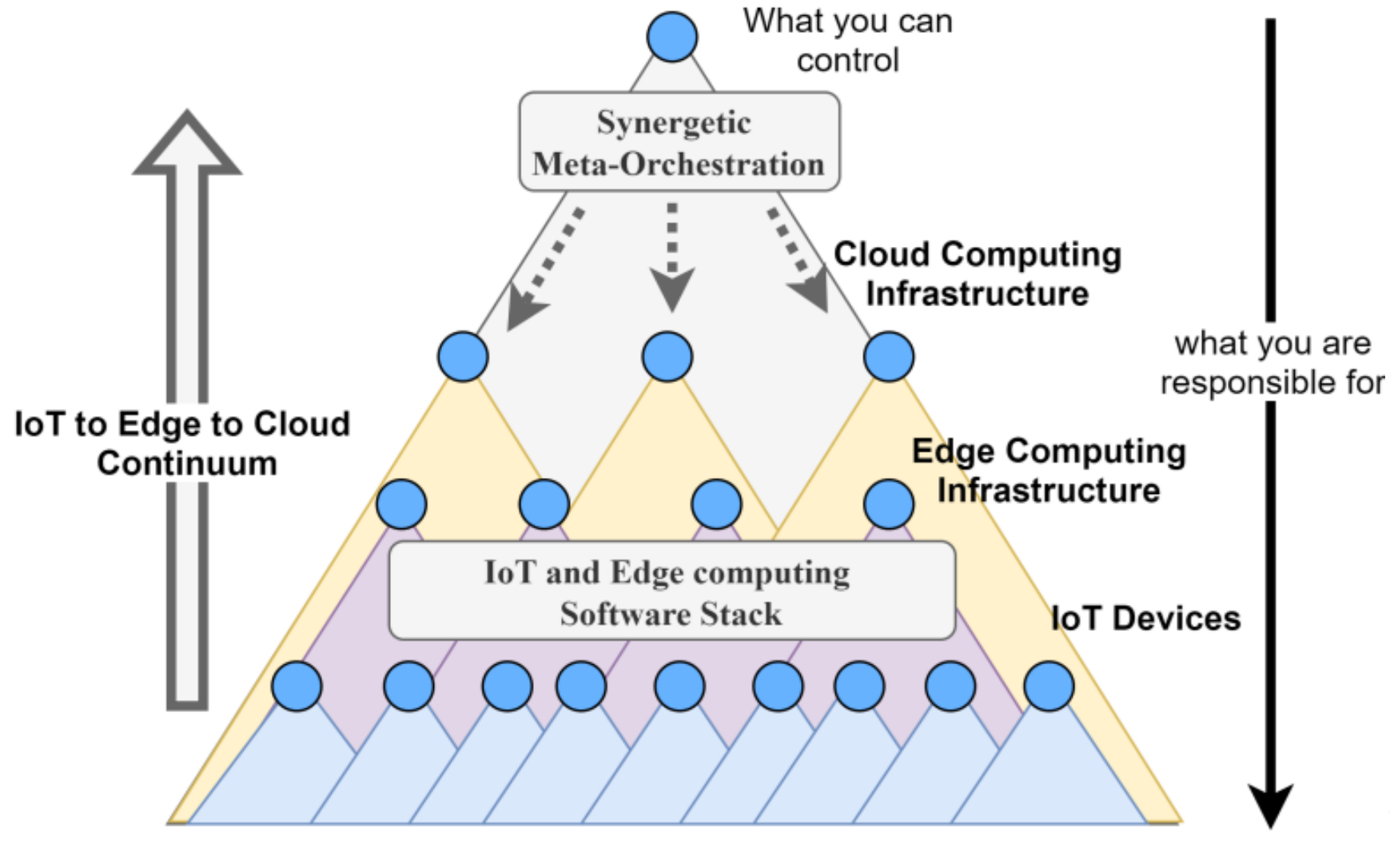
Subgroups and projects

	Name	Stars	Time ago
N	Nephele-Dashboard	0	14 hours ago
N	nephele-HDAR	0	2 weeks ago
N	Nephele-Integration	0	3 months ago
S	SMO	0	1 day ago
V	VO-Discovery-Server	0	1 month ago
V	VO-LwM2M	0	3 weeks ago
V	VO-SDN	0	2 weeks ago
V	VO-Security	0	5 days ago
V	VO-TSN	0	2 weeks ago
V	VO-WoT	1	4 days ago

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<https://gitlab.eclipse.org/eclipse-research-labs/nephele-project>

