SummerSoC
Service Oriented Computing

A smart computing continuum for smart environments

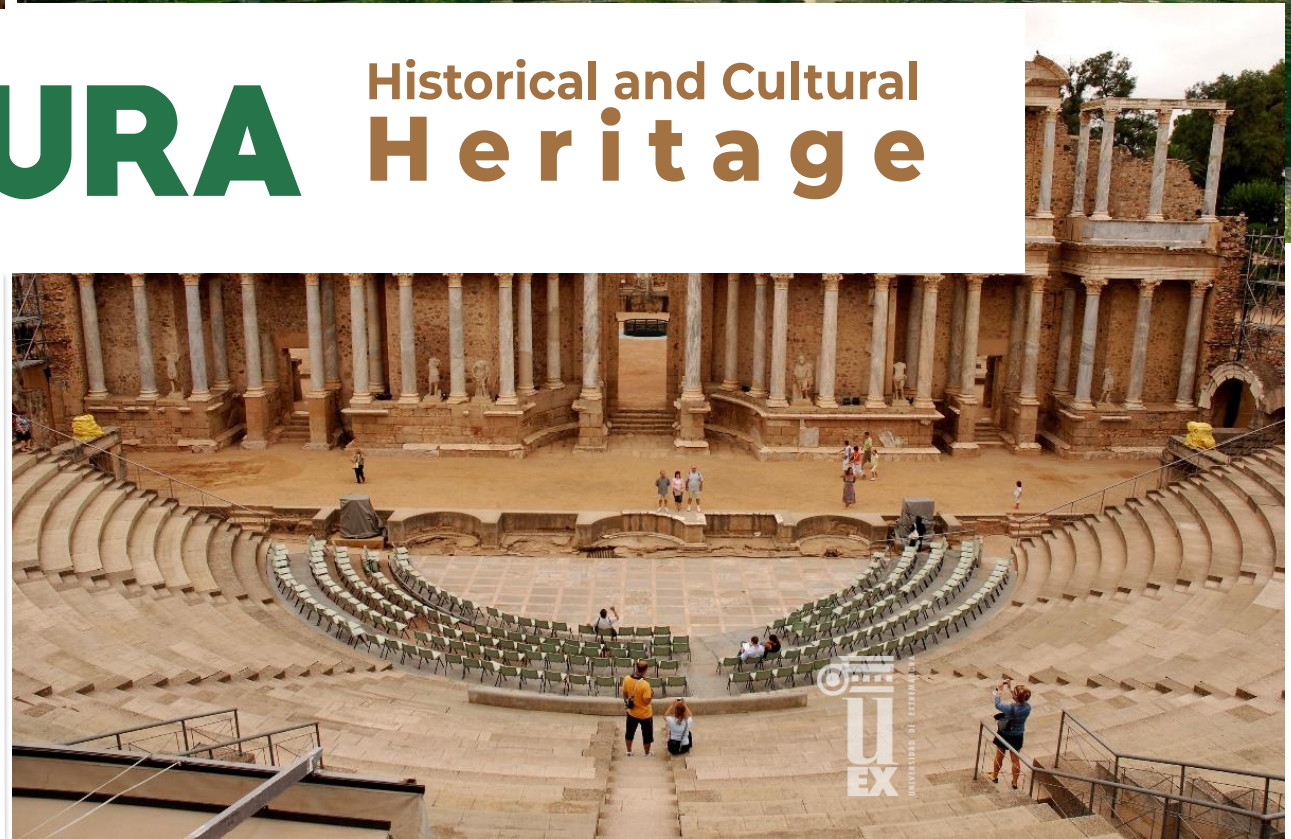
SPILab
by QuercusSEG

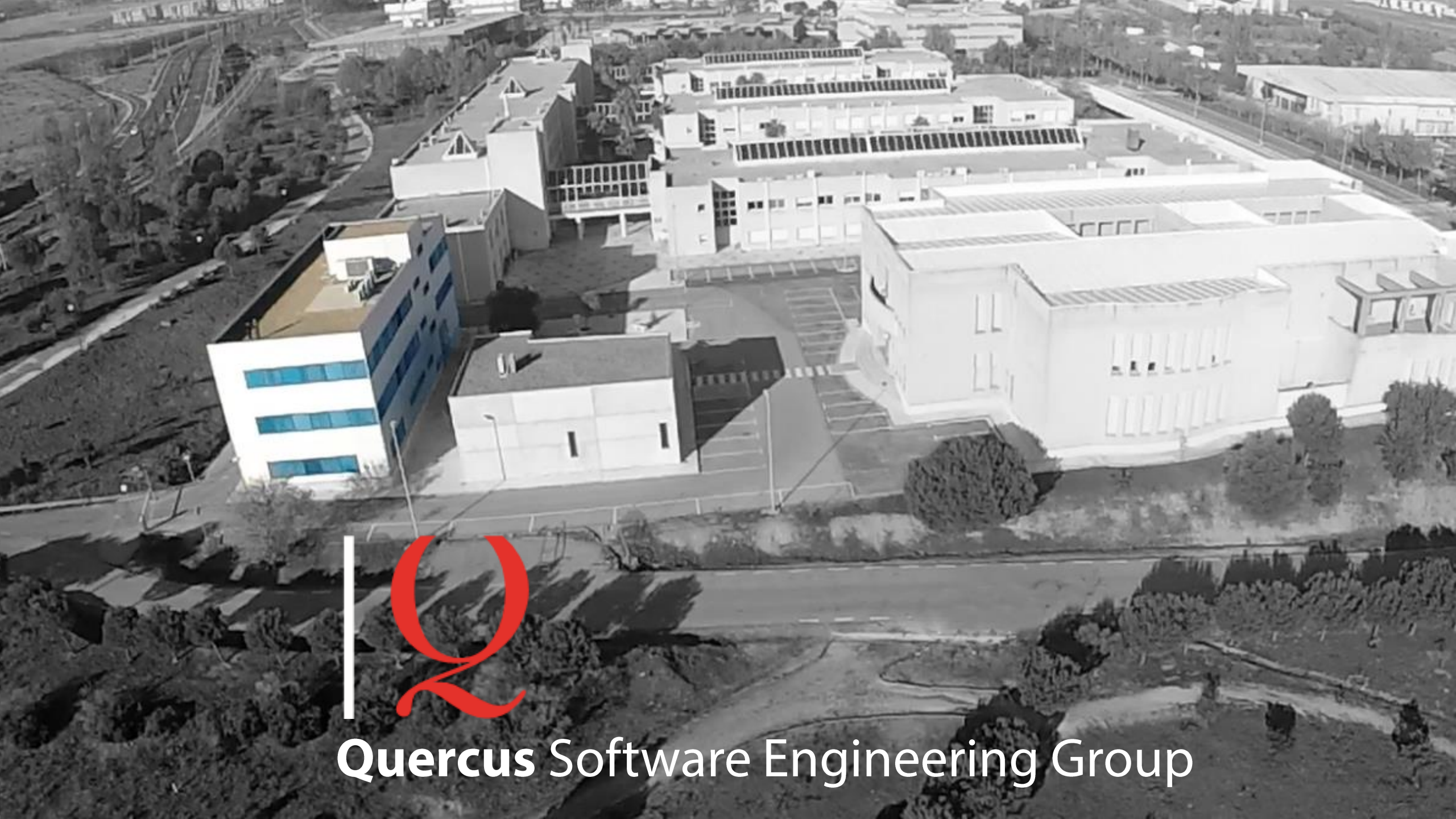
Javier Berrocal
University of Extremadura

- **BORDERING PORTUGAL** SOUTH-WEST REGION OF SPAIN
- **ONE OF THE BIGGEST IN EUROPE** (41.600 KM2)
- WIDE **HISTORICAL AND CULTURAL HERITAGE**
- 3 CITIES NAMED **WORLD HERITAGE SITES:** CÁCERES, MÉRIDA AND GUADALUPE
- **NATURAL PARADISE**

EXTREMADURA

Historical and Cultural Heritage



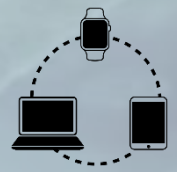

Quercus Software Engineering Group

Research Lines

Software Engineering

Big Data

Open Linked Data



Internet of Things

Social & Pervasive Computing

17
Researchers

10
PhD’s

7
PhD’s students

7
Students


QUANTUM
COMPUTING
IOT


AUTOMATION
CLOUD COMPUTING
SMART FACTORY
SYSTEM INTEGRATION
BIG DATA
+47%
INDUSTRY
4.0
CYBER SECURITY
AUTONOMOUS ROBOTS
INDUSTRIAL REVOLUTION

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(Towards) A smart computing continuum for smart environments

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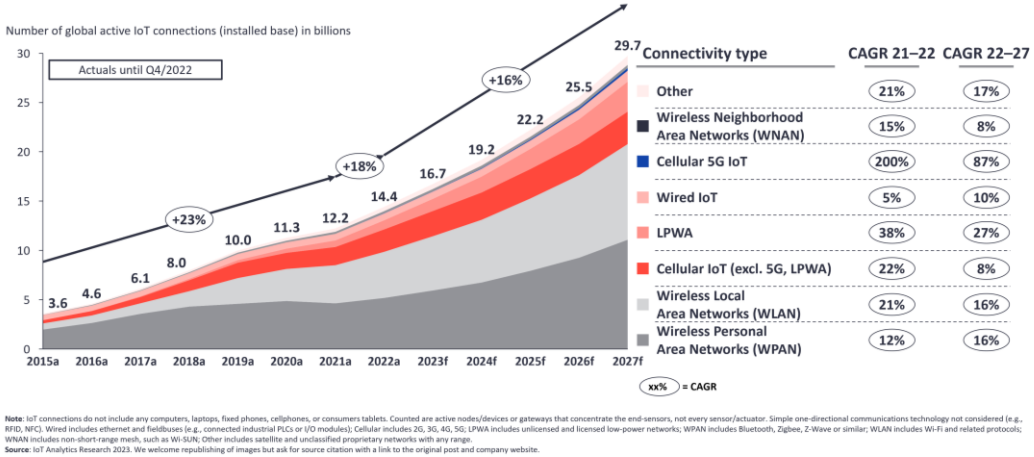
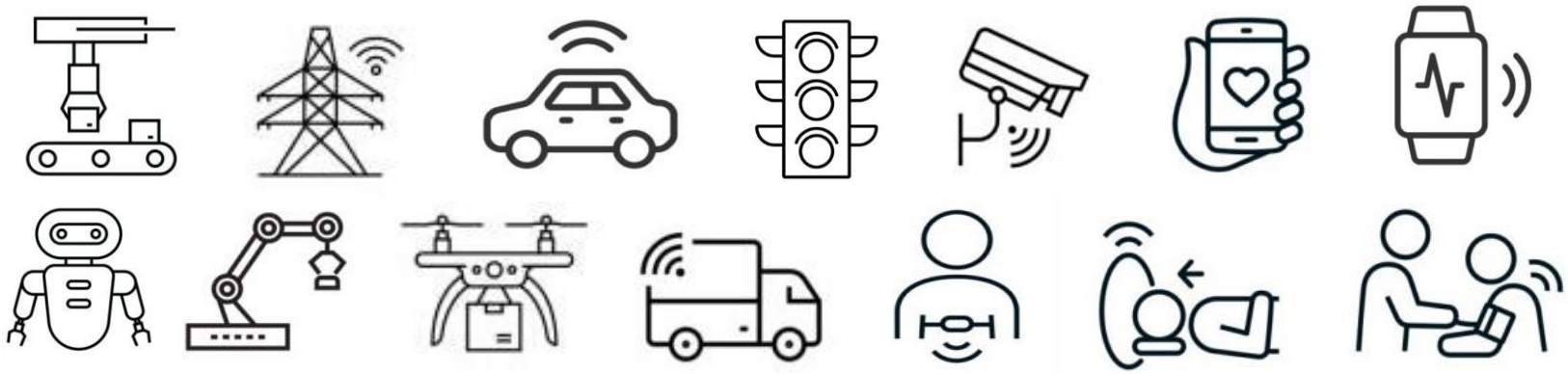
Introduction

Global IoT market forecast (in billions of connected IoT devices)



Note: IoT connections do not include any computers, laptops, fixed phones, cellphones, or consumers tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes ethernet and fieldbuses (e.g., connected industrial PLCs or I/O modules); Cellular includes 2G, 3G, 4G, 5G; LPWA includes unlicensed and licensed low-power networks; WPAN includes Bluetooth, Zigbee, Z-Wave or similar; WLAN includes Wi-Fi and related protocols; WNAN includes non-short-range mesh, such as Wi-SUN; Other includes satellite and unclassified proprietary networks with any range.
Source: IoT Analytics Research 2023. We welcome republishing of images but ask for source citation with a link to the original post and company website.



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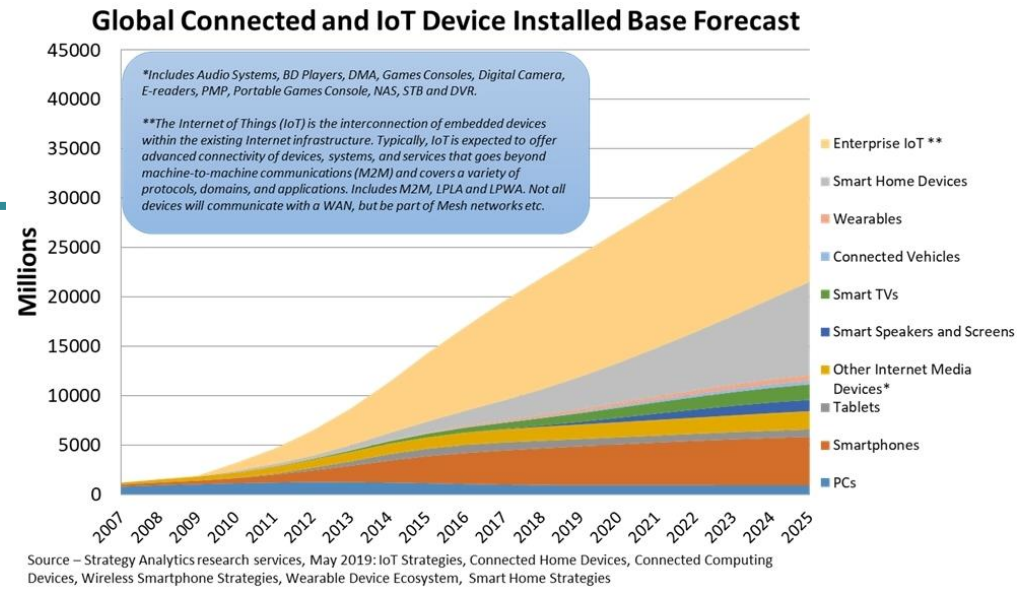
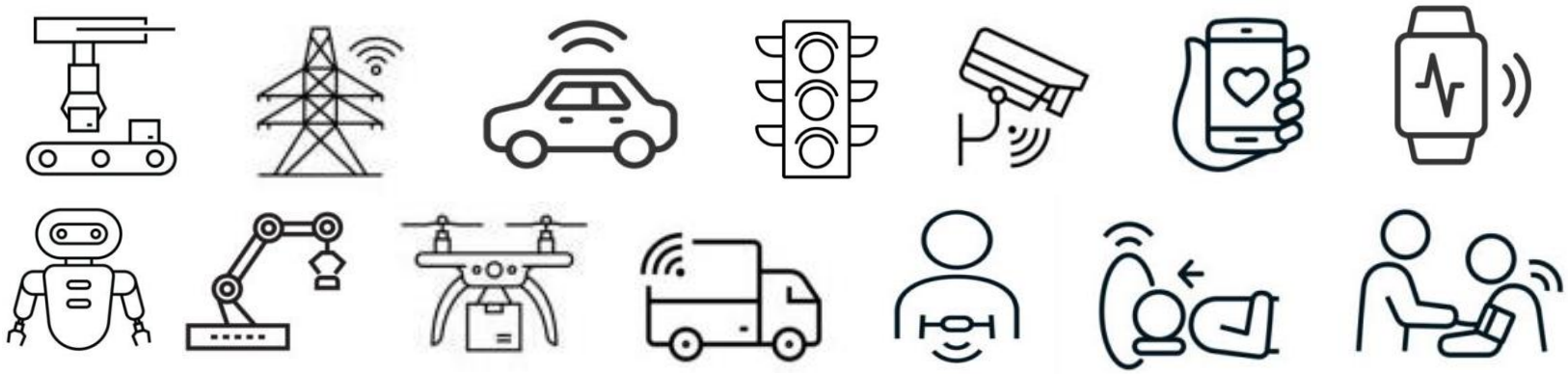


Source – Strategy Analytics research services, May 2019: IoT Strategies, Connected Home Devices, Connected Computing Devices, Wireless Smartphone Strategies, Wearable Device Ecosystem, Smart Home Strategies