# System of Systems Approach





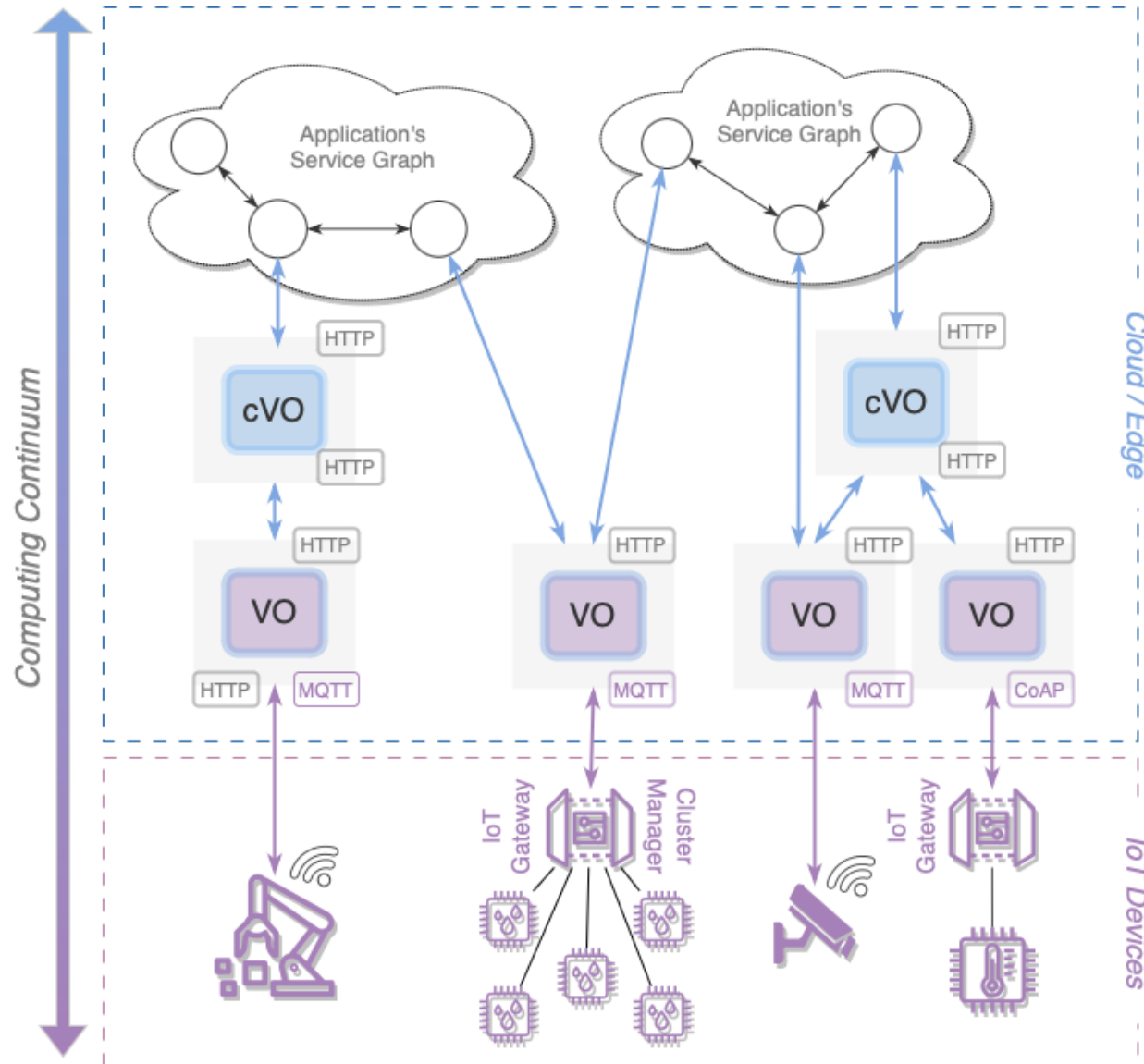
# Virtual Object (VO) Definitions



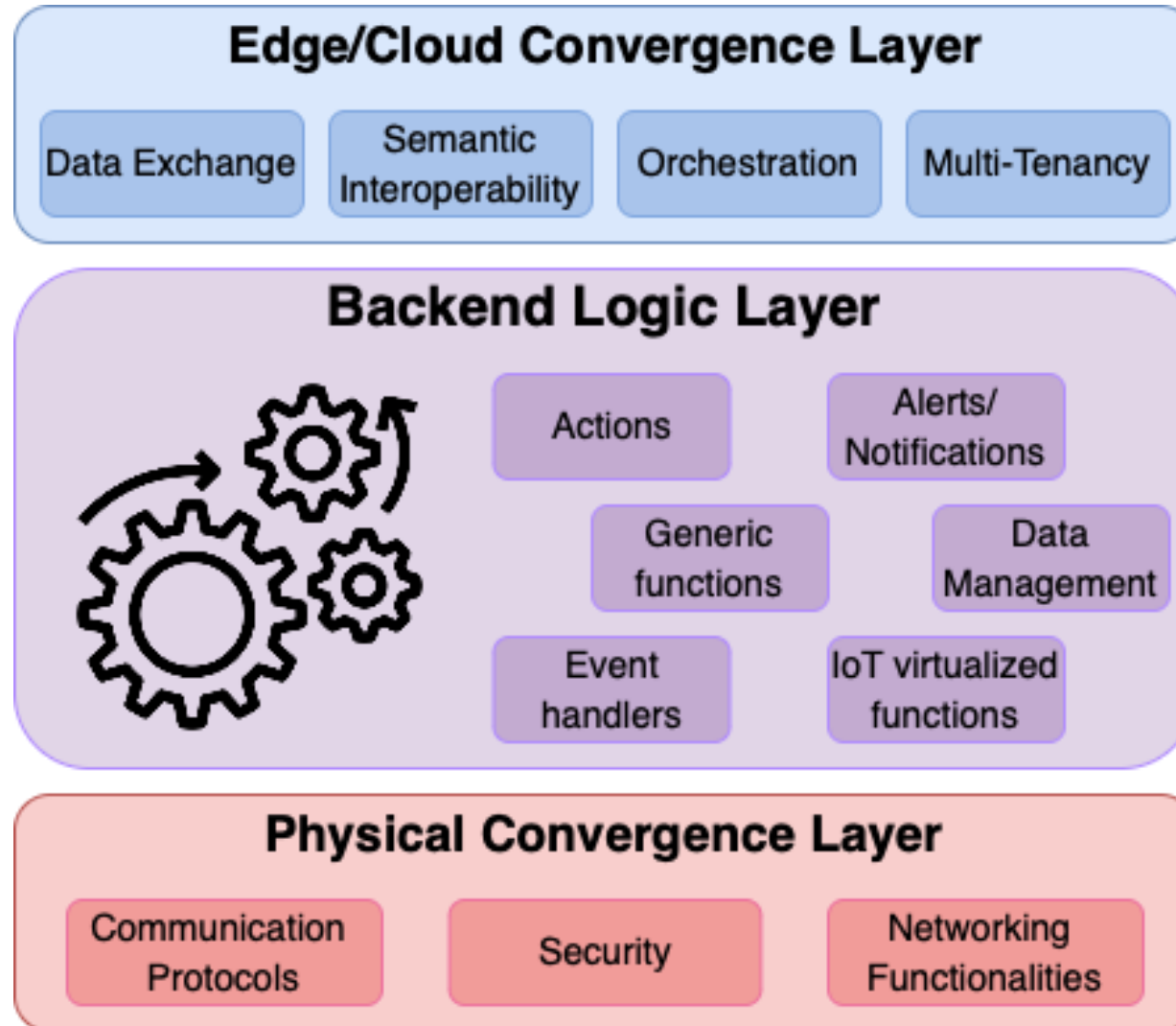
- A Virtual Object (VO) is considered as a virtual counterpart of a physical device on the Internet of Things domain
  - set of abstractions for managing any type of IoT device through a virtualized instance;
  - augments the supported functionalities through the development of a multilayer software stack, called **Virtual Object Stack (VOStack)**.
- A Composite Virtual Object (cVO) is a software entity that can manage the information coming from one or multiple VOs and provide advanced functionalities.
  - a cVO is connected with multiple VOs that manage IoT devices of several types;
  - a cVO enhances the capabilities of the VO through the provision of application-oriented functionalities.