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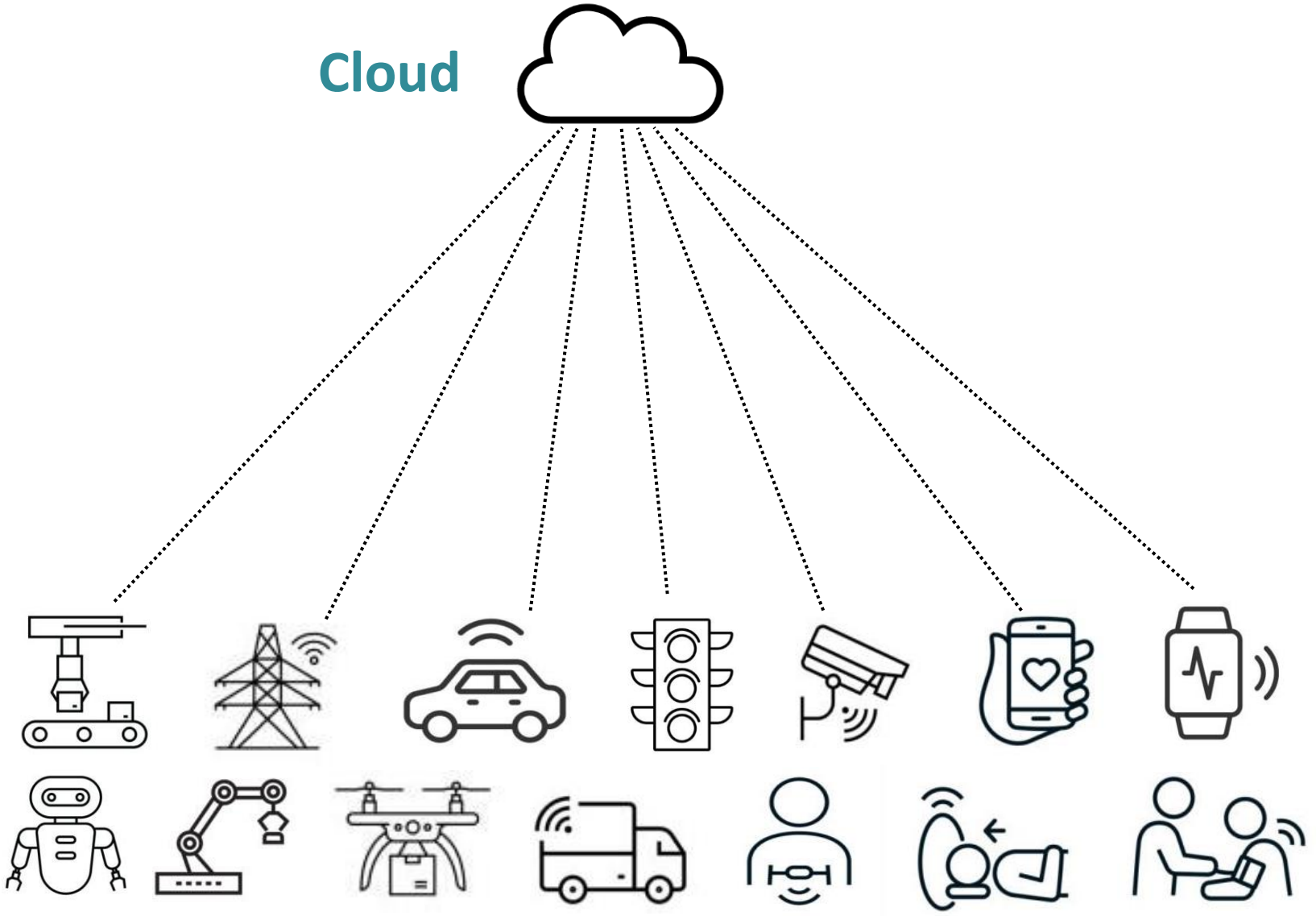

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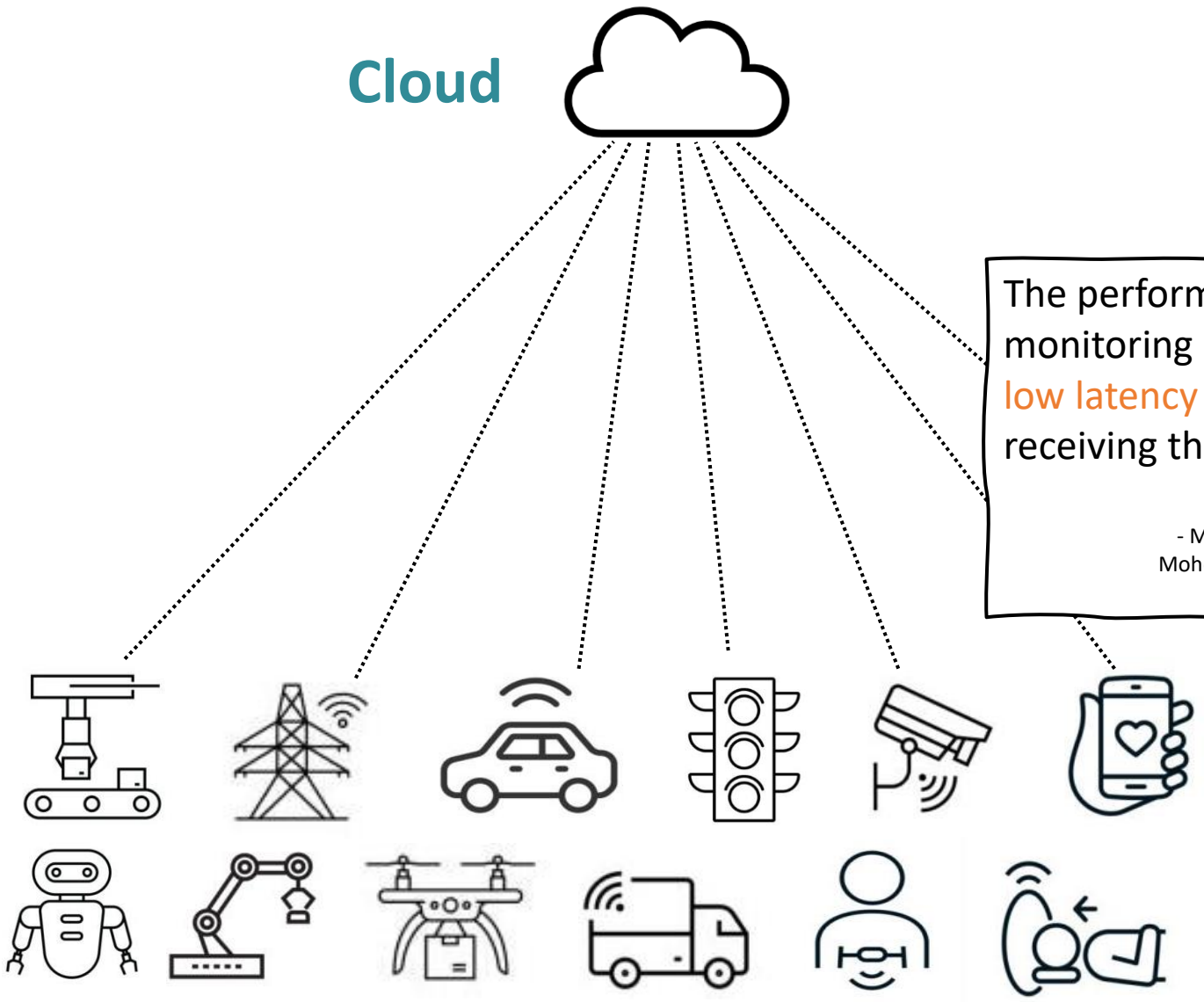


The real-time capability principle is one of the most outstanding aspects of industry 4.0 as it ensures that the industry has the best possible response time to internal and external stimuli.

- Industry 4.0 - What Is It?

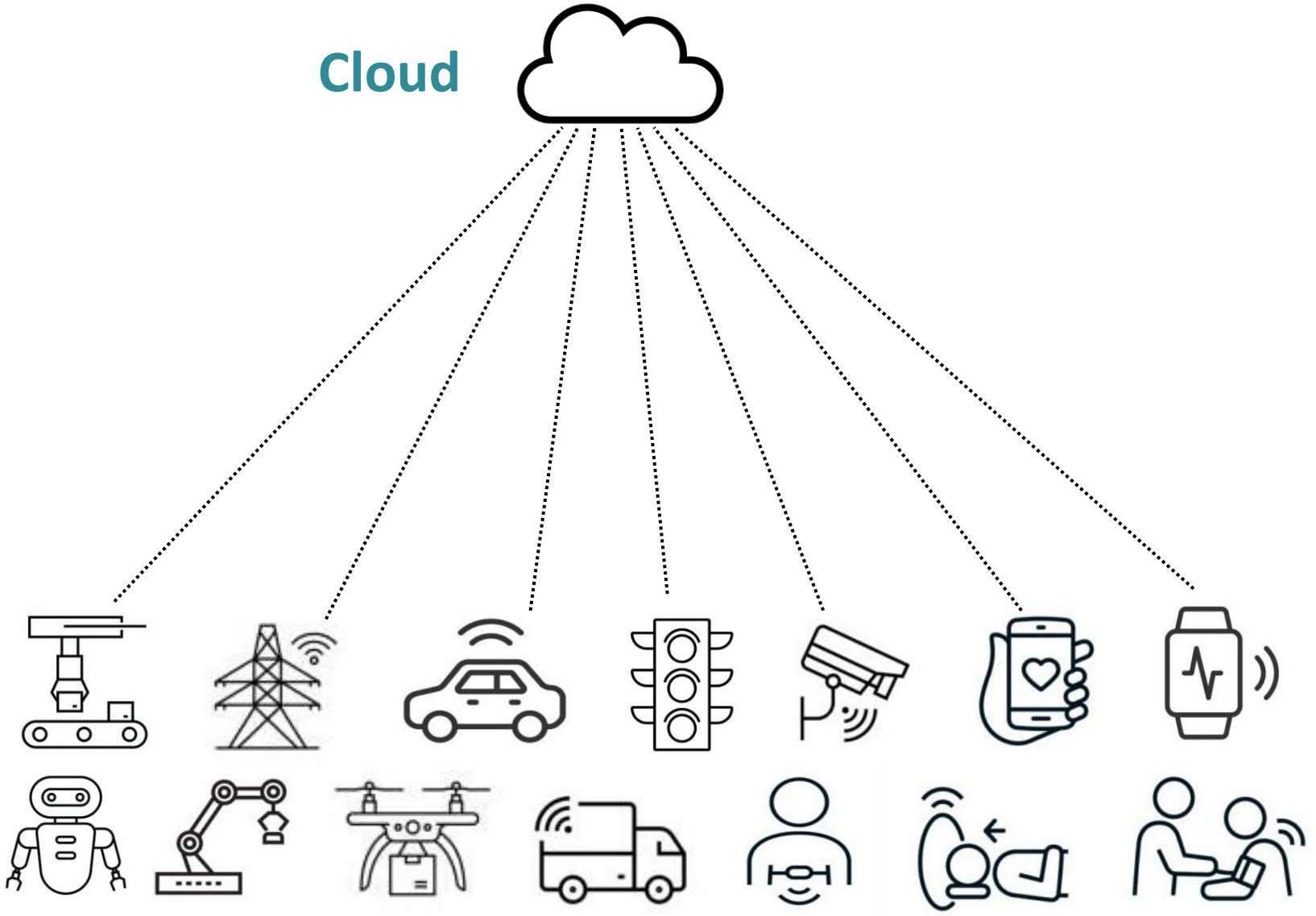
The performance of emergency and health monitoring services can be affected in terms of low latency while transferring data to the cloud or receiving the instructions back to the application

- Mutlag, A. A., Abd Ghani, M. K., Arunkumar, N. A., Mohammed, M. A., & Mohd, O. (2019). Enabling technologies for fog computing in healthcare IoT systems. Future Generation Computer Systems, 90, 62-78

Sensitive information of patients has the risk of being sold on the black market, which can lead to data privacy leakage and potentially threaten the lives of patients.

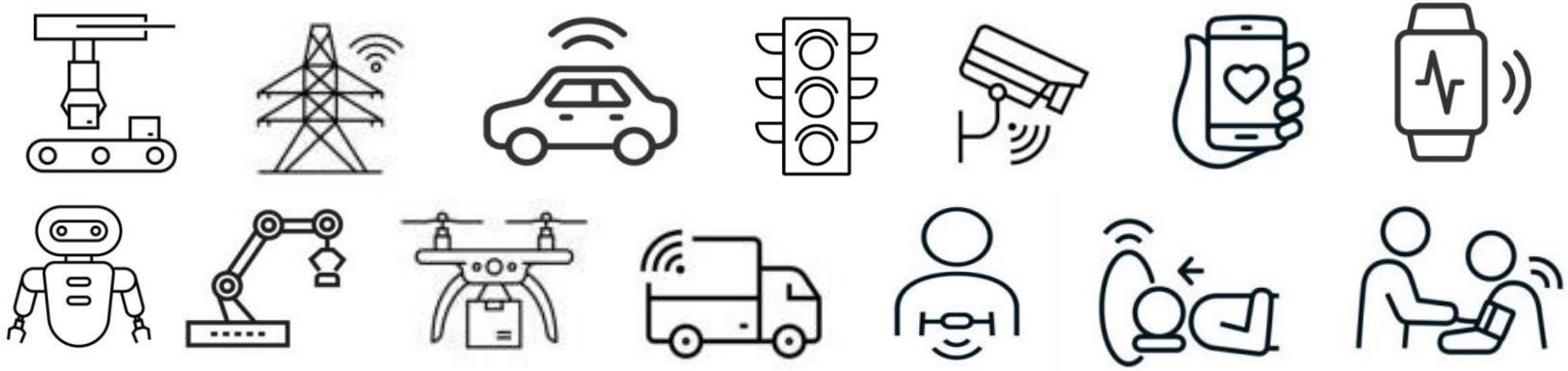
- Guo, X., Lin, H., Wu, Y., & Peng, M. (2020). A new data clustering strategy for enhancing mutual privacy in healthcare IoT systems. Future Generation Computer Systems, 113, 407-417

Introduction



Introduction

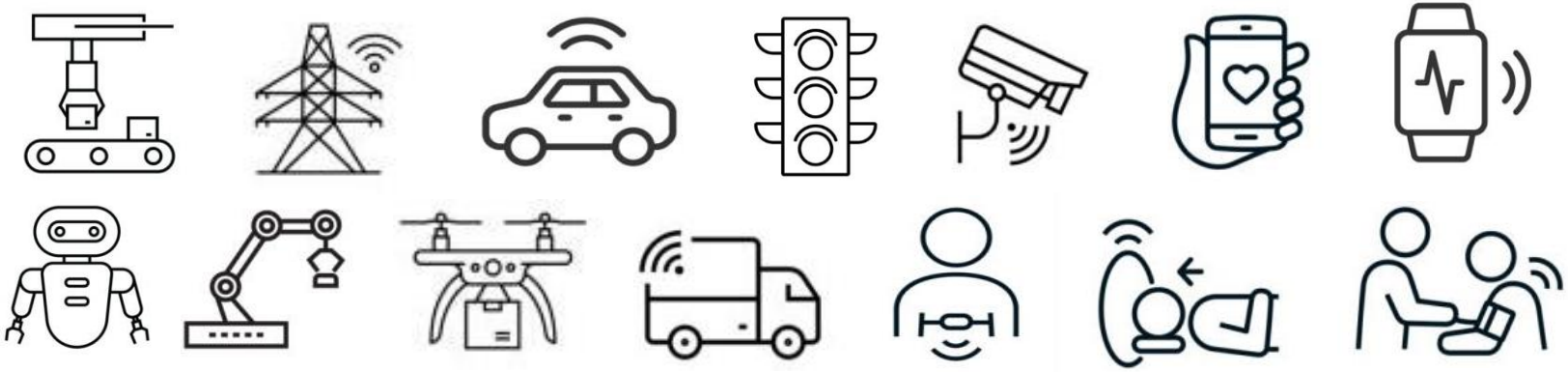
Cloud



Introduction

Cloud

Fog



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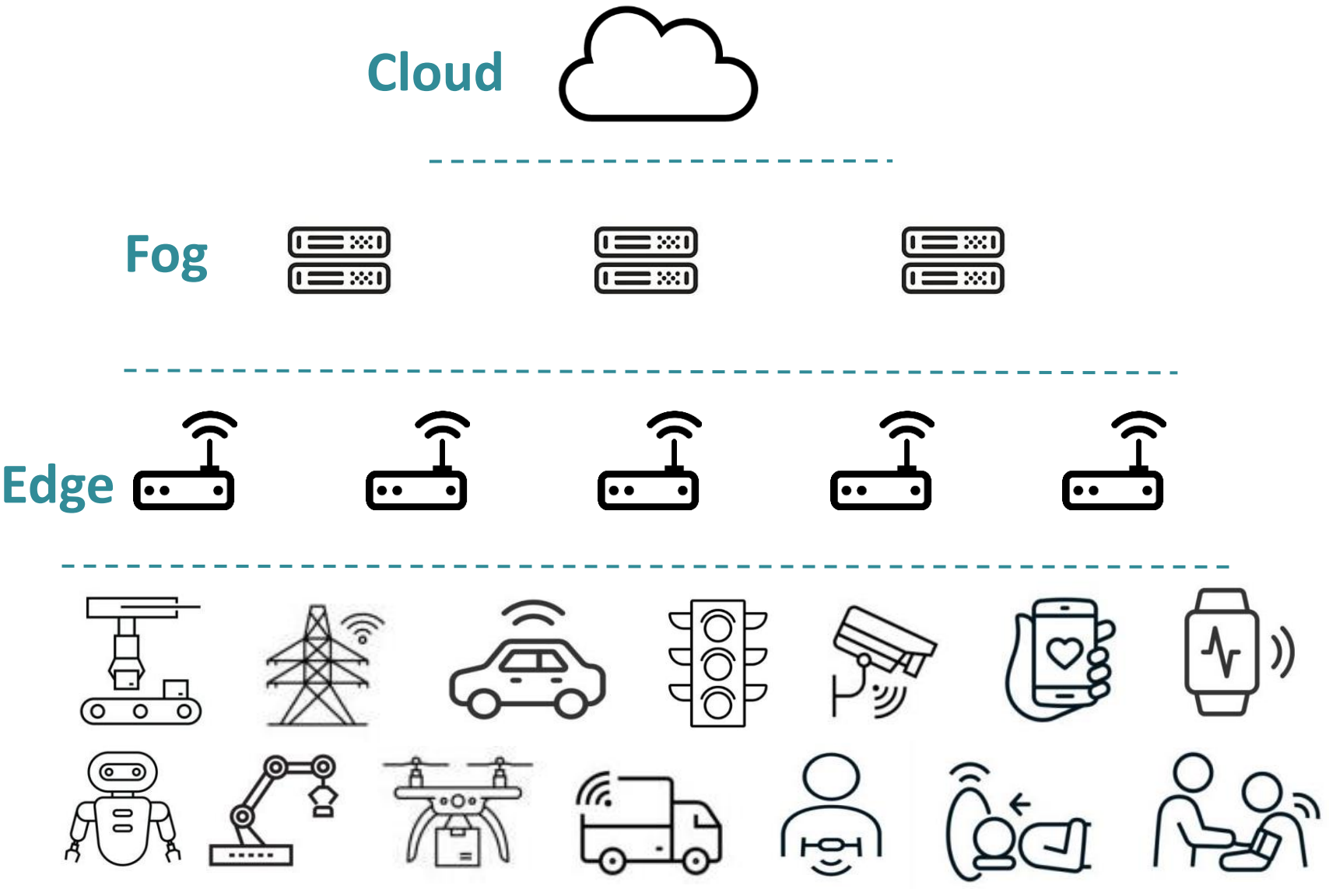