# VOs, Composite VOs and Application Graph

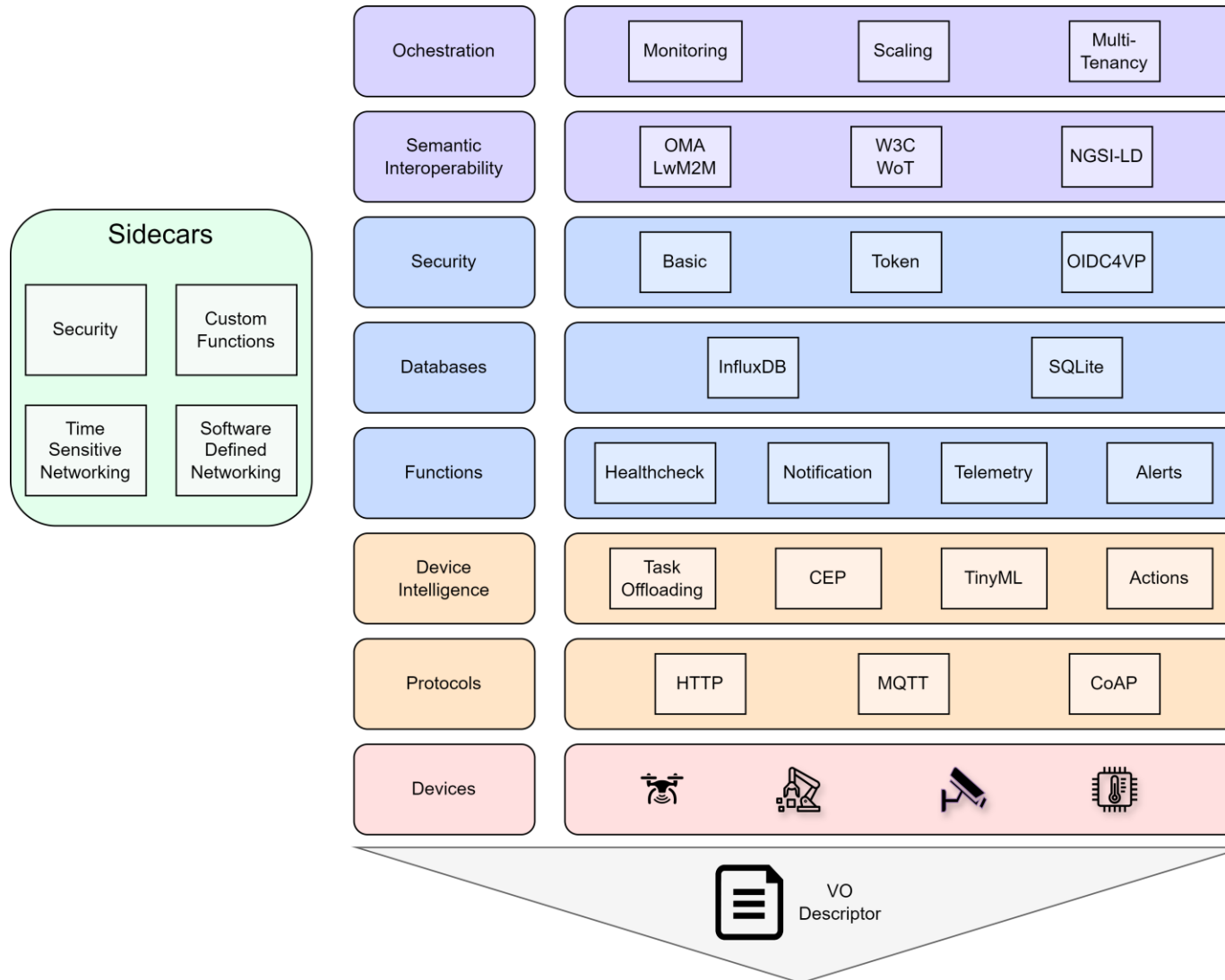


# Virtual Object Stack (VOStack) Layers

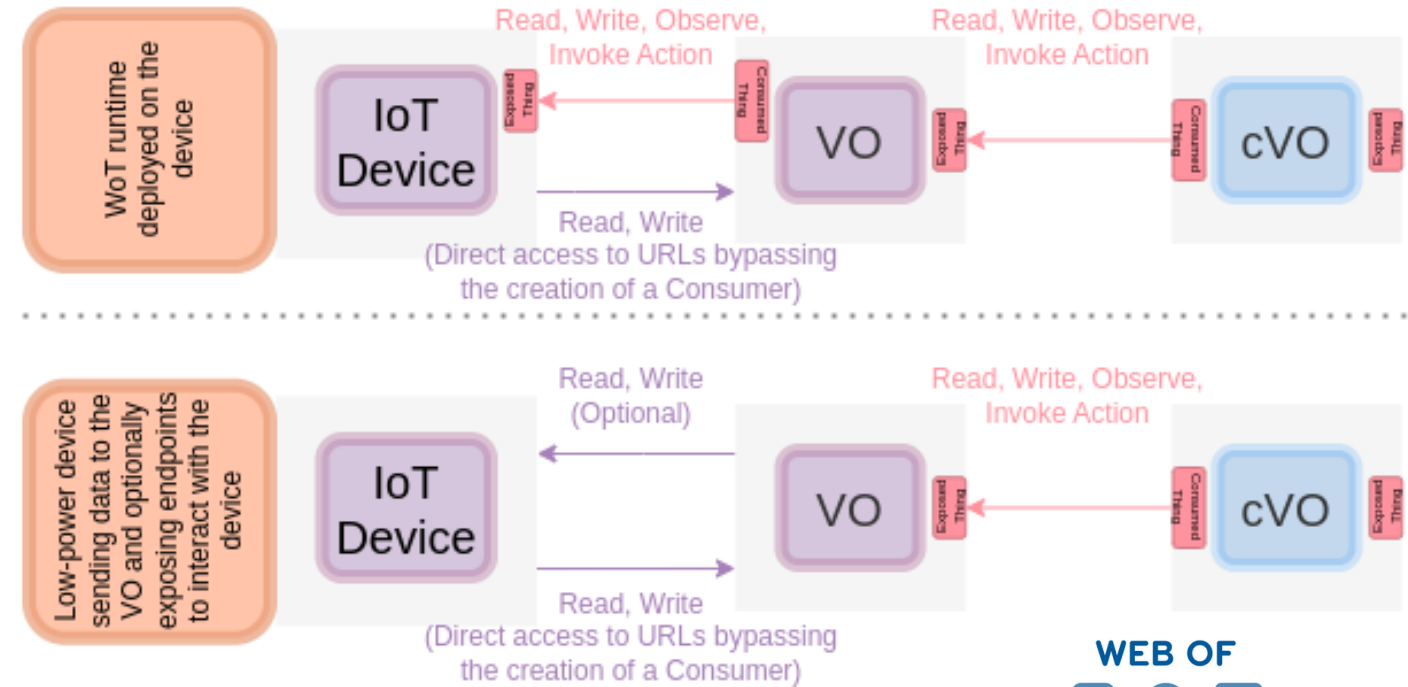
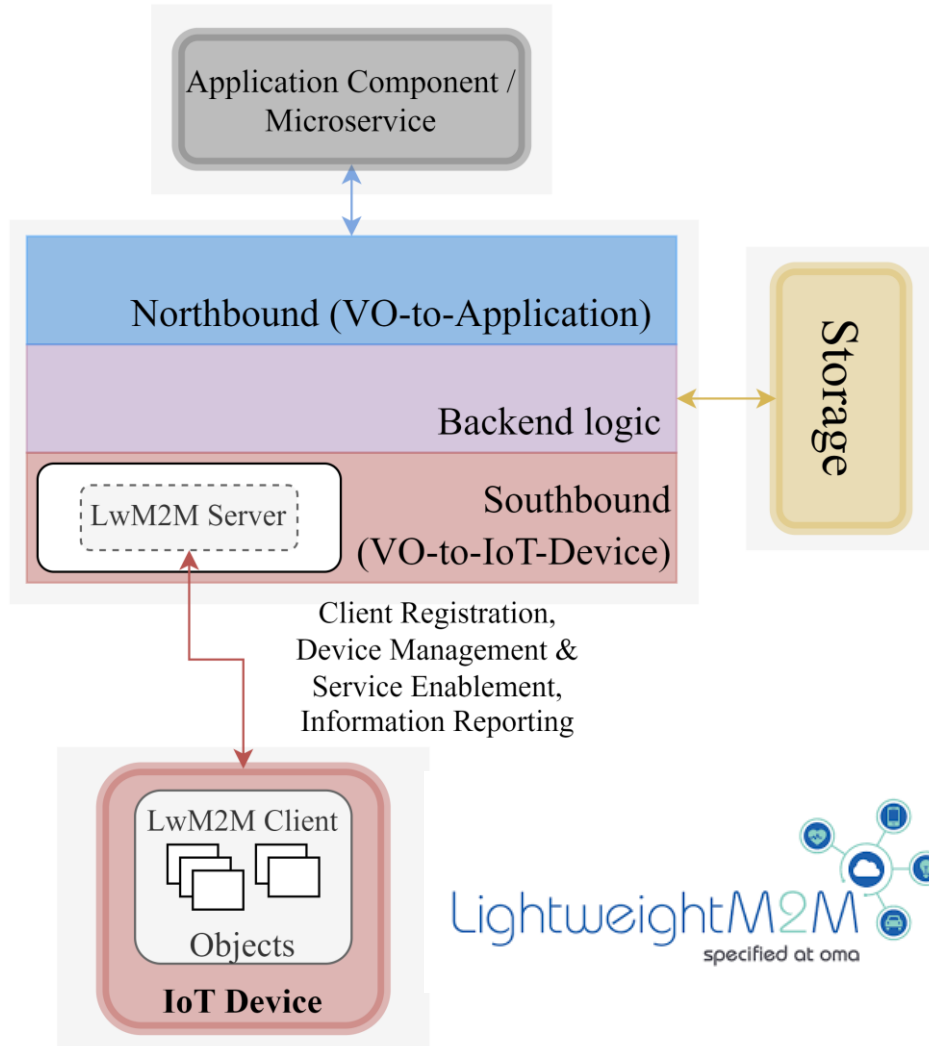




# Detailed view of VOSTack



# VOSTack implementation



# VOStack implementation in W3C WoT Developer Resources



Standards · Participate · Membership

W3C™

Groups- Activities- Developers Documentation Videos About-

## Developer Resources

There are various resources available to build Web of Things applications. These are libraries, ready-to-use software, services or SDKs, which can be used in different stages of development or for development needs and are grouped below.



TD Tooling



WoT Development Tools

<https://netmode.gitlab.io/vo-wot/>



Runtimes for TD Exposers



Runtimes for TD Consumers



TD Directories



WoT Software and Middleware



Other Tooling



Online Things

<https://www.w3.org/WoT/developers/>

## WoT Software and Middleware

Ready to use software applications that can be deployed in order to provide a certain functionality in a system, such as gateway and proxying, simulation, testing services.

- [sayWoT!](#) - Industrial-grade implementation that allows integration of devices into Siemens software products.
- [Web of Things Test Bench](#) - CLI based tool that tests a WoT Thing by executing interactions automatically, based on its TD.
- [WebThings Gateway](#) - An open source Web of Things gateway for smart buildings, which bridges a wide range of IoT protocols to the Web of Things.
- [UA Edge Translator](#) - An industrial connectivity edge reference application translating from proprietary protocols to OPC UA leveraging the W3C Web of Things (WoT) Thing Descriptions.
- [VO-WoT](#) - A Python-based stack that allows developing WoT Things with additional functionalities, called Virtual Objects (VOs). A documentation website is available [here](#).
- [Shadow Thing](#) - CLI based tool for creating and deploying a Thing based on its TD for simulation, proxy or protocol translation purposes.

<https://netmode.gitlab.io/vo-wot/>

# Open Call - Overview of the functionalities from the selected projects



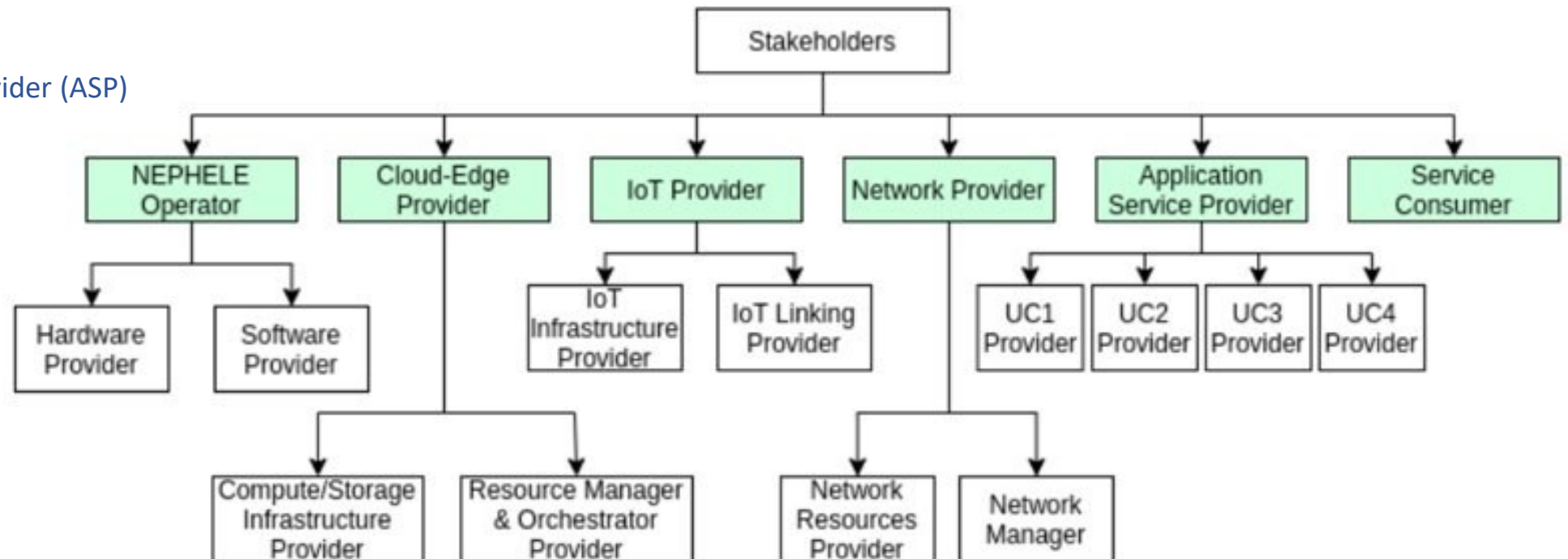
- Development of VOs/cVOs/DTs to:
  - Support haptic communications (gloves as DT of the human hand)
  - Virtual human representation based on wearable devices
  - Manage heterogeneous devices (e.g., charging stations, access control devices) in the Electric Vehicle Parking/Charging Business
  - Optimize irrigation procedures (data coming from sensors and weather services)
  - Sustainable living comfort by optimizing energy consumption and maximizing indoor comfort
  - Retail security based on fixed IoT sensors and an autonomous LiDAR-equipped wheeled robot
- Extensions in VOStack
  - Semantic interoperability mechanisms
  - Virtual object factory to manage multiple VOs
- New vertical areas: Haptic communications and wearables, Electric vehicles, Agriculture, Retail Security