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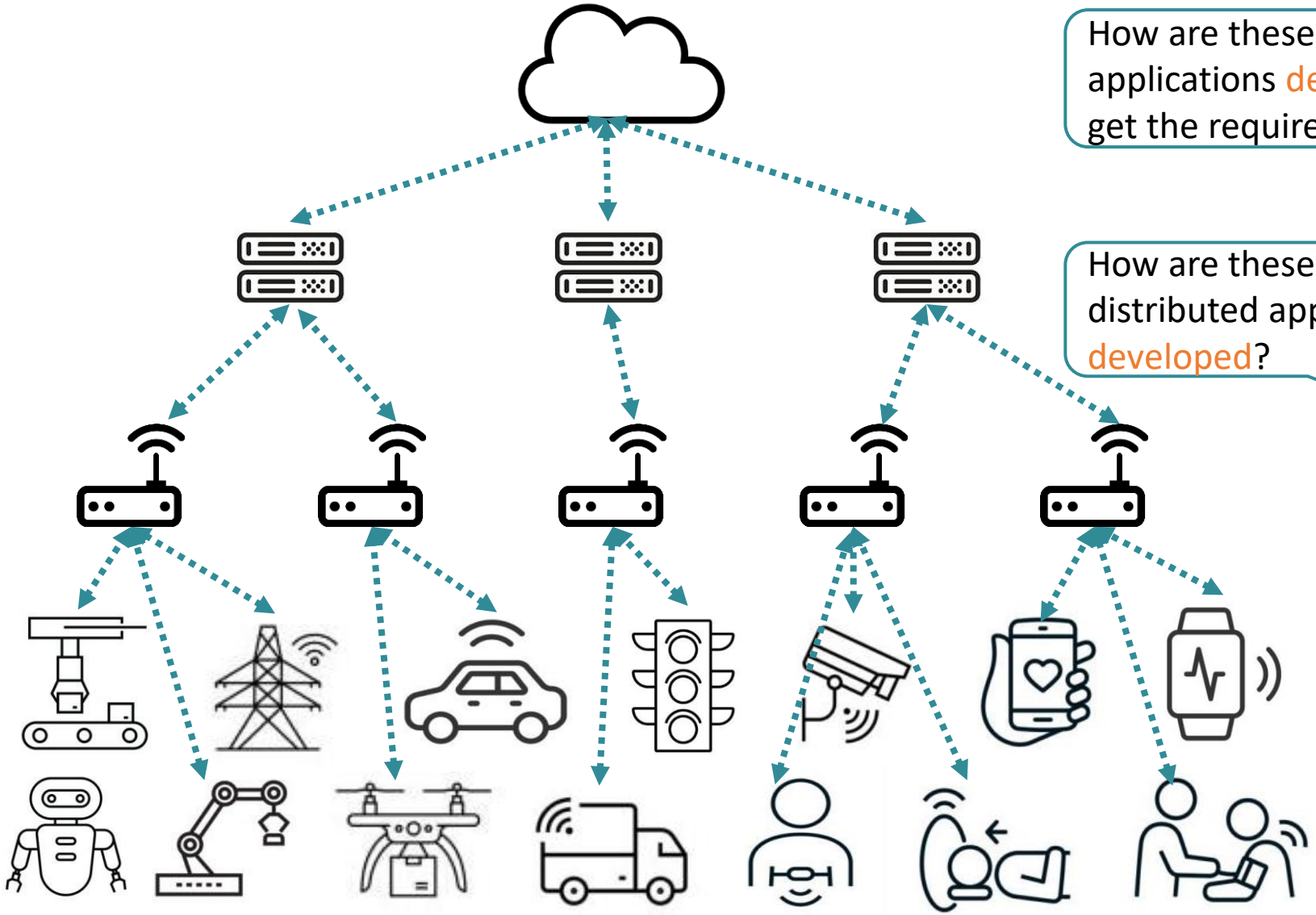


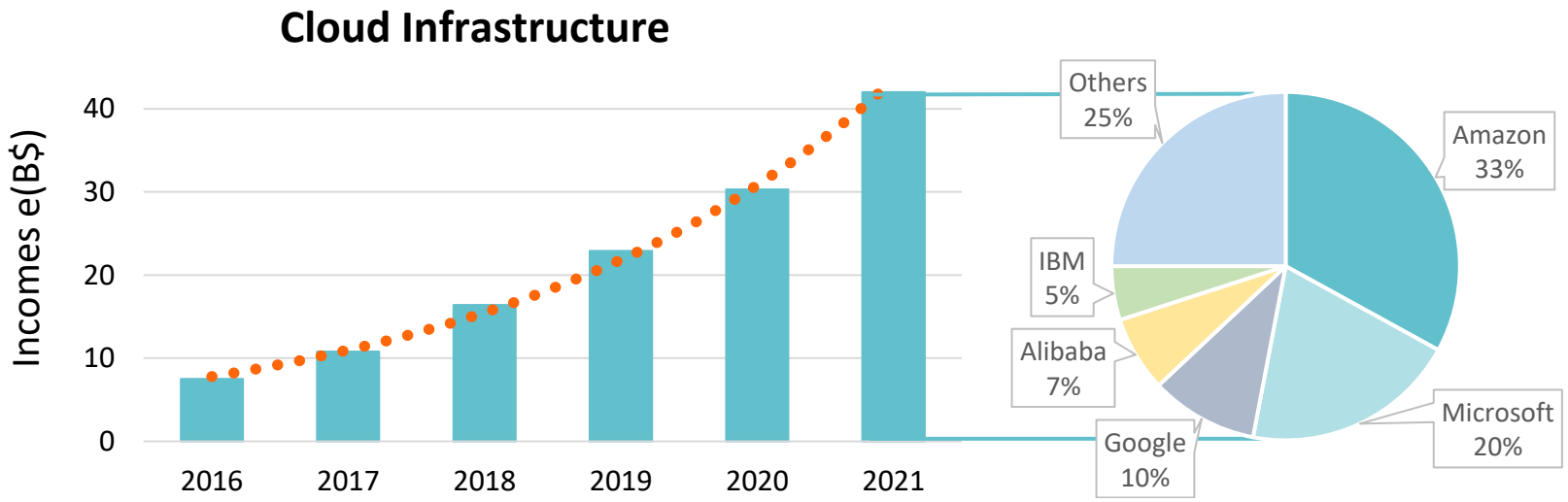
How are the different resources managed?

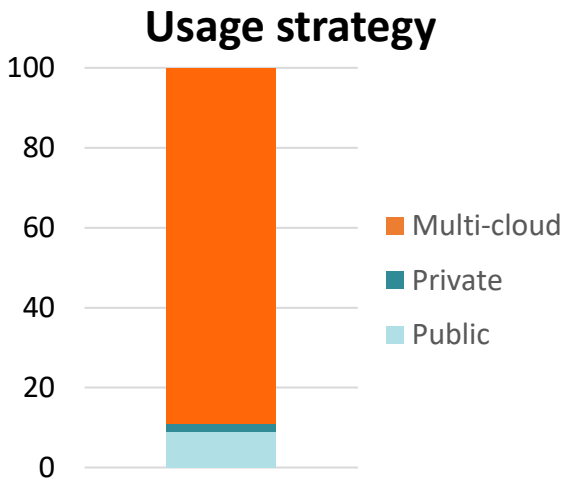
How are these distributed applications deployed to get the required QoS?

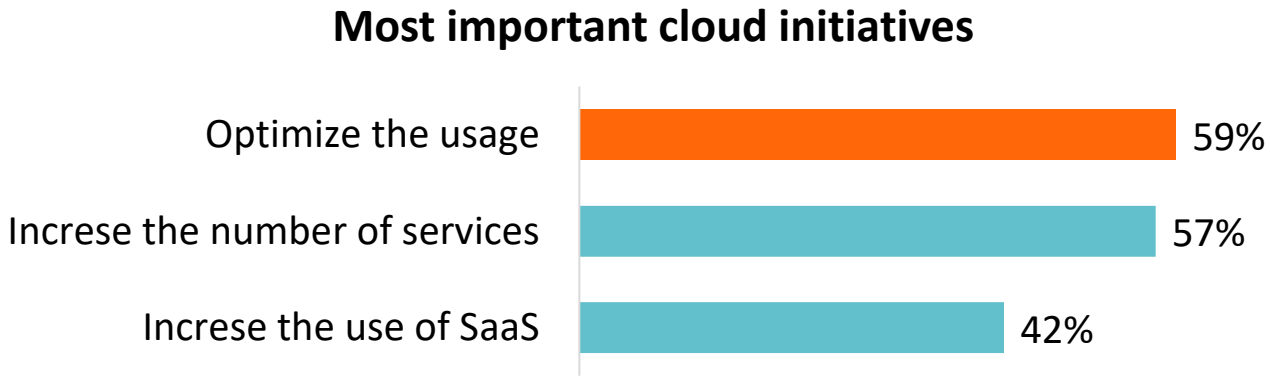
What happen with the QoS if the context changes?

How are these distributed applications developed?

Introduction



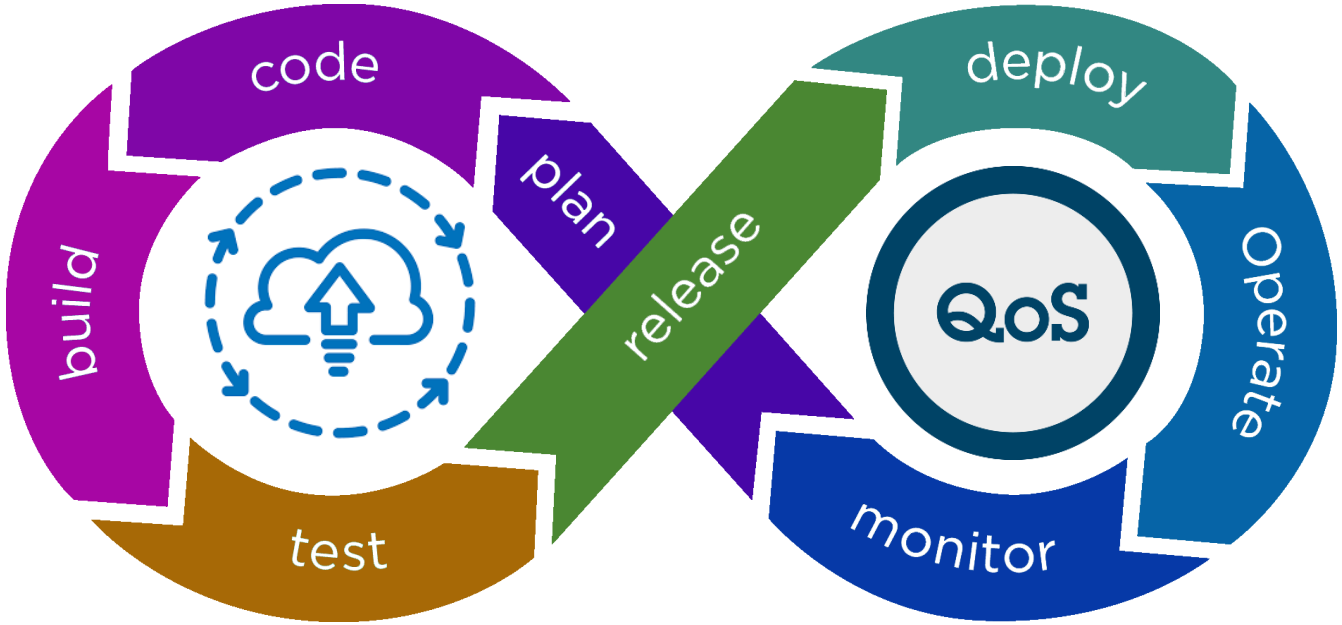




Introduction

We need new or adapted methodologies and tools guiding and helping developer, system operators and stakeholder

Introduction



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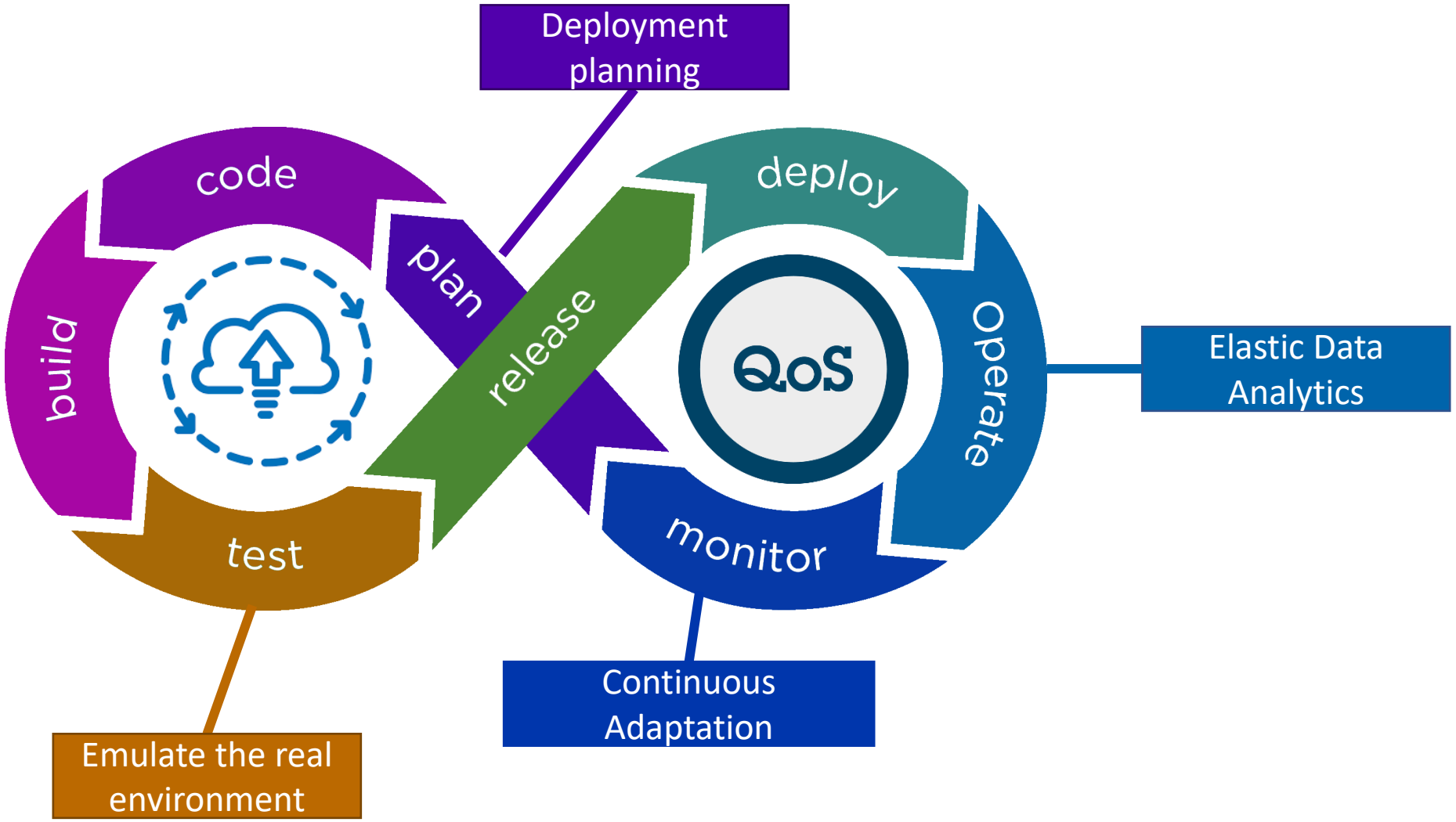
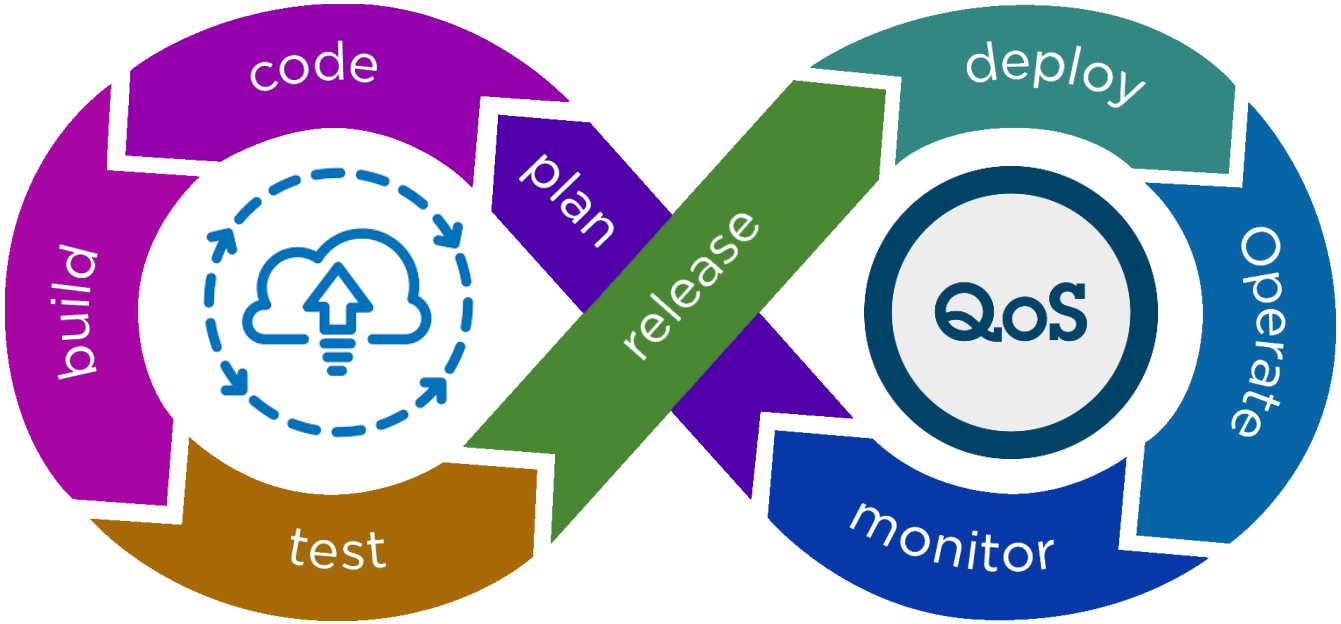