# Stakeholders



Stakeholders include individual or groups within the system

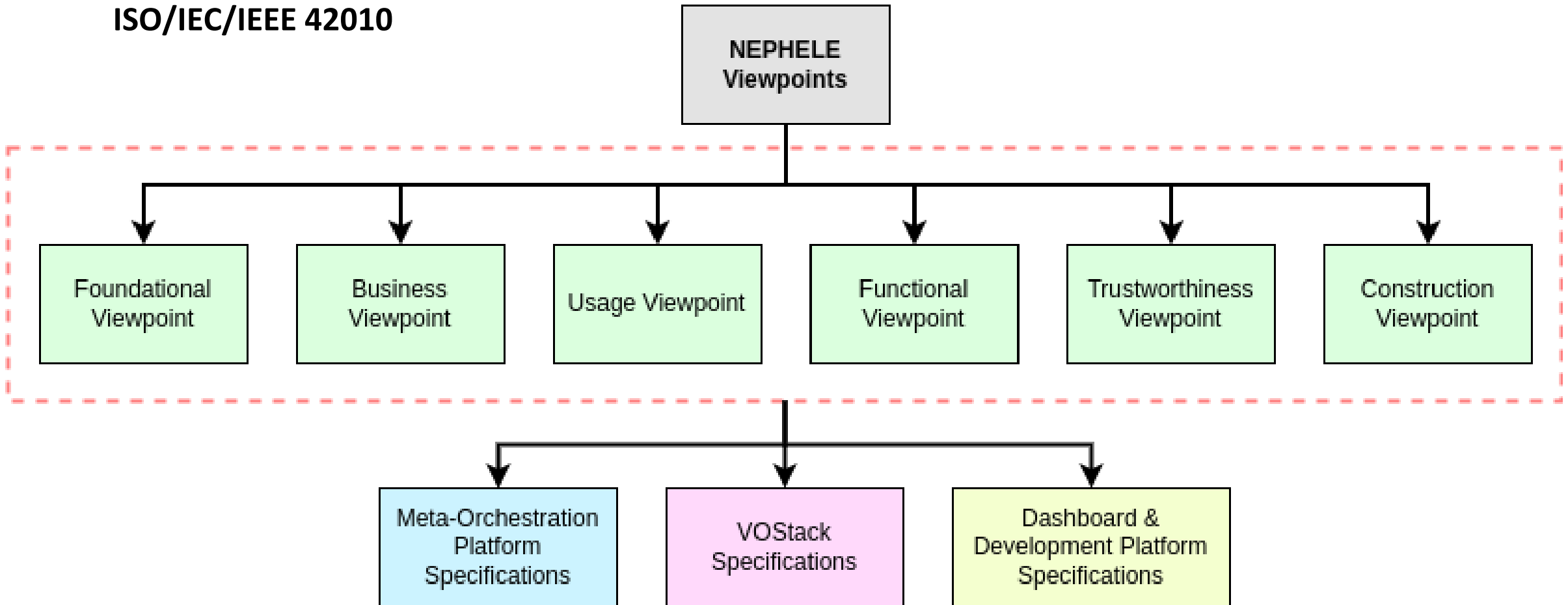
- NEPHELE Operator:
- Cloud-Edge Provider (CEP)
- IoT Provider
- Network Provider
- Application Service Provider (ASP)
- Service Consumer



# Viewpoints & Specifications

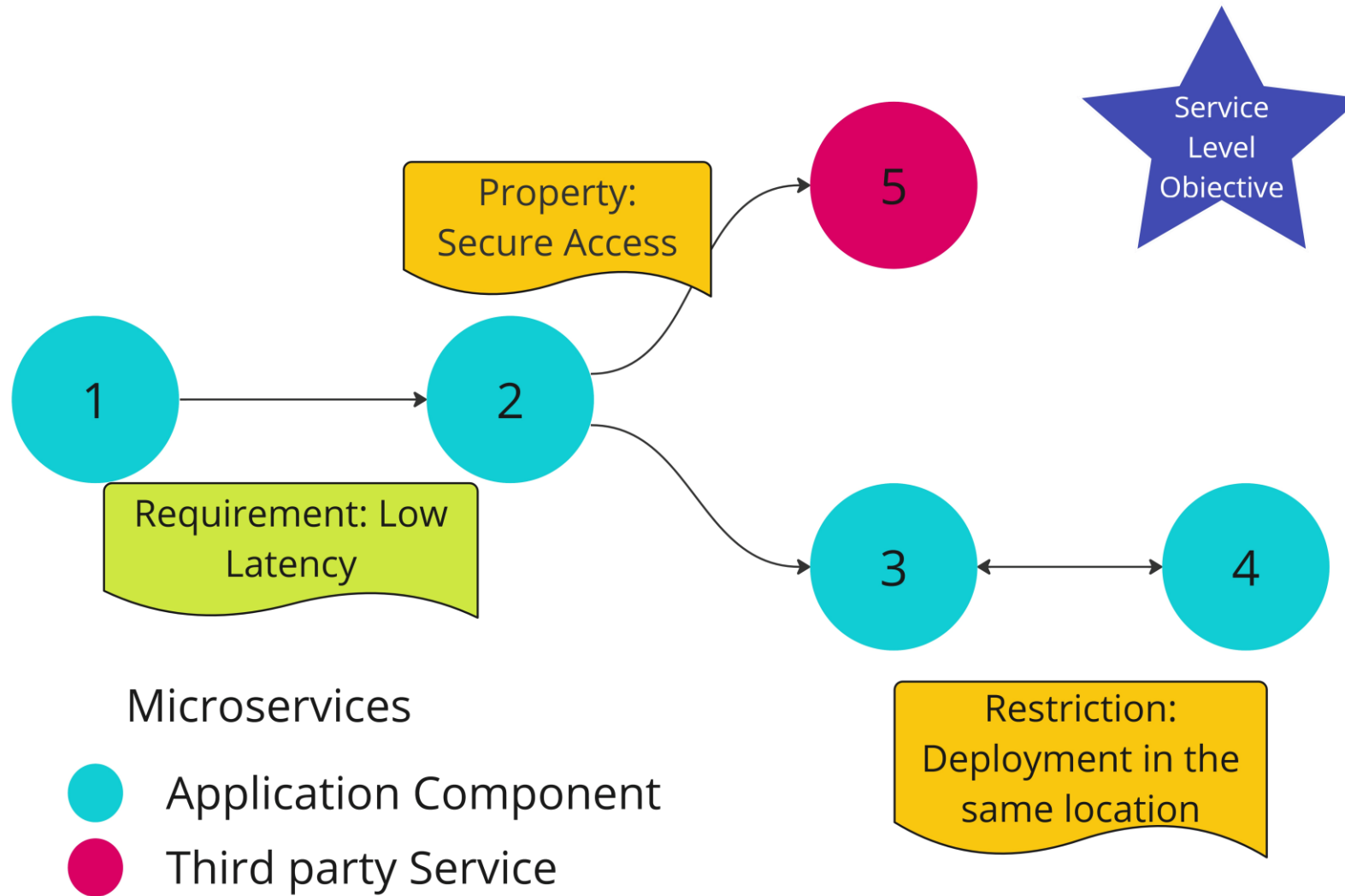


ISO/IEC/IEEE 42010

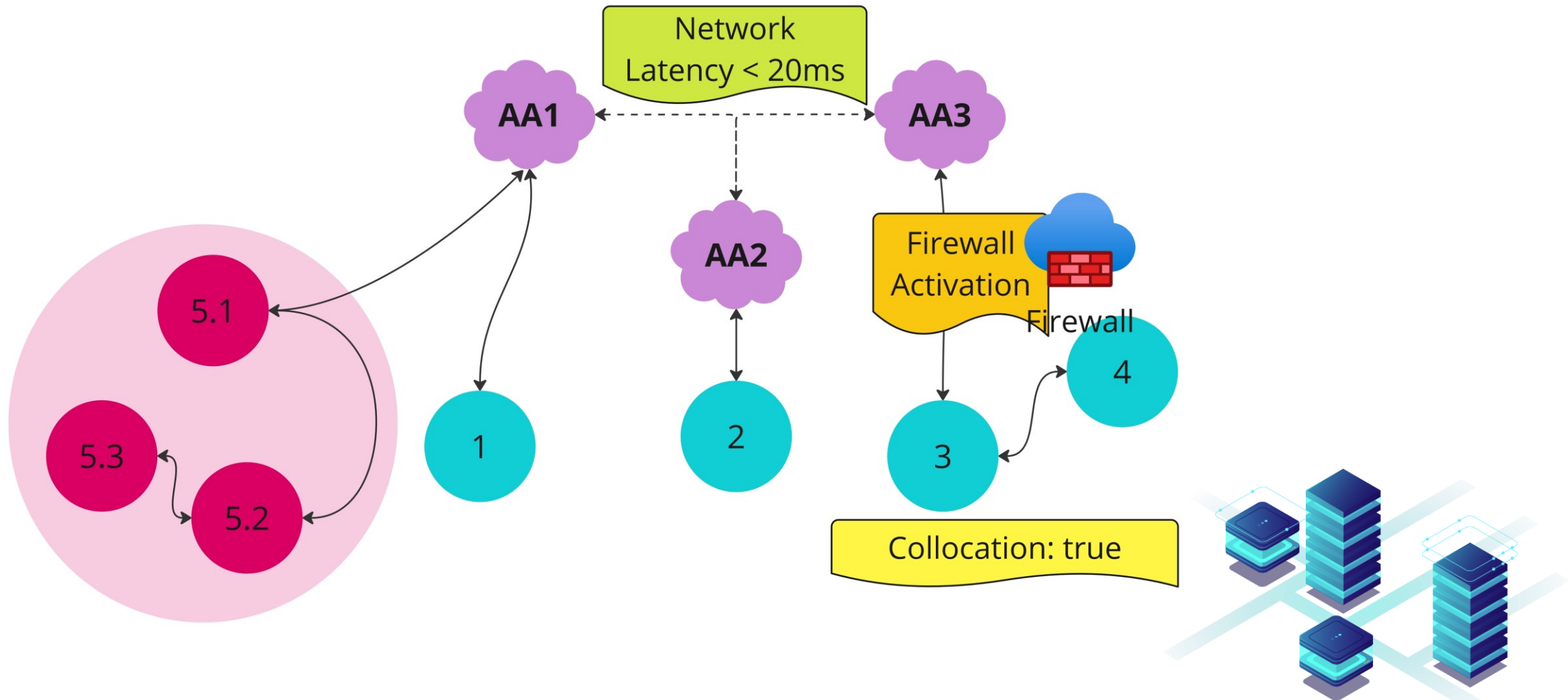




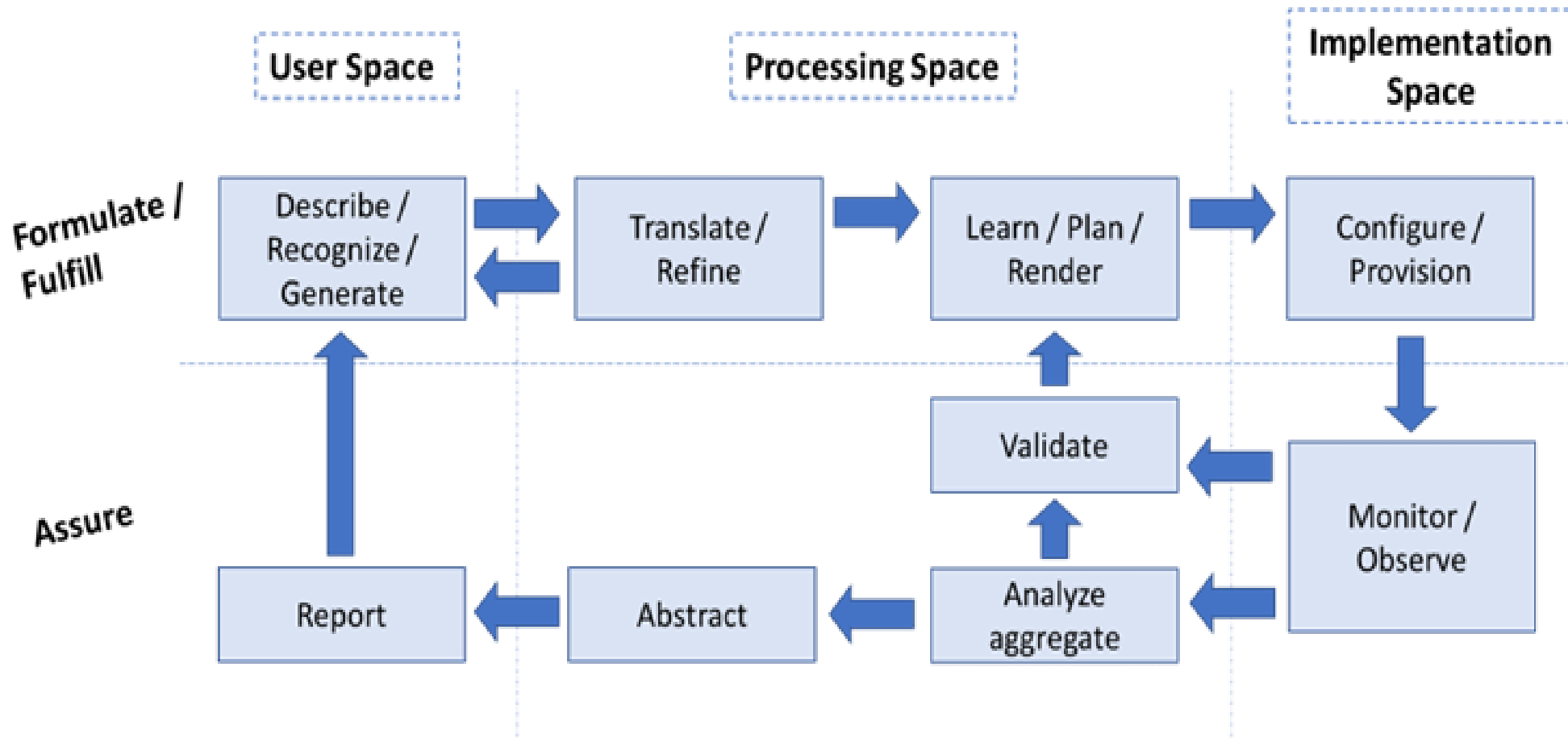
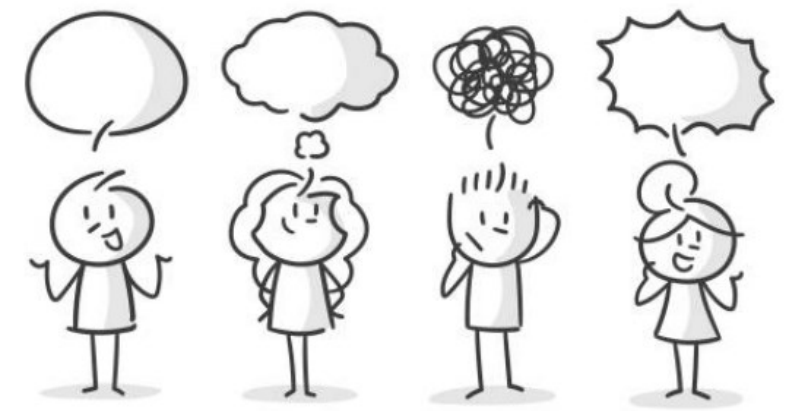
# Application Graph