Placing Services on the Continuum



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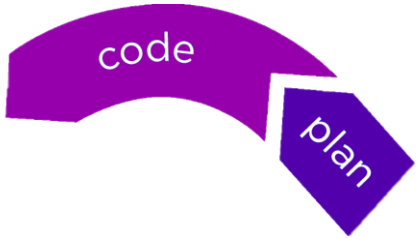

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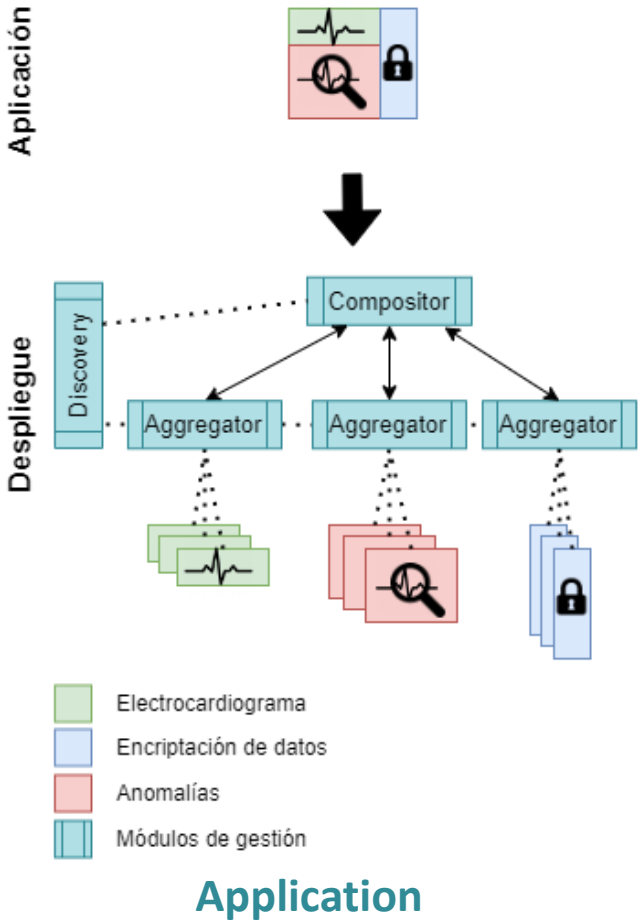
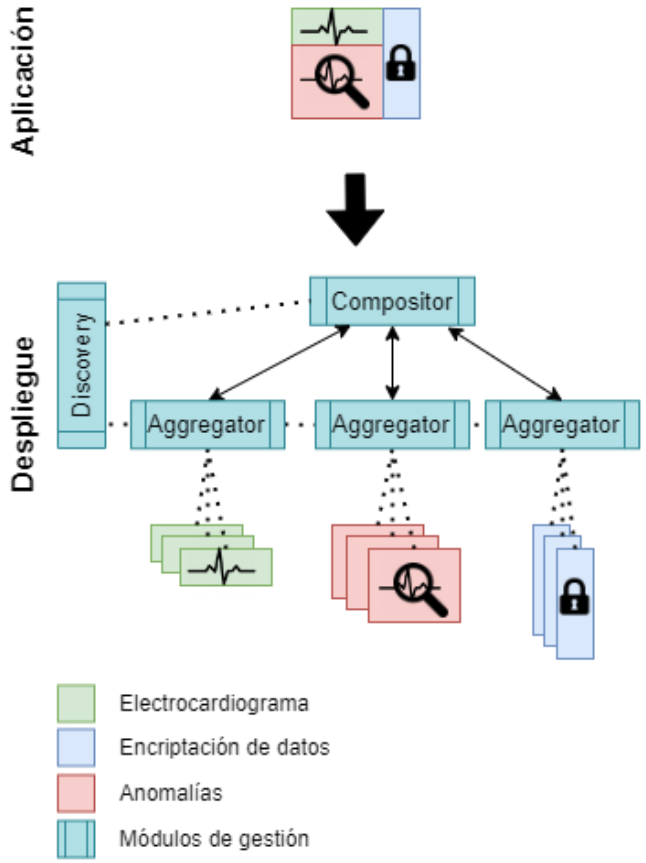
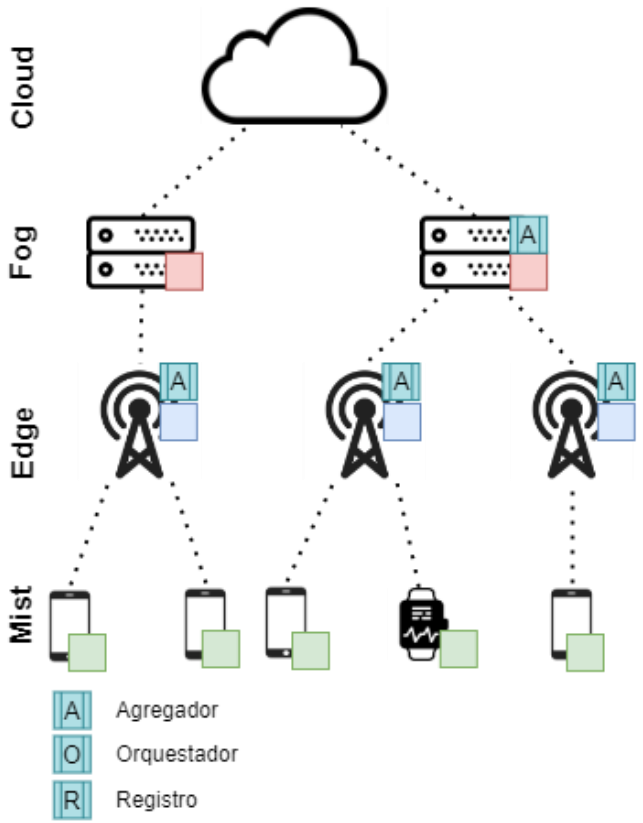