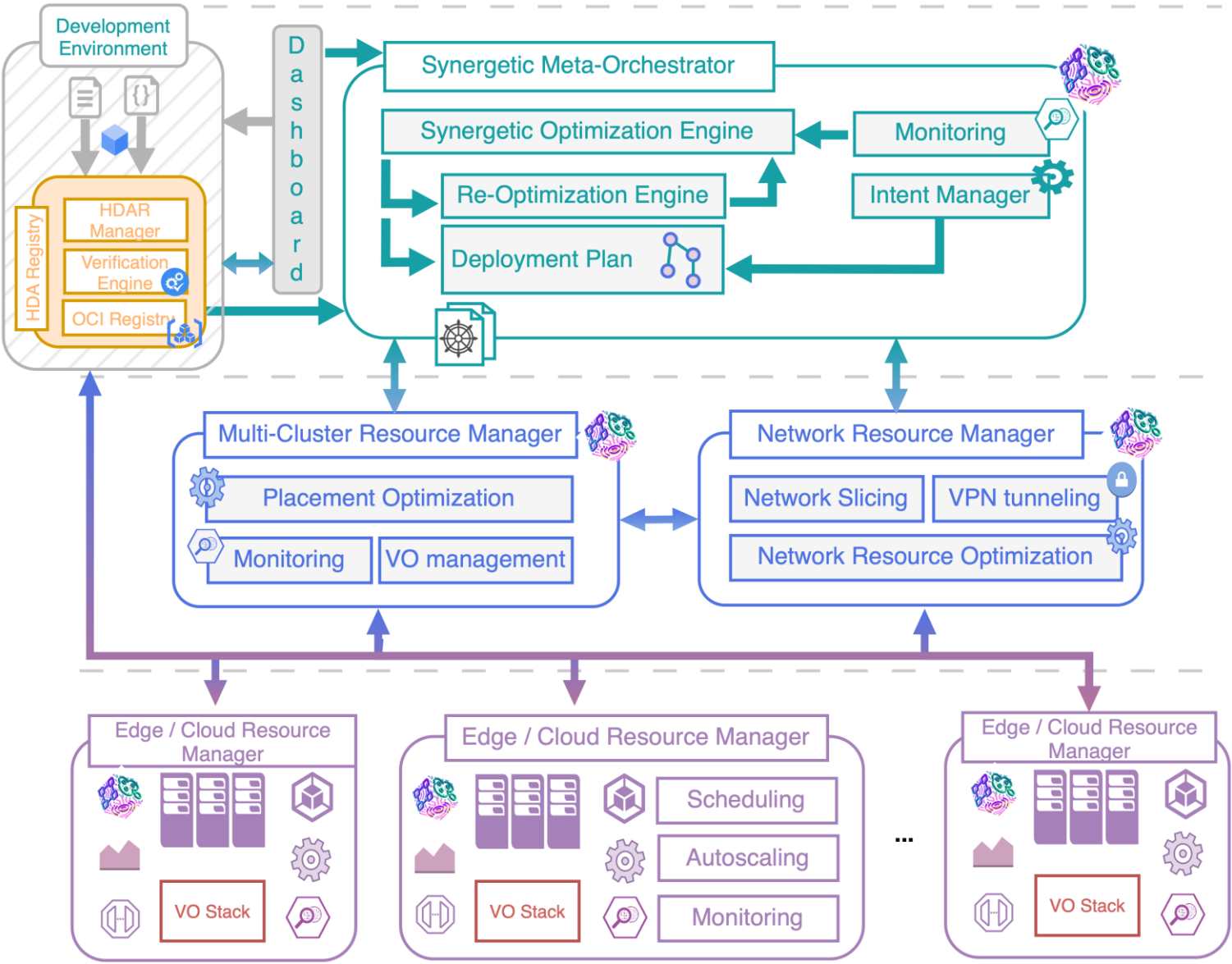
# Application Graph



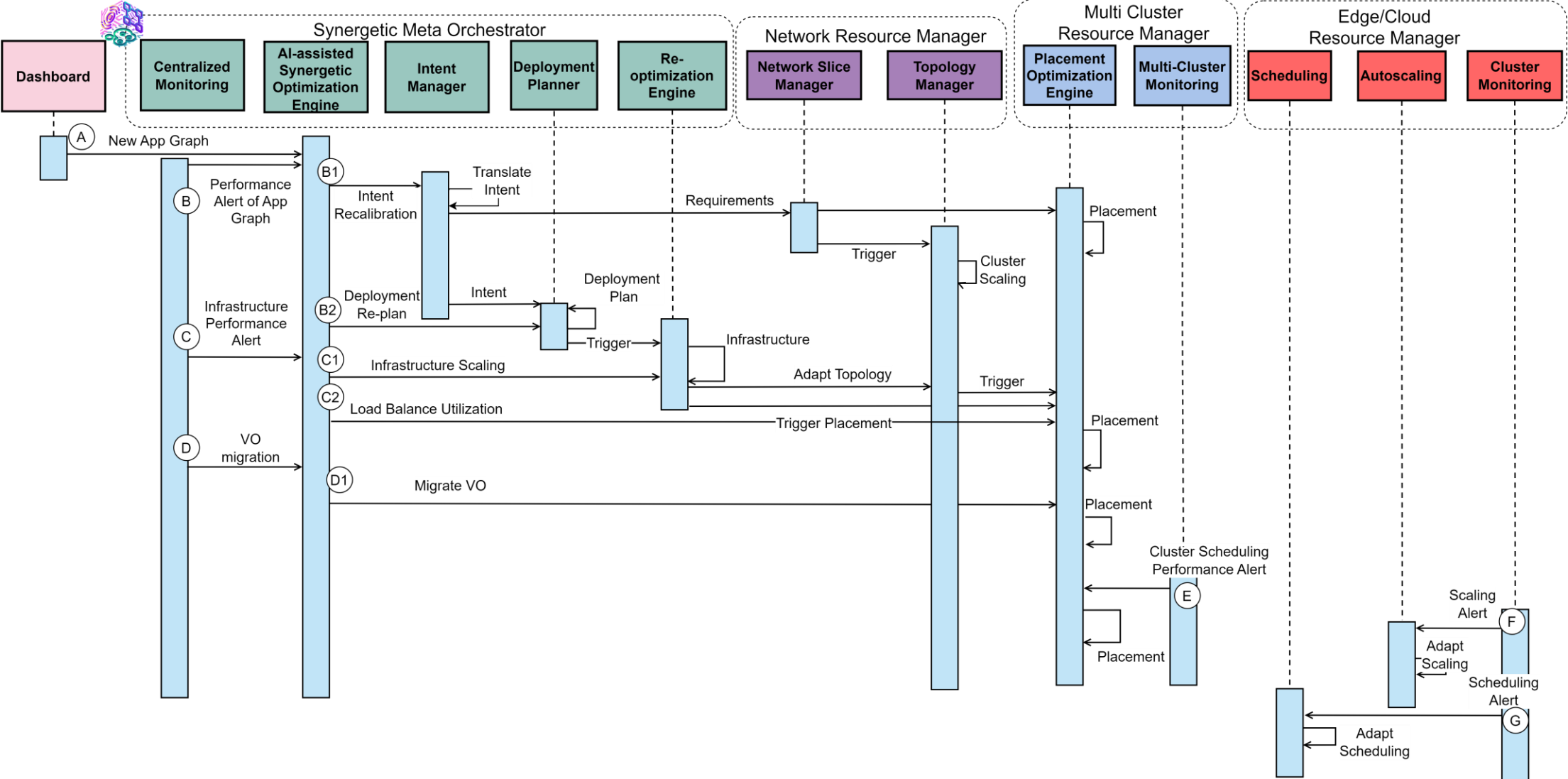
# Intent-based Orchestration



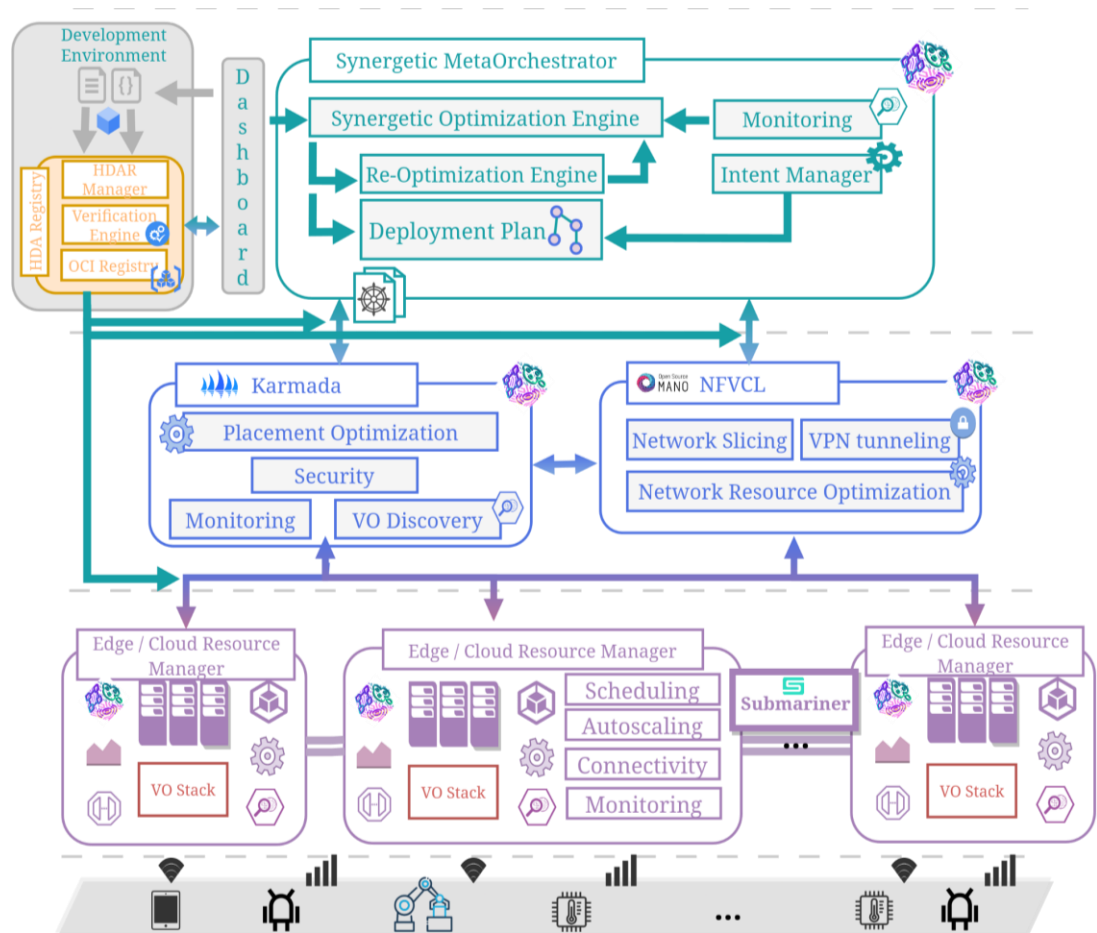
# Reference Architecture



# Synergetic Optimization Mechanisms



# NEPHELE Platform Development



brussels-demo

Logout

Home > Infrastructure

### Nephele Cluster Information

Cluster Name	Availability	Location	Available CPU	Available RAM	Grafana Link
Netmode	Yes	NTUA	72 vCPUs	234 GiB	GRAFANA
CNIT	Yes	Italy	50 vCPUs	150 GiB	GRAFANA

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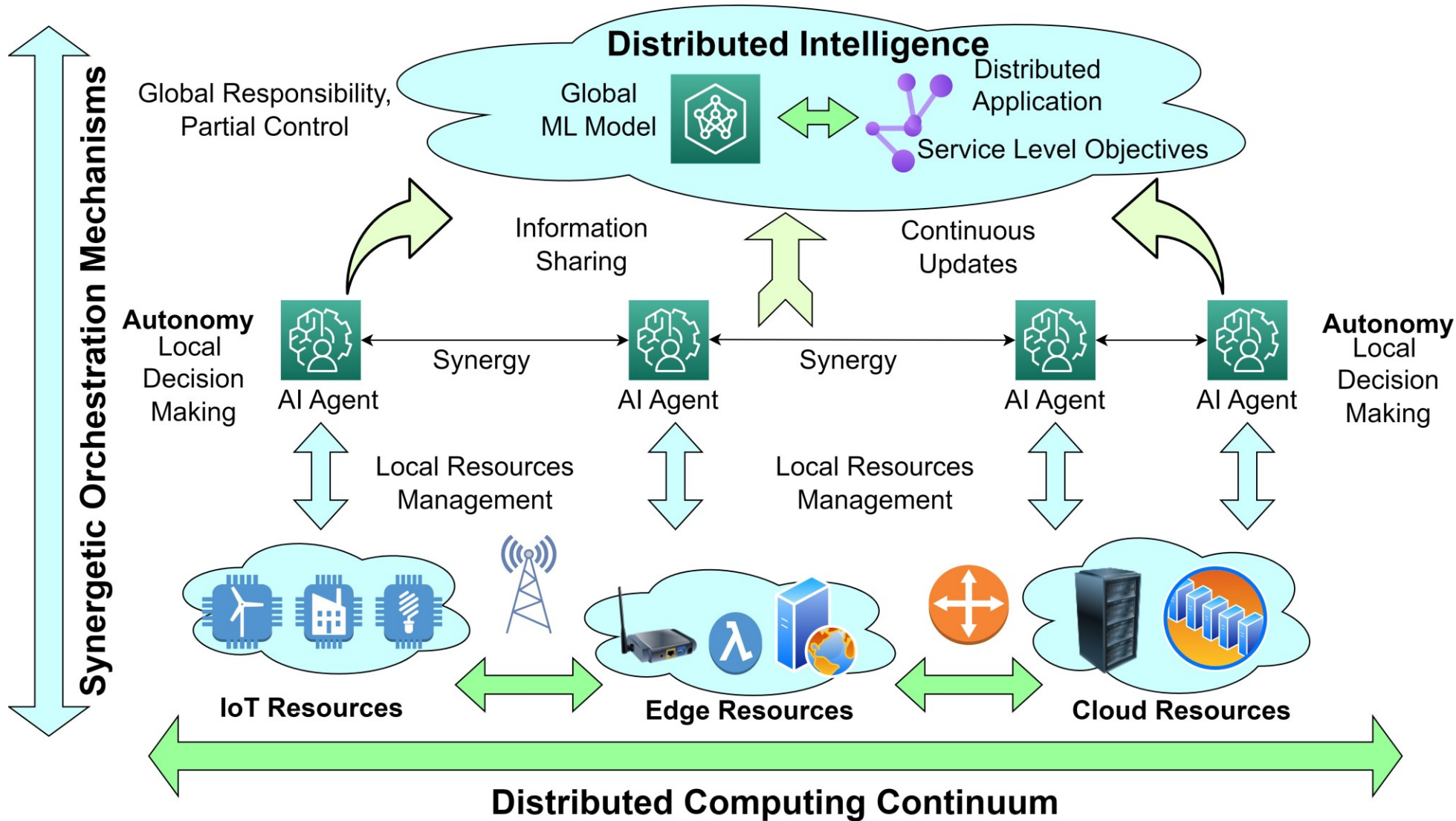
### Nephele Registered IoT Devices

Title	Device Type	IP	Location	Descriptor
vo	Raspberry Pi	147.102.13.100	Netmode	VIEW DESCRIPTOR

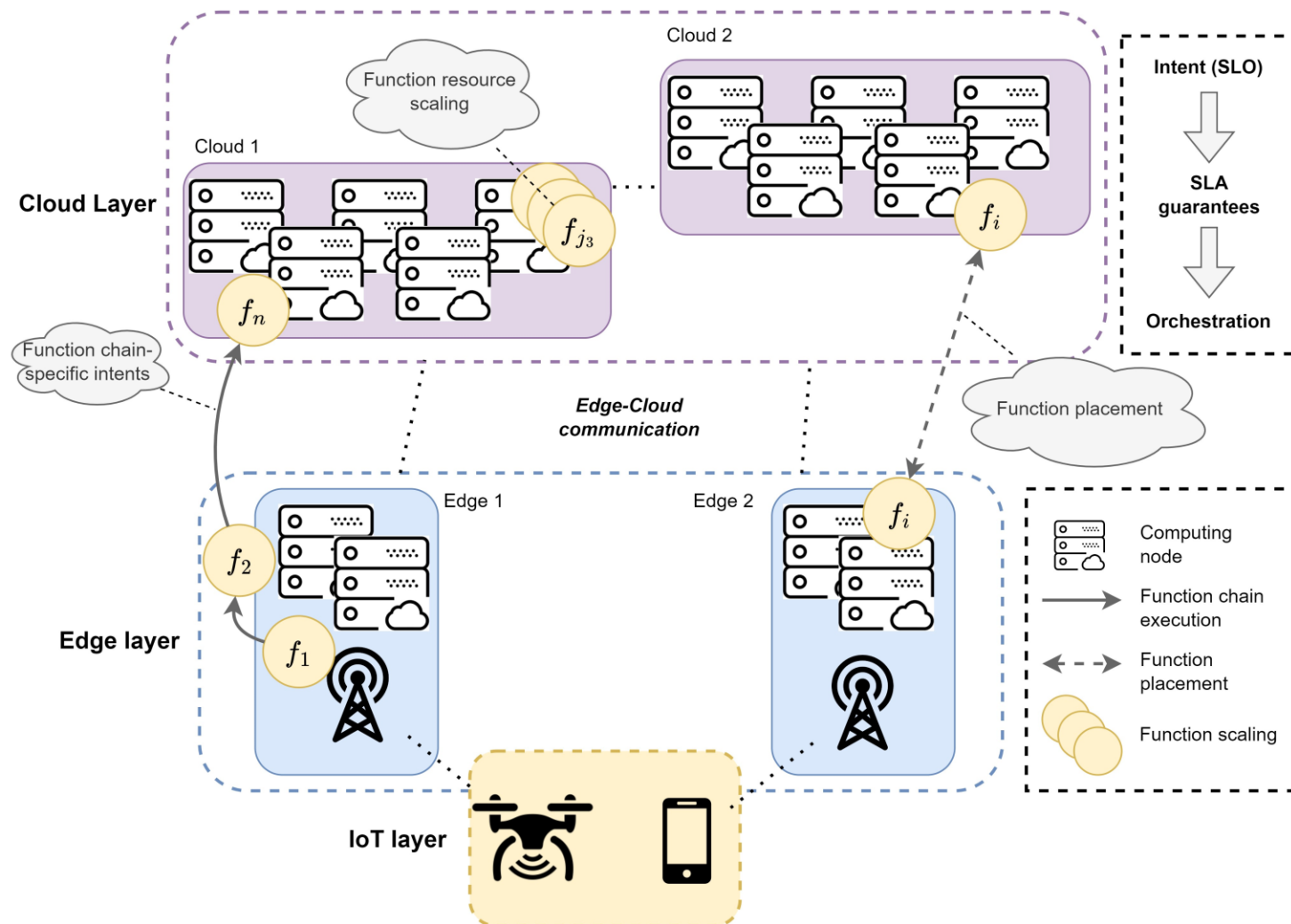
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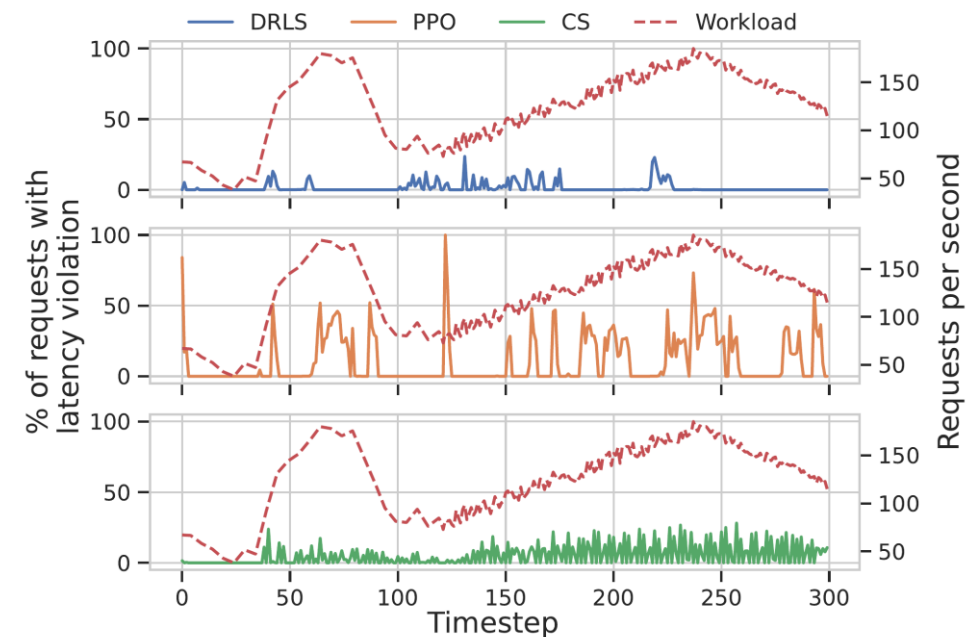
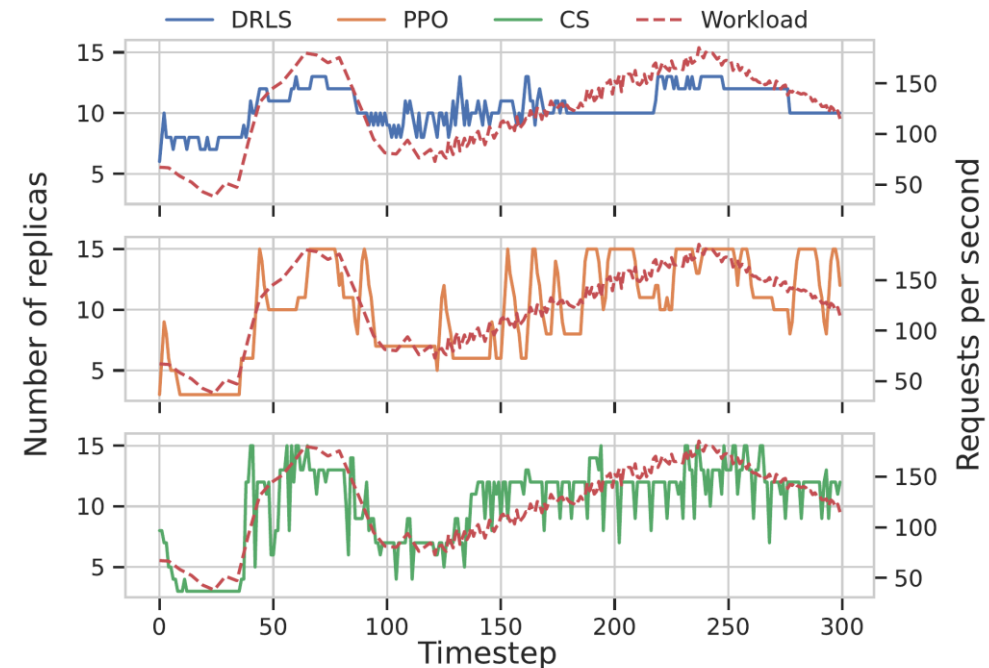
# Synergetic Orchestration Mechanisms