Application

Placing Services on the Continuum

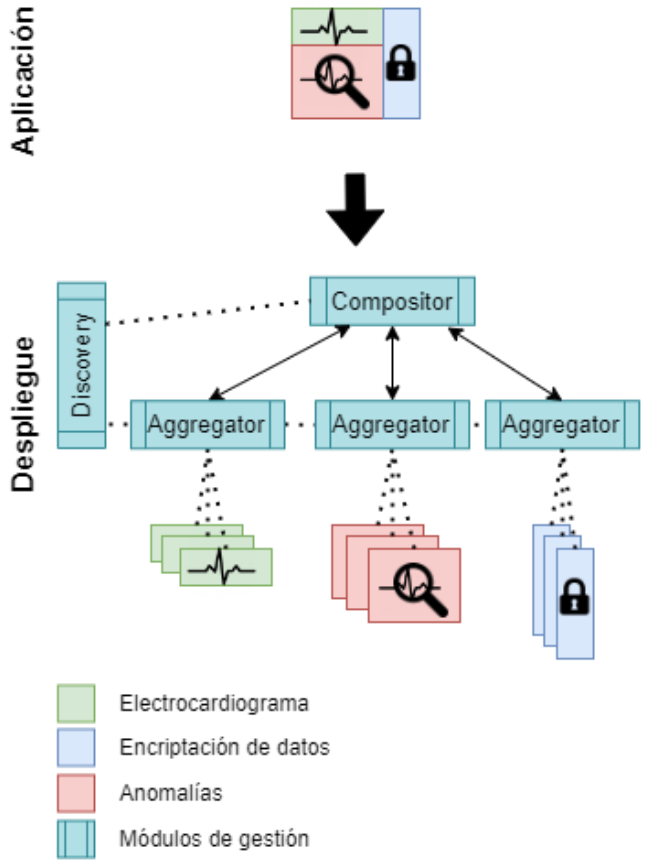


Application

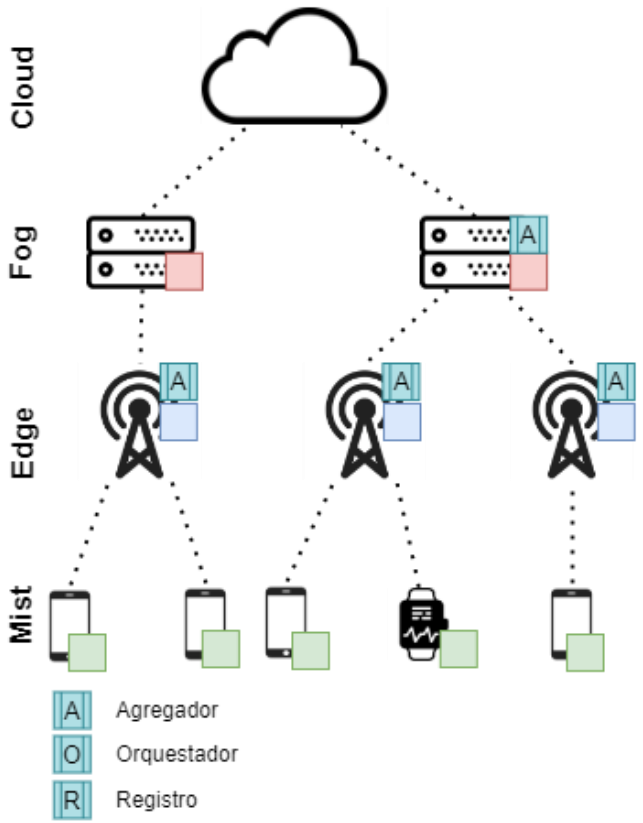


Computation

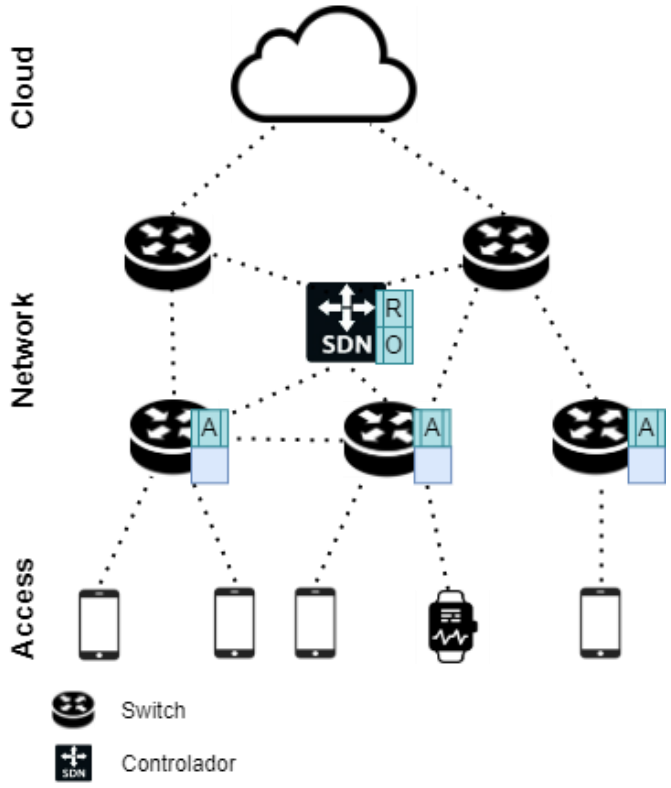
Placing Services on the Continuum



Application

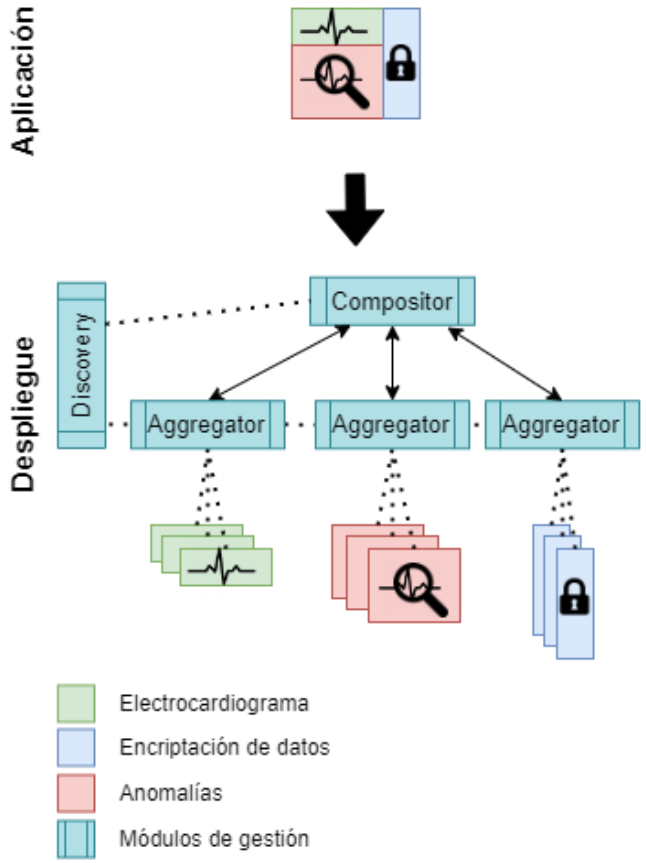


Computation

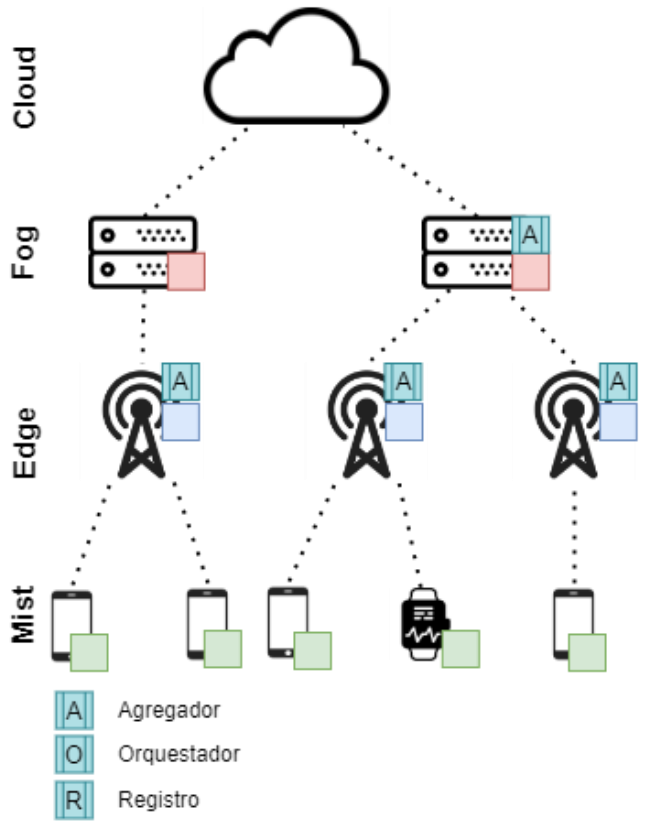


Network

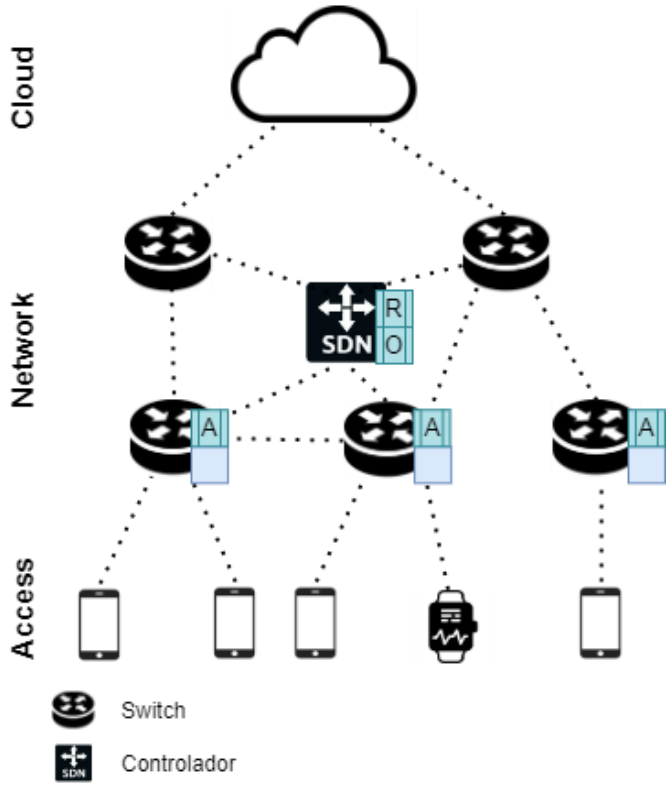
Placing Services on the Continuum



Application



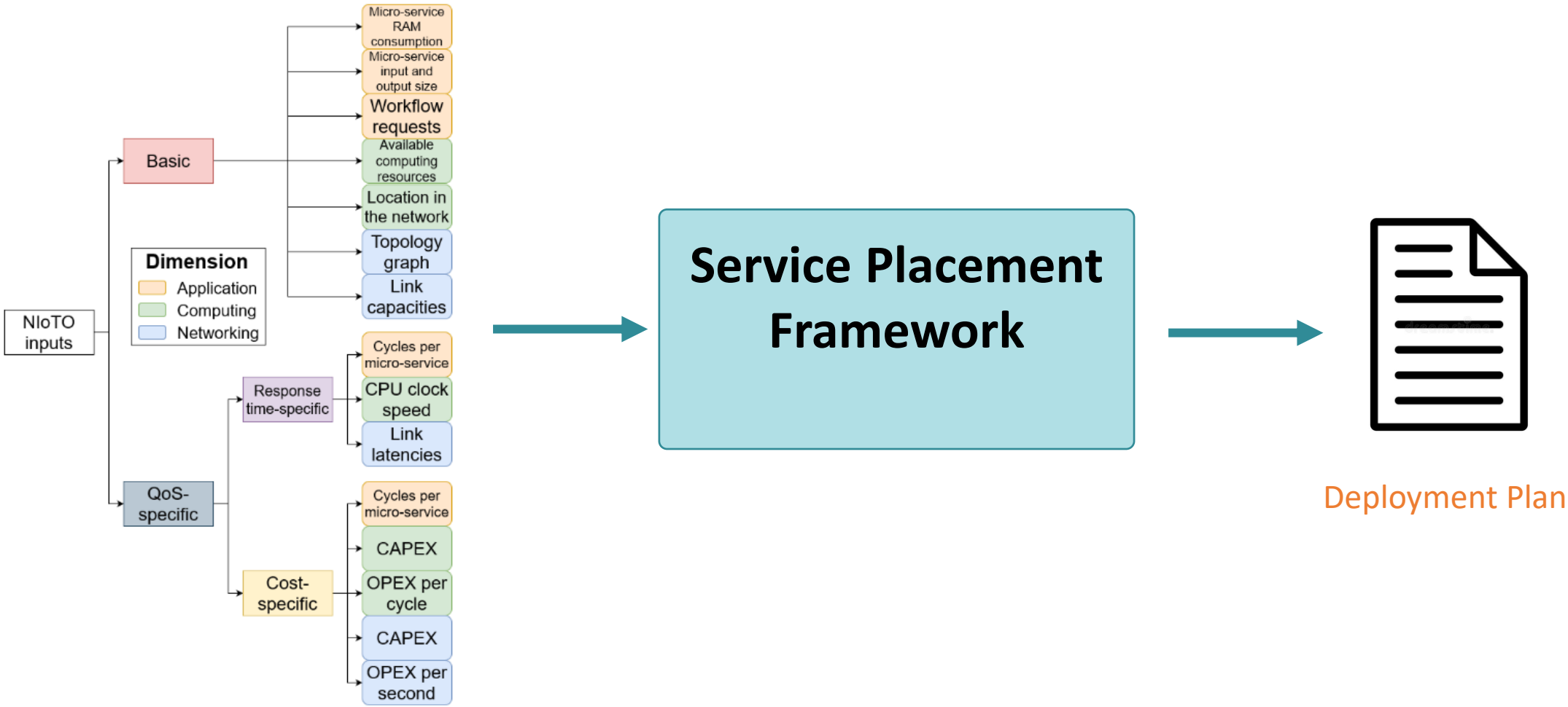
Computation



Network

Achieving a specific QoS requires managing different layers, abstractions, dimensions and objectives for each stakeholder. Tools are needed to facilitate this work.

Placing Services on the Continuum



Juan Luis Herrera, Jaime Galán-Jiménez, José García-Alonso, Javier Berrocal, Juan Manuel Murillo: Joint Optimization of Response Time and Deployment Cost in Next-Gen IoT Applications. IEEE Internet Things J. 10(5): 3968-3981 (2023)

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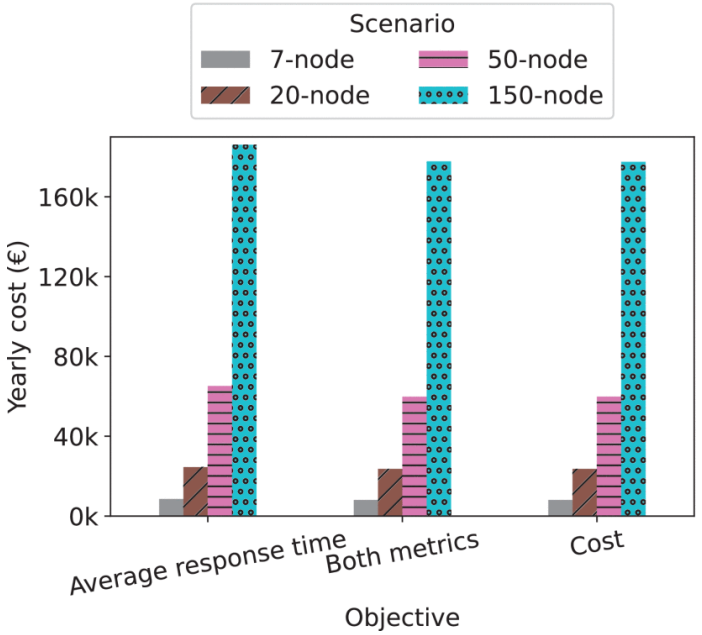

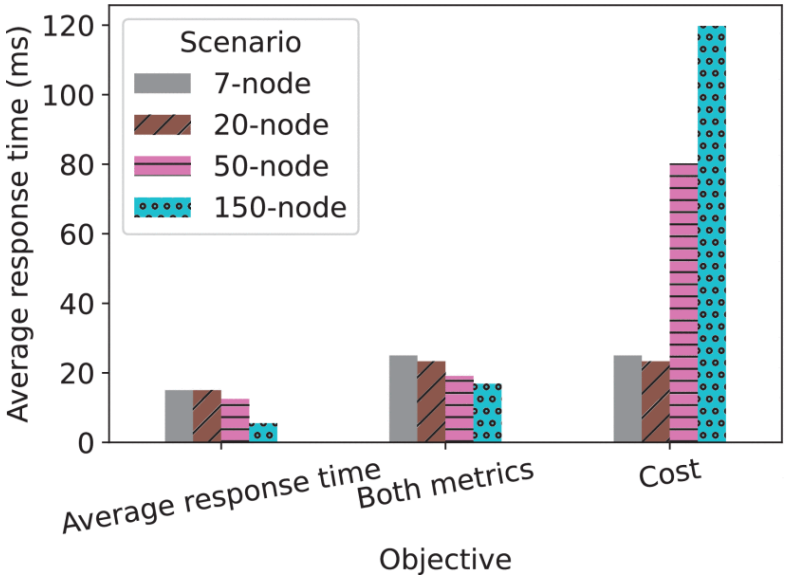

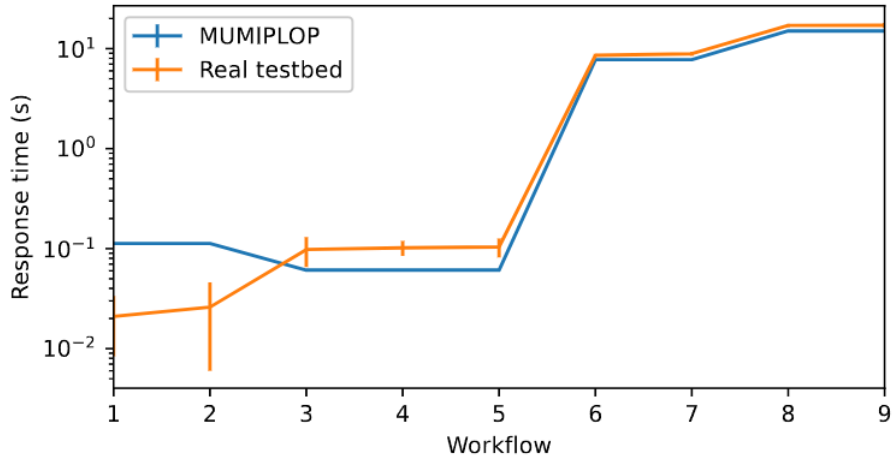

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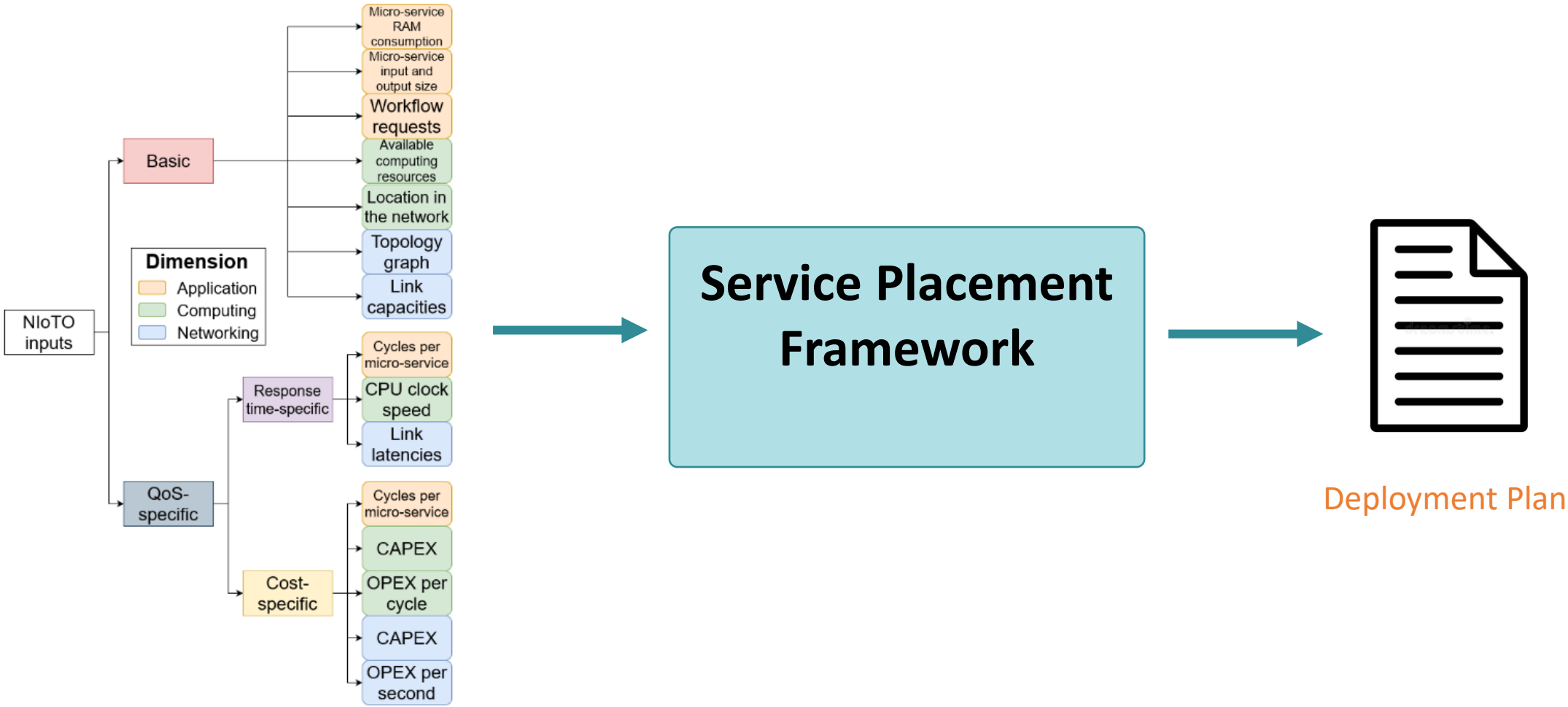

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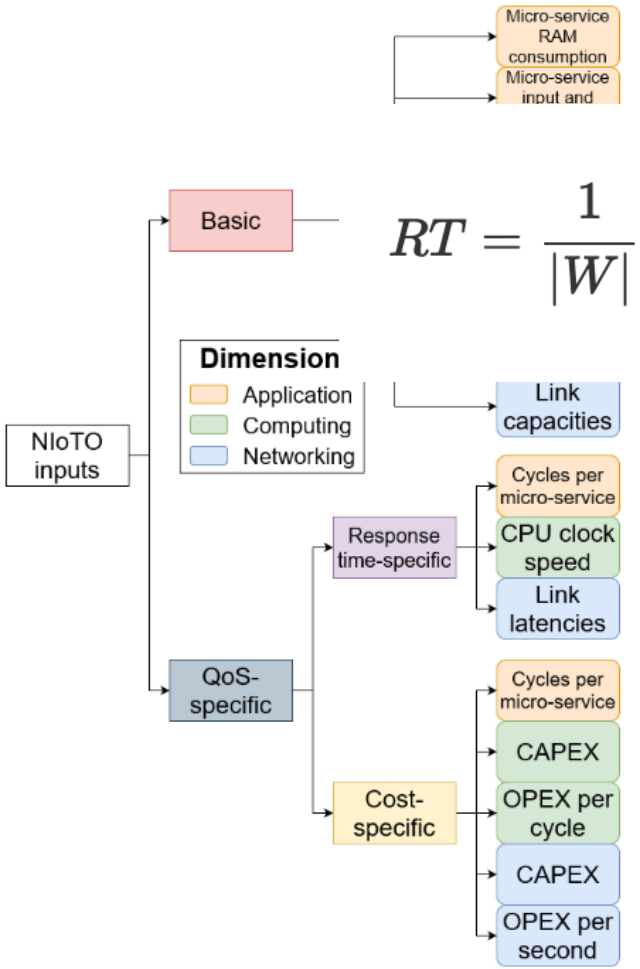

$$RT = \frac{1}{|W|} \sum_{w \in W} EXEC_w + LAT_\iota$$

$$\mathrm{CAPEX} = \sum_{c \in C} (\mathrm{CAPEX}_c u_c) + \sum_{s \in S} \left(\mathrm{CAPEX}_s u_s + \mathrm{CAPEX}_s^{\mathrm{CNT}} x_s \right).$$

$$\mathrm{OPEX} = \sum_{c \in C} \left(\sum_{w \in W} \sum_{a=1}^{|w|} \mathrm{OPEX}_c^{\Omega} \Omega_{m_a} z_{cm_a}^{w} \right) + \sum_{s \in S} \left(\mathrm{OPEX}_s u_s + \mathrm{OPEX}_s^{\mathrm{CNT}} x_s \right).$$

Deployment Plan

$$\min \epsilon_{RT} RT + \epsilon_{\mathrm{COST}} (\mathrm{CAPEX} + \mathrm{OPEX}).$$

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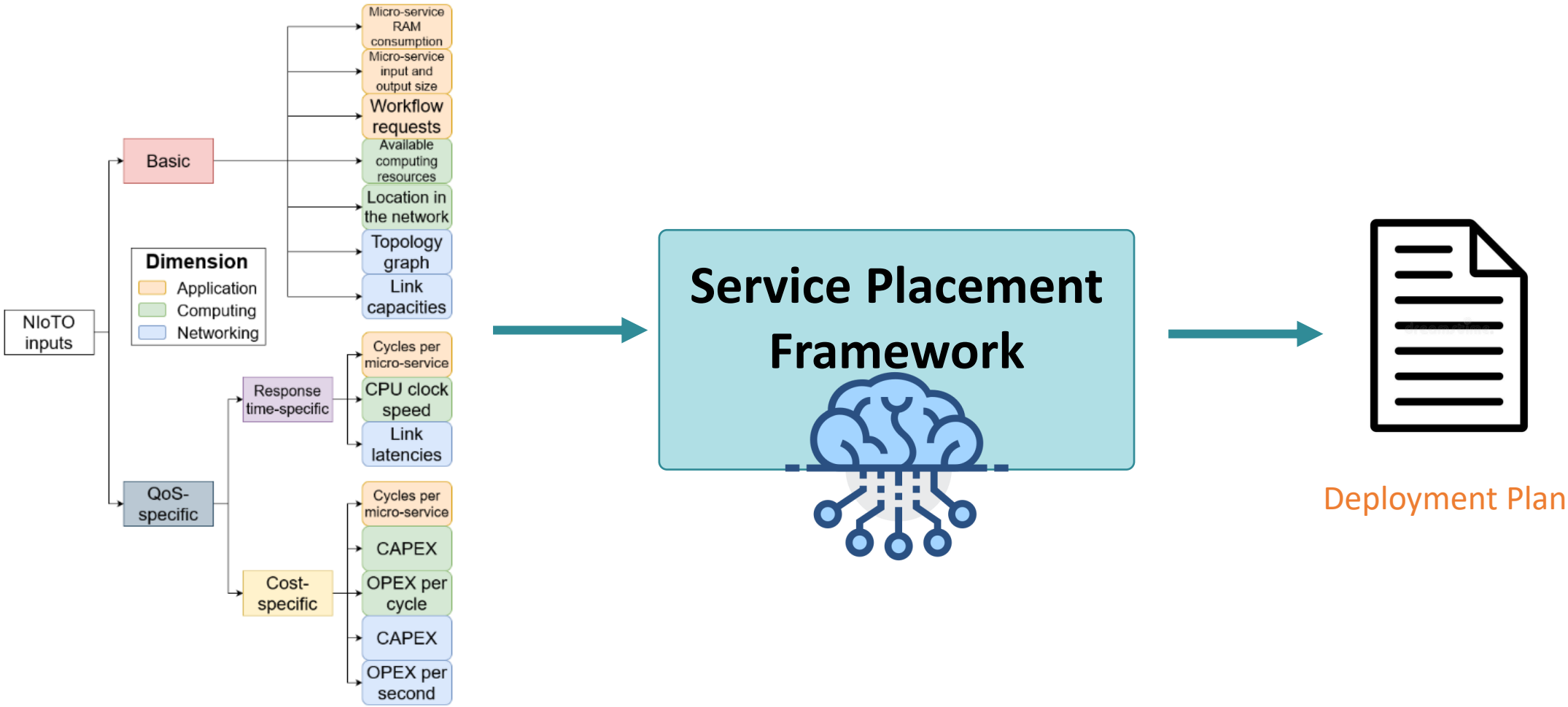
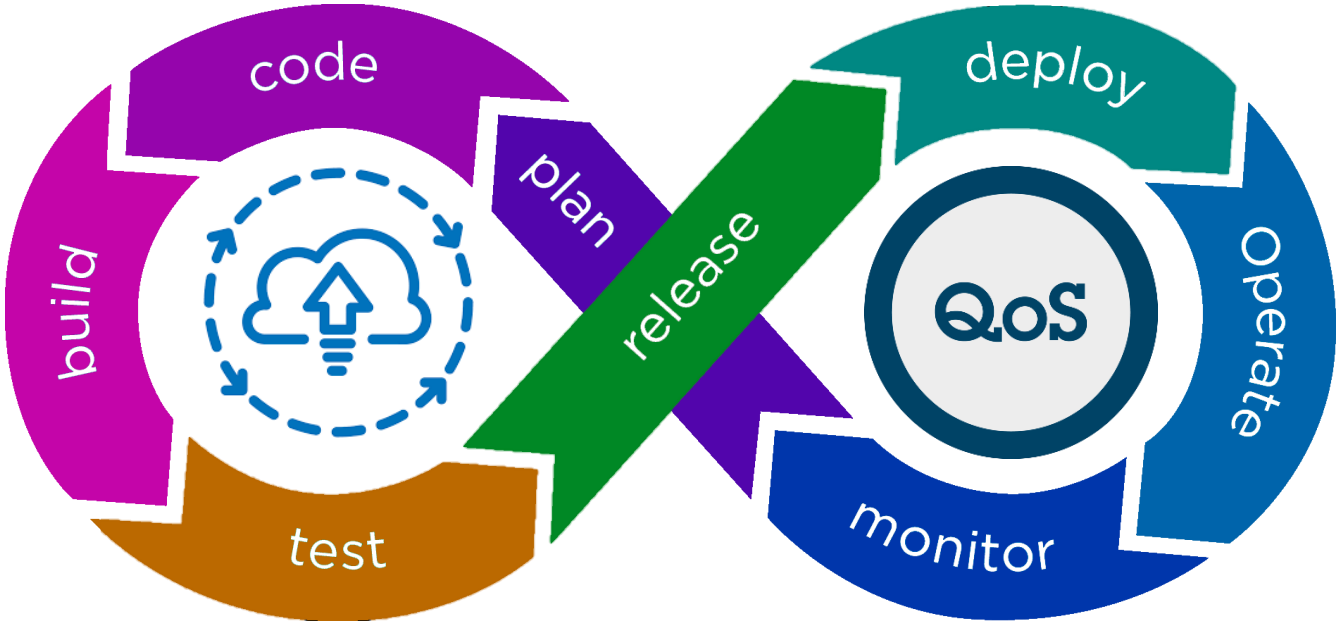


Continuous Deployment on the Continuum



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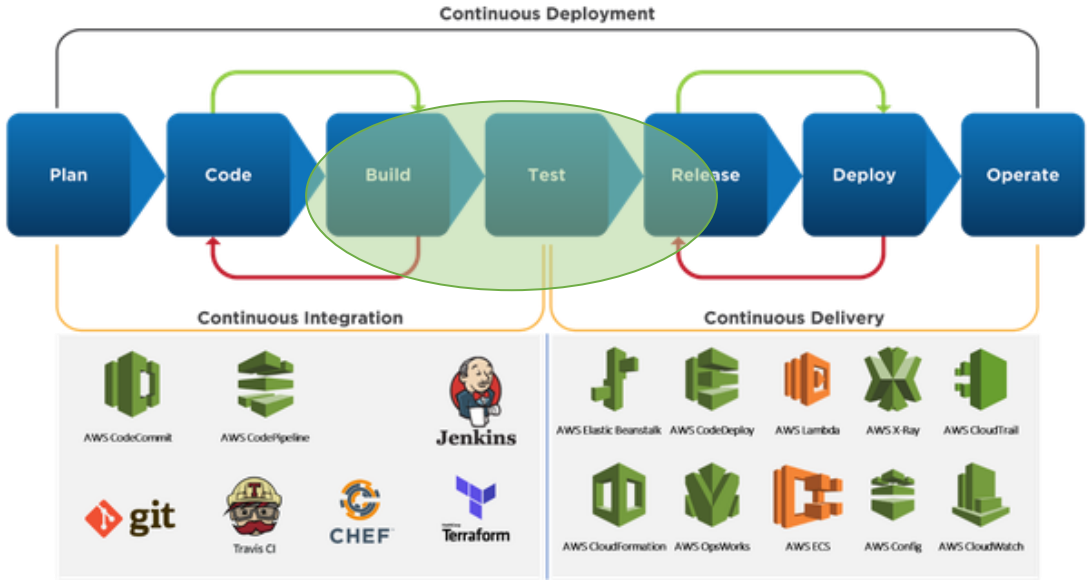

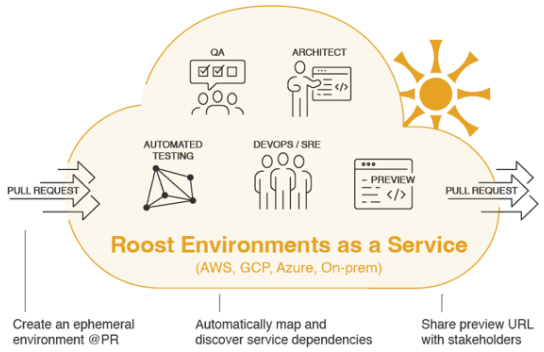

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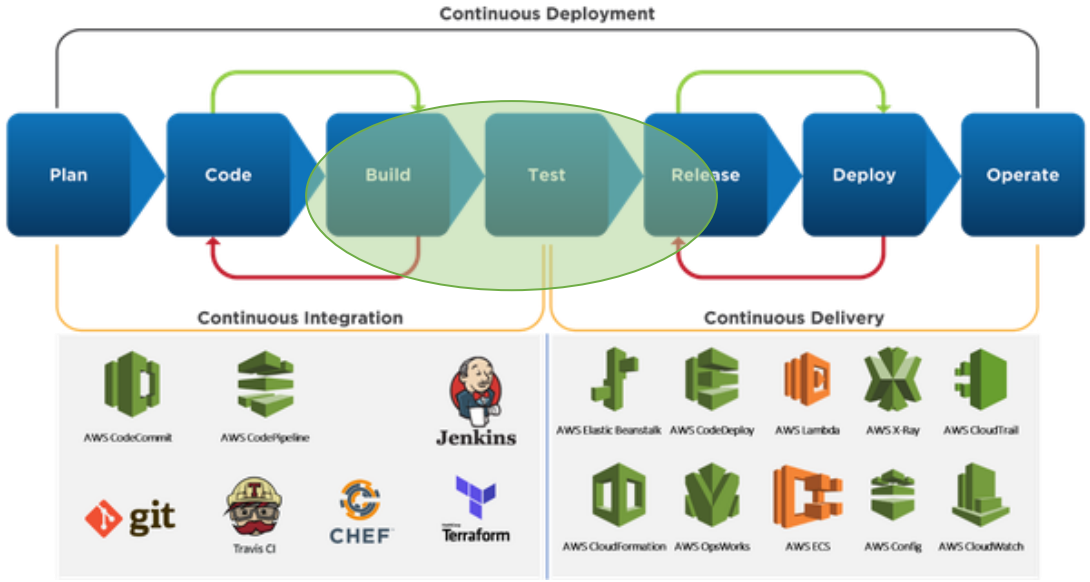
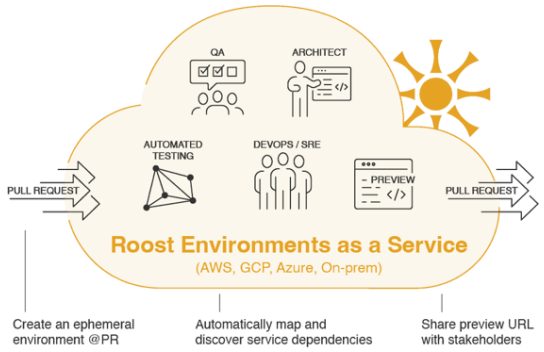
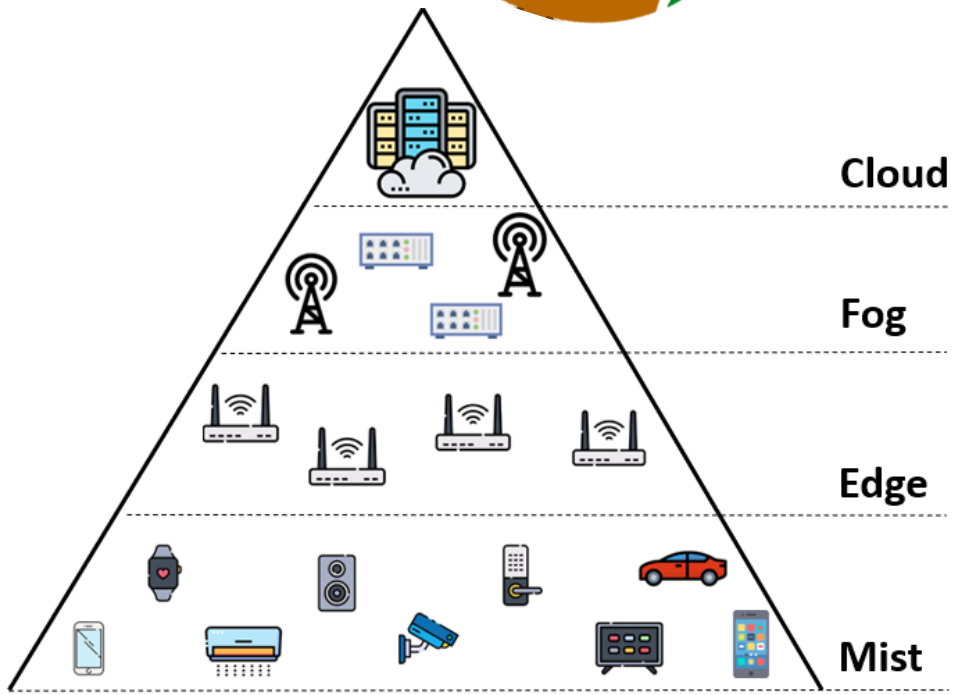
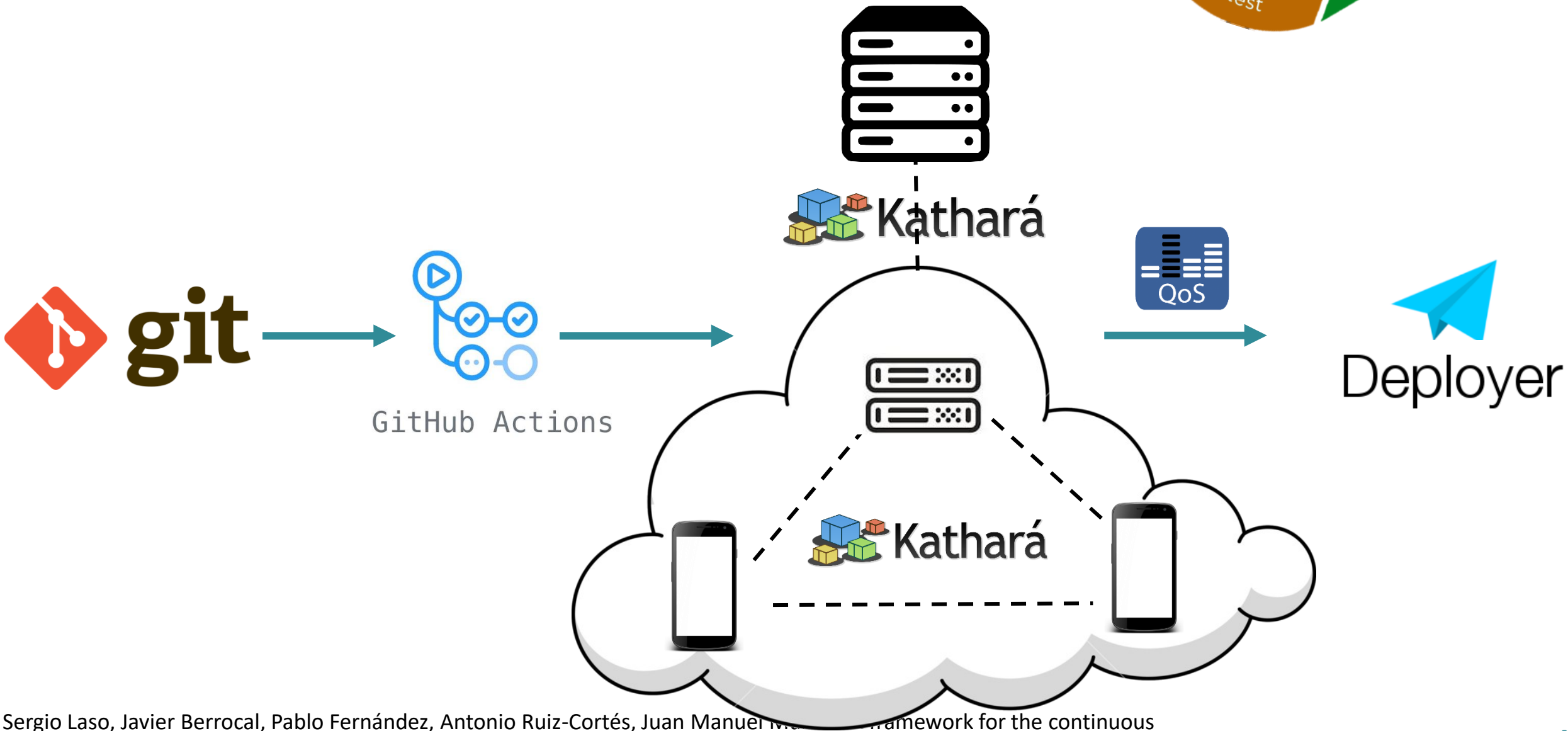






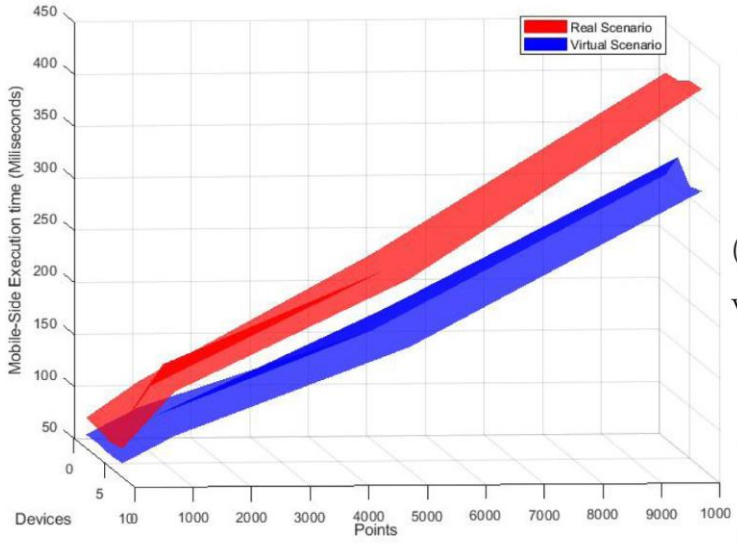
How can we test distributed application in an environments close to the real infrastructure?