# RL-driven autoscaling of serverless functions in the computing continuum



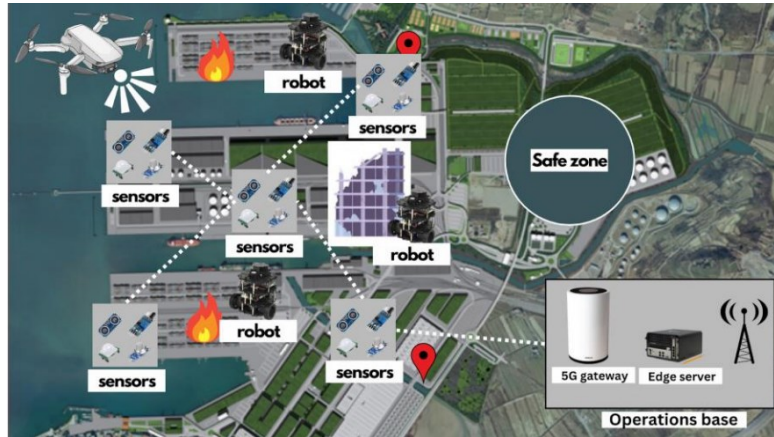
<https://www.sciencedirect.com/science/article/pii/S0167739X23004910>



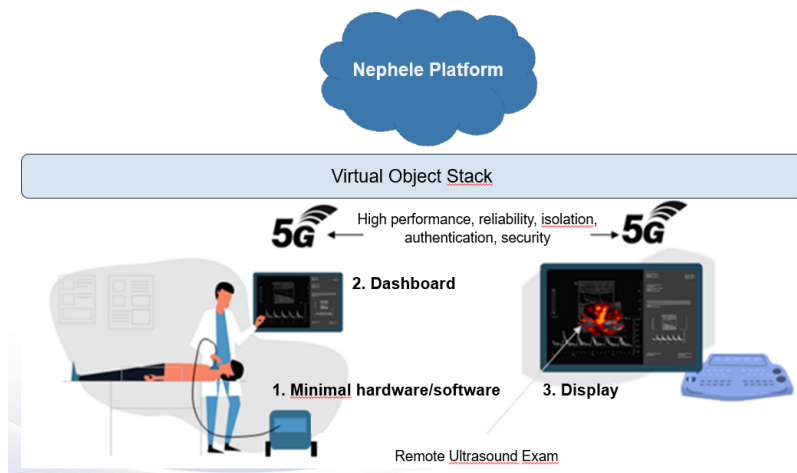
# NEPHELE Use cases



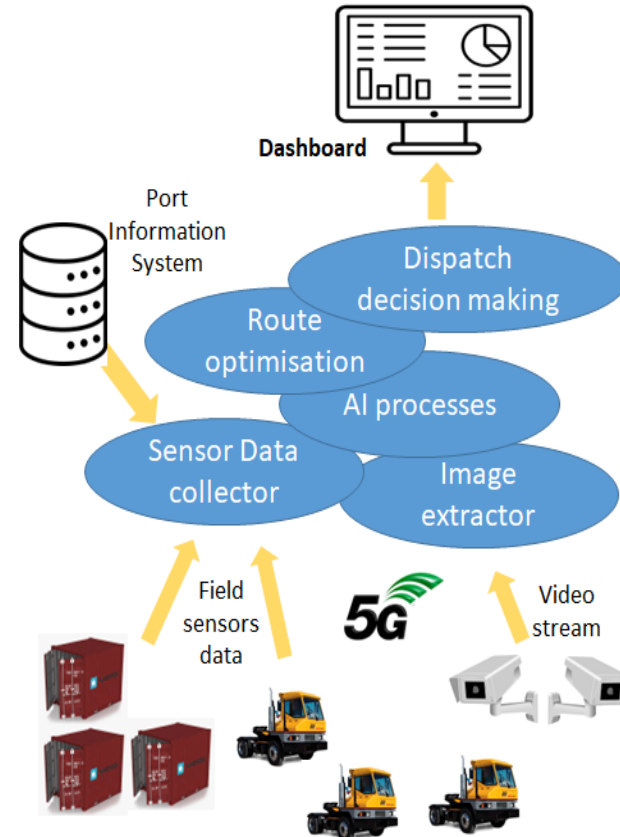
## Emergency/Disaster Recovery



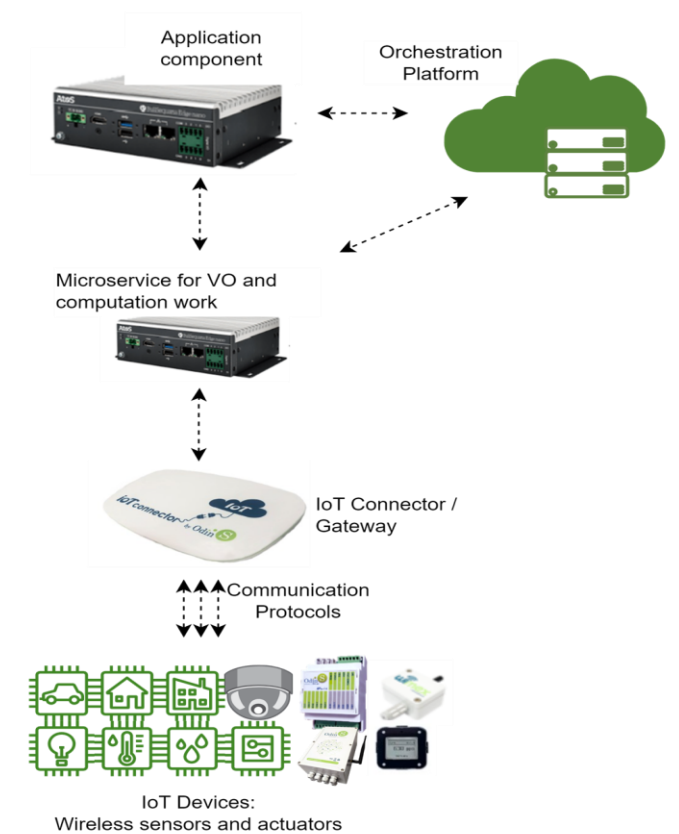
## Remote Healthcare



## Smart Port



## Energy Management in Smart Buildings



# Thank you for your attention!



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**Website:** <https://www.netmode.ntua.gr/>



nephele

<https://nephele-project.eu/>

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