Continuous Deployment on the Continuum

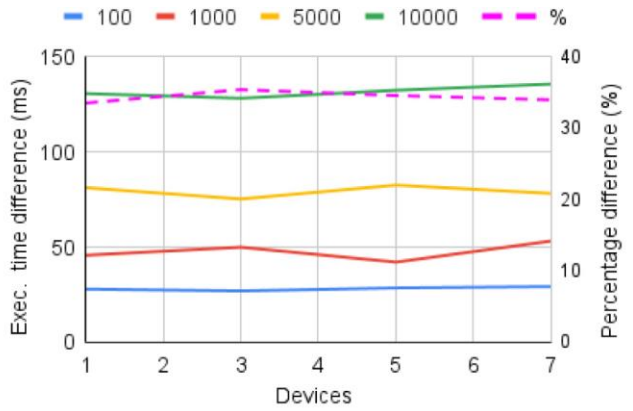


Sergio Laso, Javier Berrocal, Pablo Fernández, Antonio Ruiz-Cortés, Juan Manuel M[illegible]framework for the continuous evaluation of the QoS of distributed mobile applications. Pervasive Mob. Comput. 84: 101627 (2022)

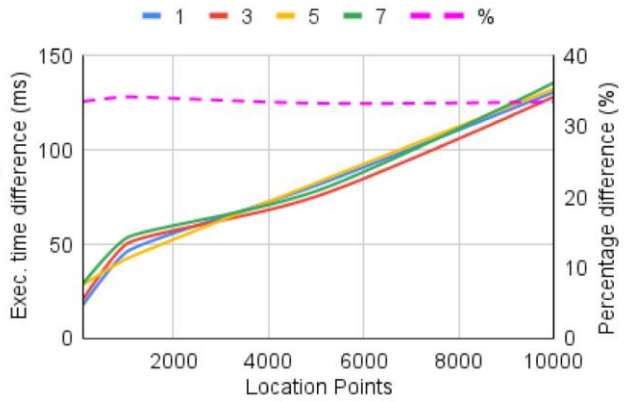
Continuous Deployment on the Continuum



(a) Execution time



(b) Differences depending on the num of devices



(c) Differences depending on the num of points

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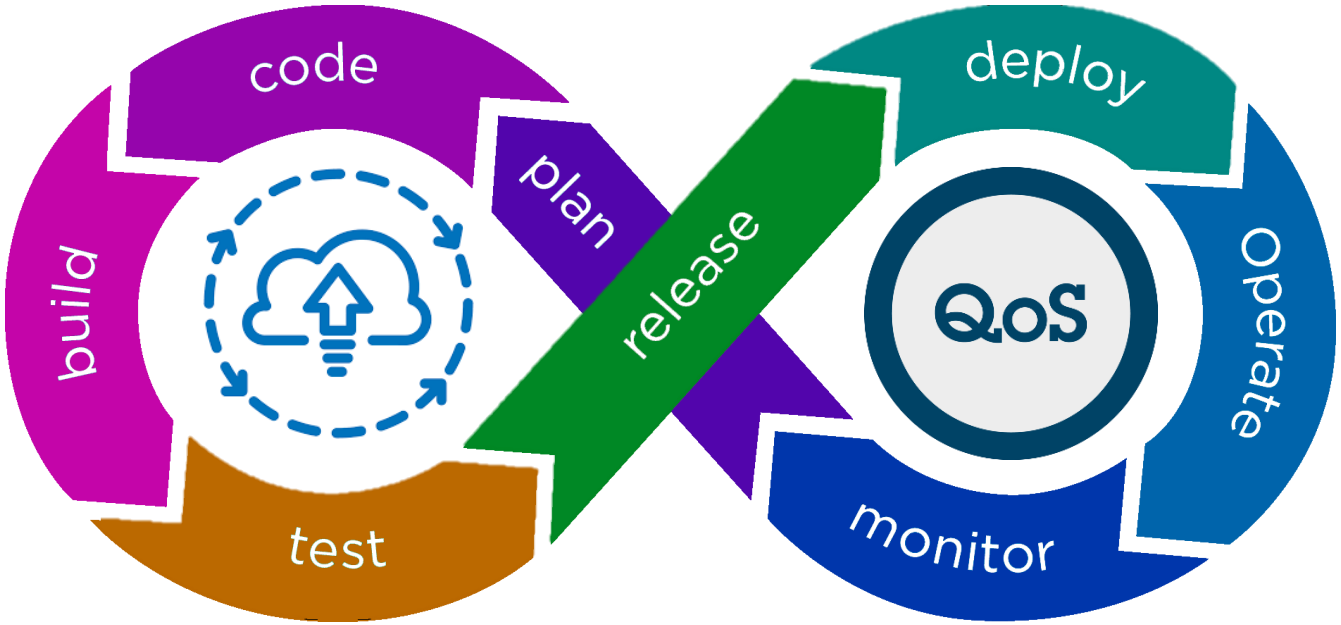
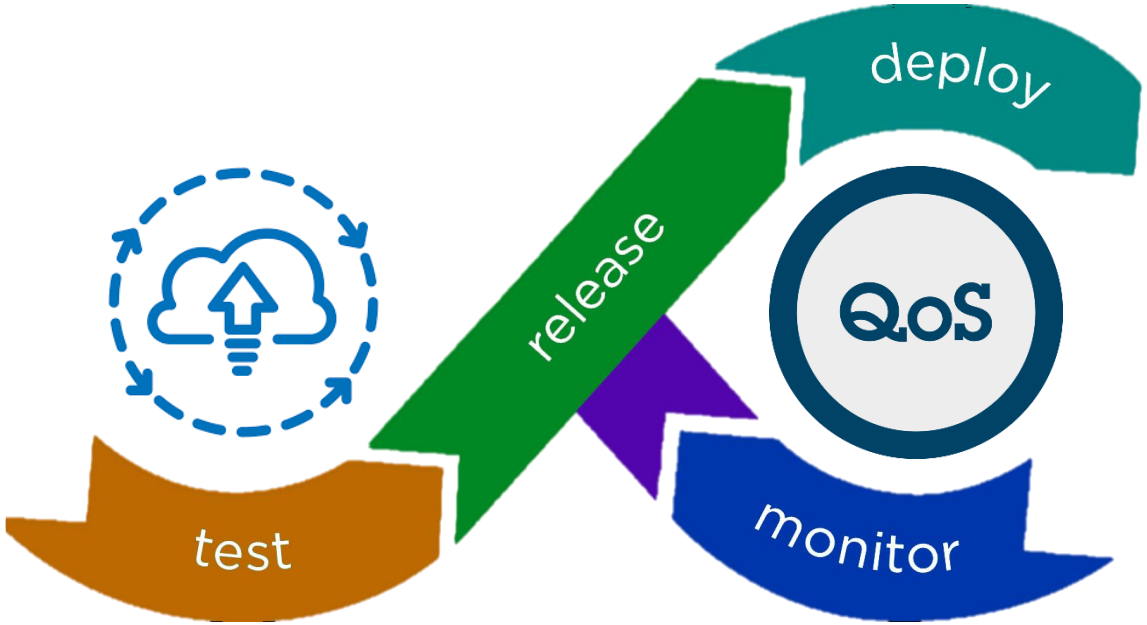
Continuous Deployment on the Continuum

Continuous Deployment on the Continuum



Continuous Deployment on the Continuum



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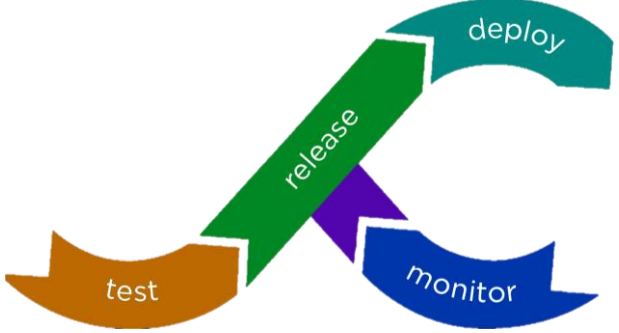
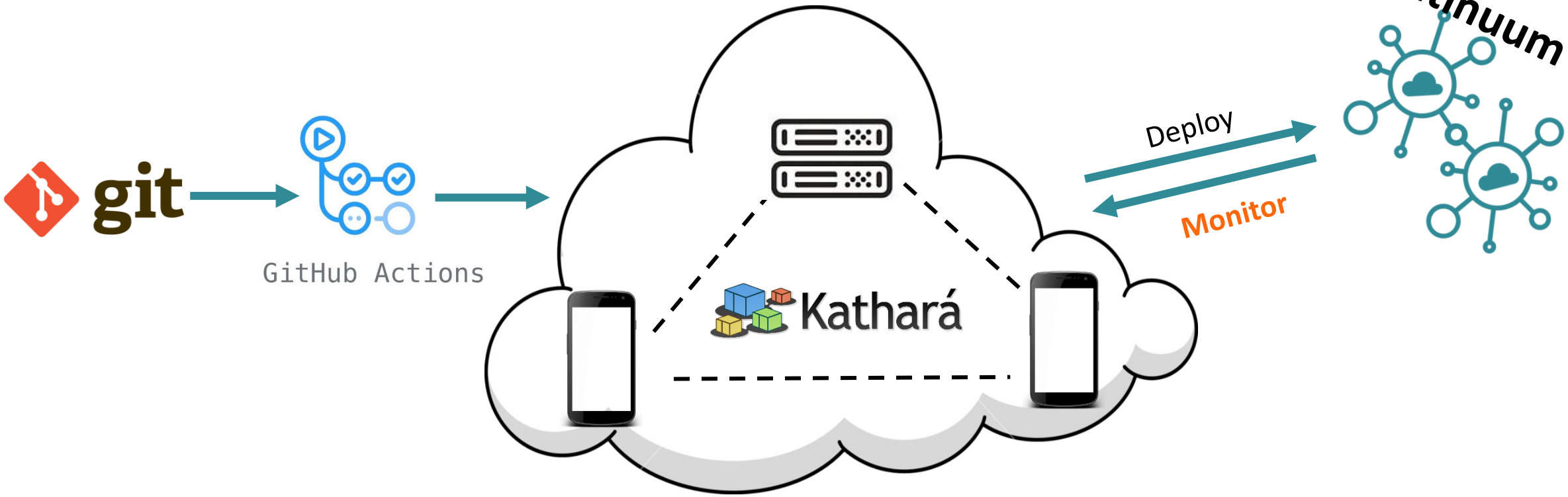
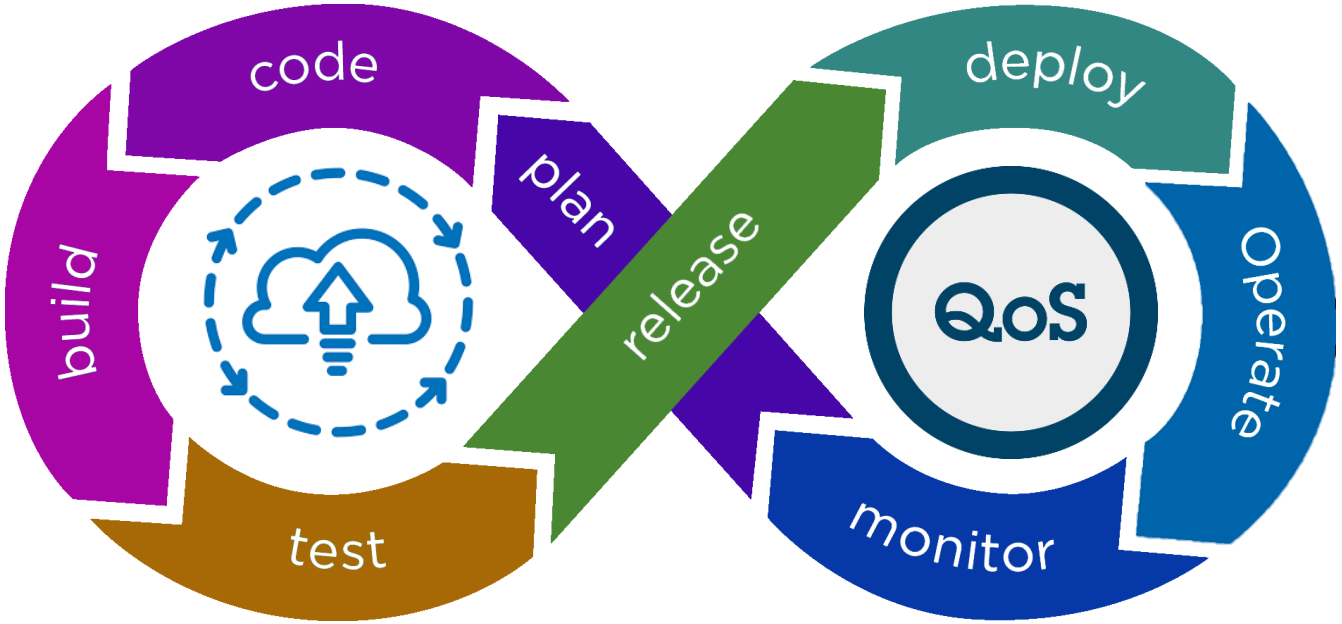


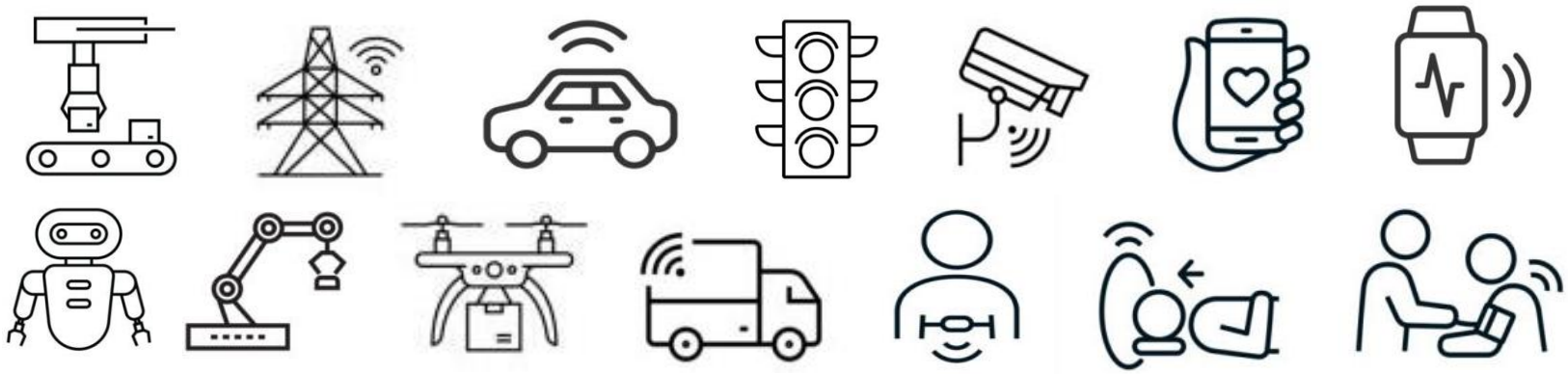


Digital Shadow

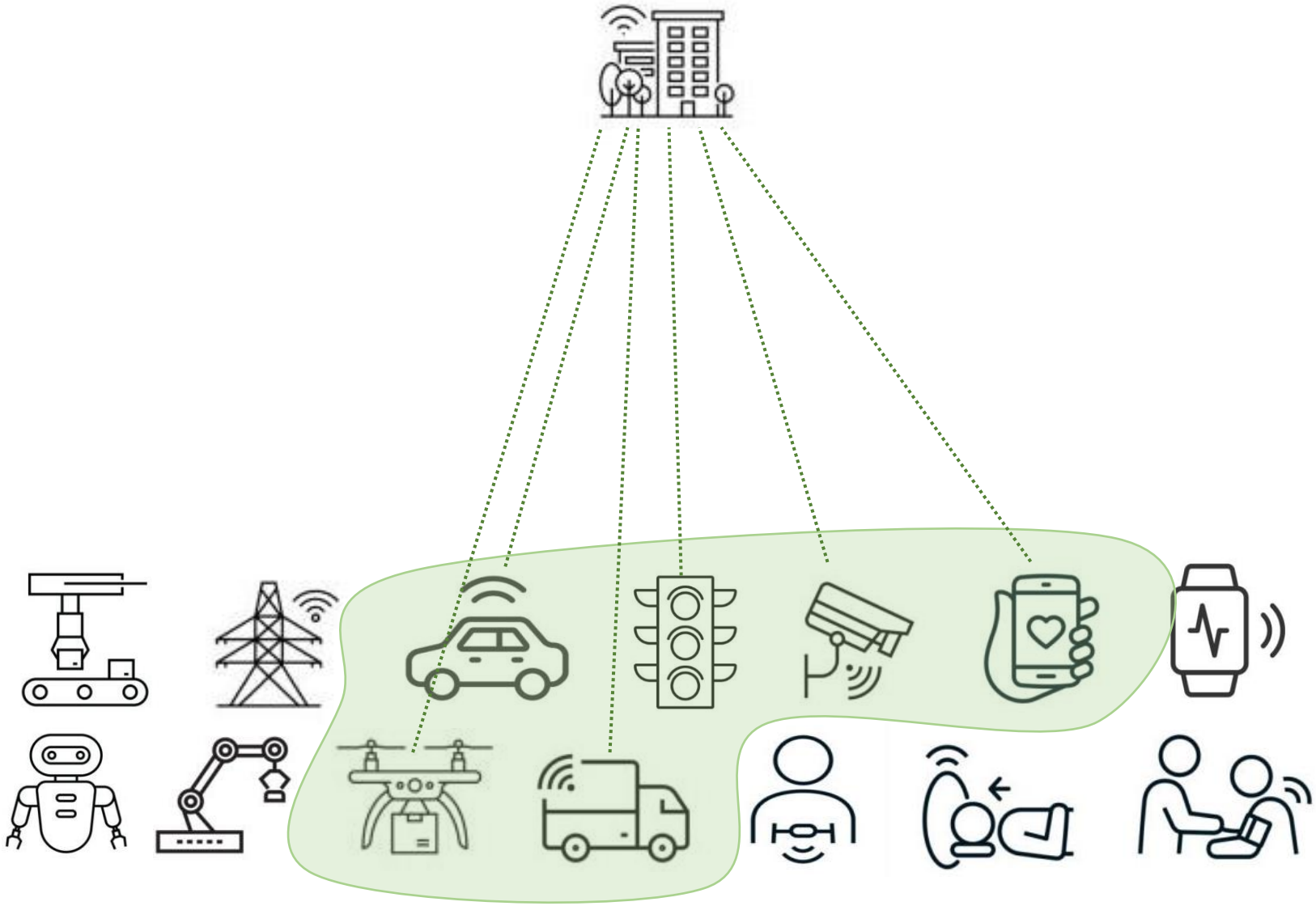
Elastic Computing Continuum



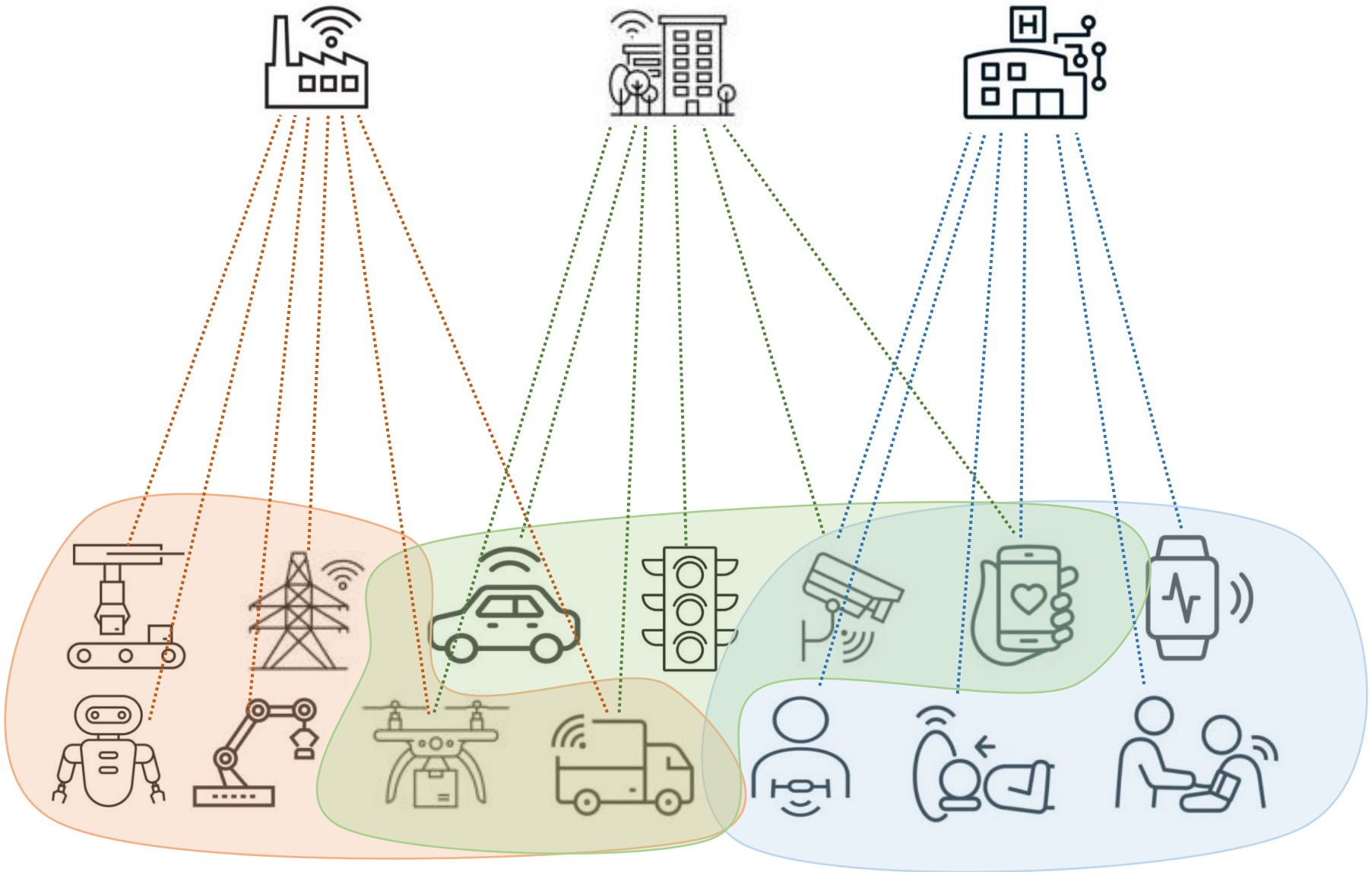
Elastic Computing Continuum



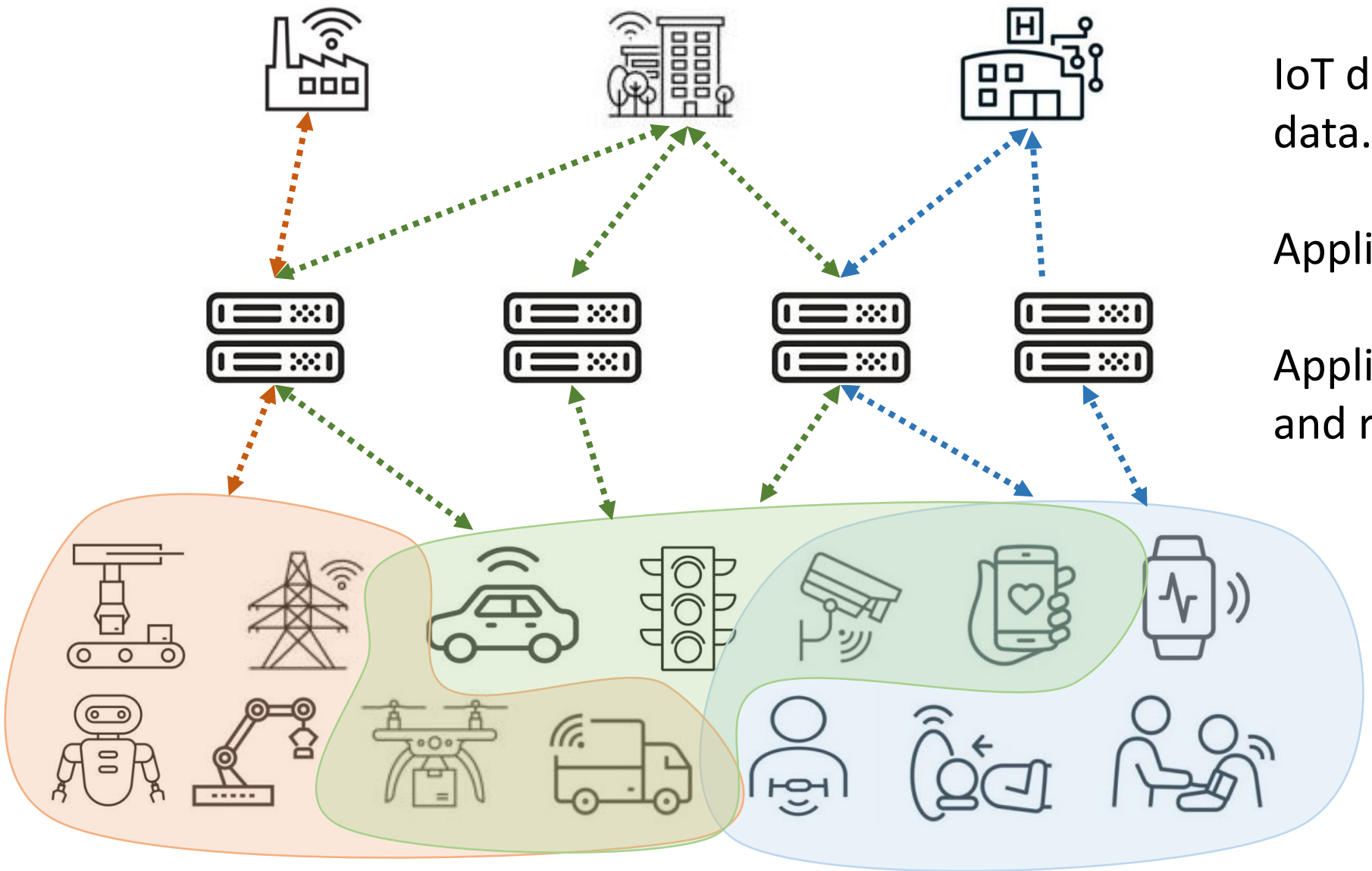
Elastic Computing Continuum



Elastic Computing Continuum



Elastic Computing Continuum

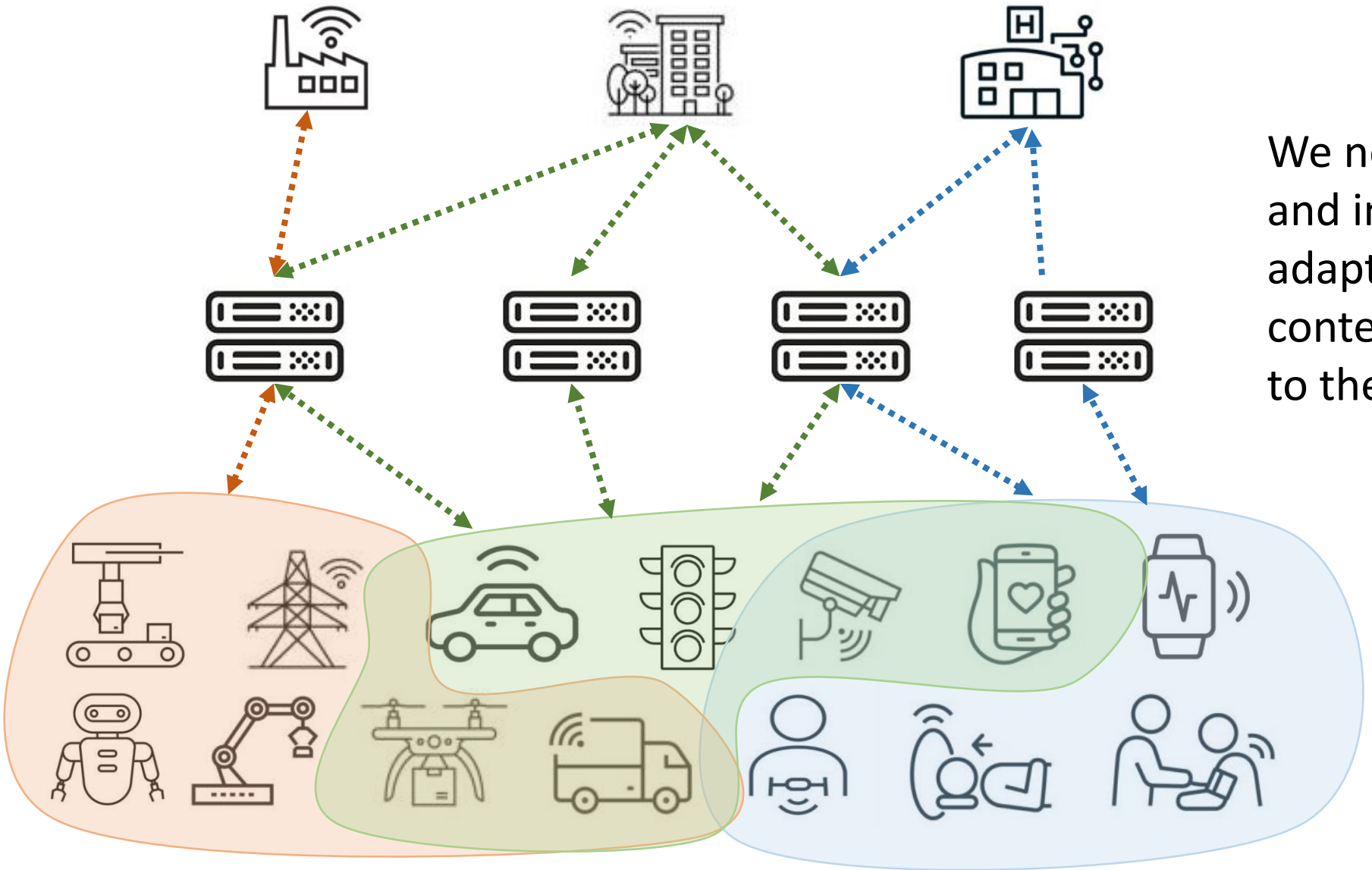


IoT devices generate the same data.

Applications use similar data.

Applications compete for data and resources.

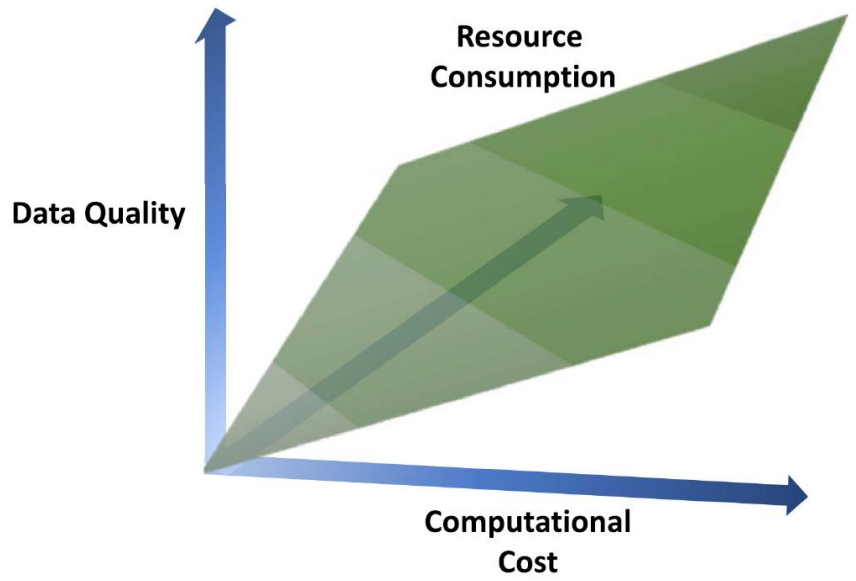
Elastic Computing Continuum

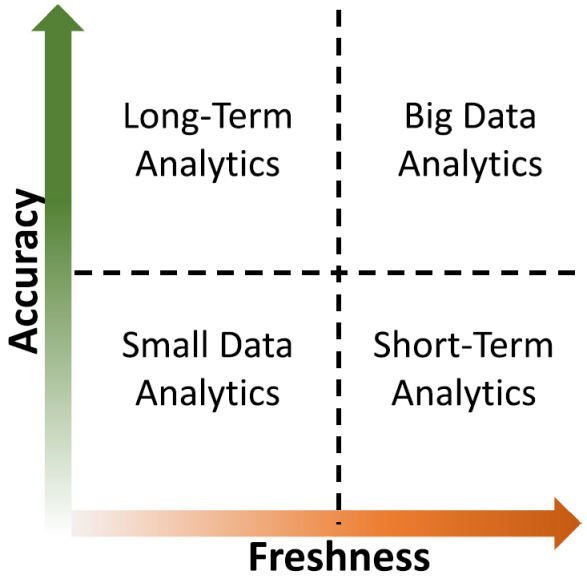


We need elastic applications and infrastructures able to adapt themselves to the context, the environment and to the users.

Elastic Computing Continuum

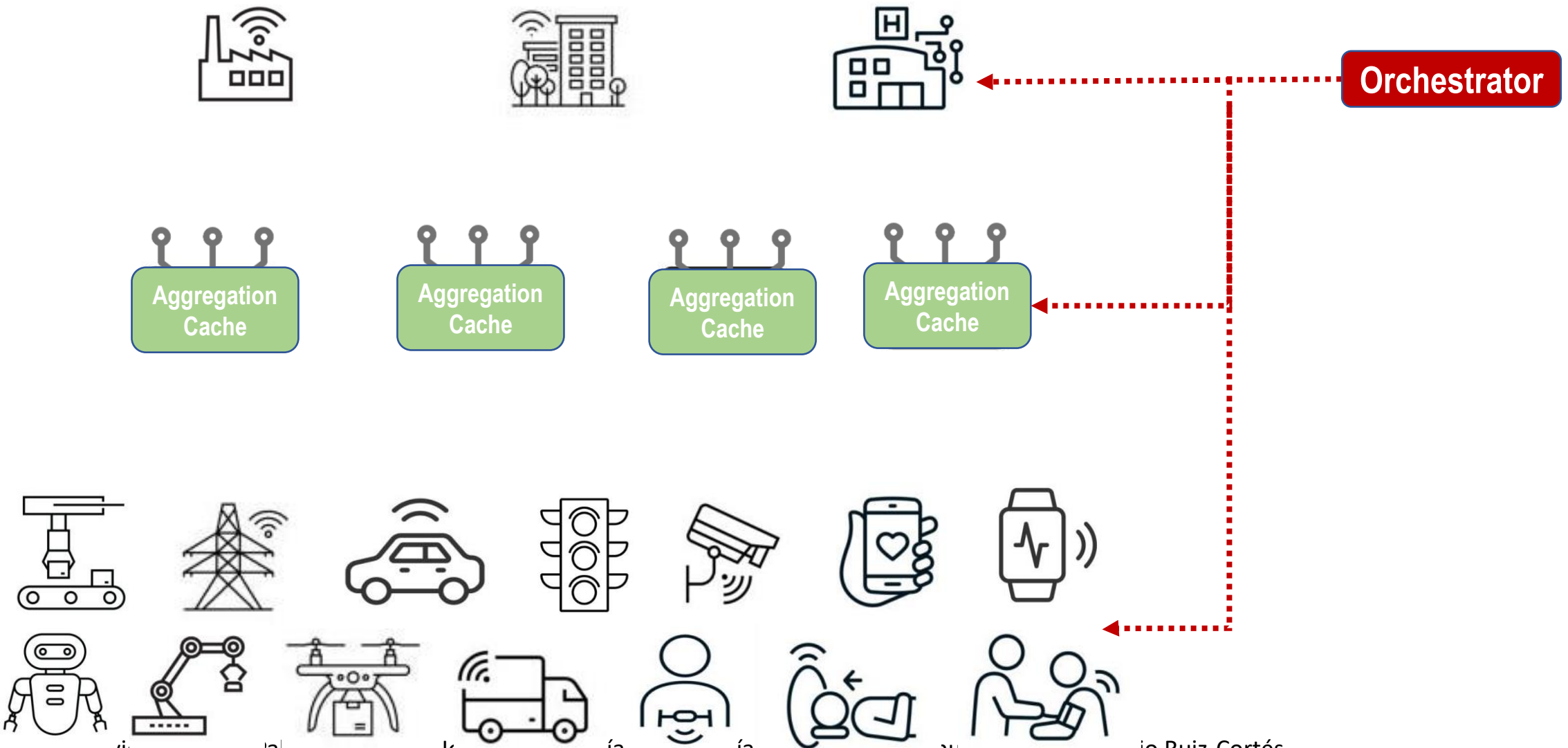
Data analytics allow companies to process large volumes of information in order to: control the procedures, find trends, problems, etc.





Sergio Laso, Javier Berrocal, Pablo Fernandez, José María García, José García-Alonso, Juan Manuel Murillo, Antonio Ruiz-Cortés, Schahram Dustdar: Elastic Data Analytics for the Cloud-to-Things Continuum. IEEE Internet Comput. 26(6): 42-49 (2022)

Elastic Computing Continuum



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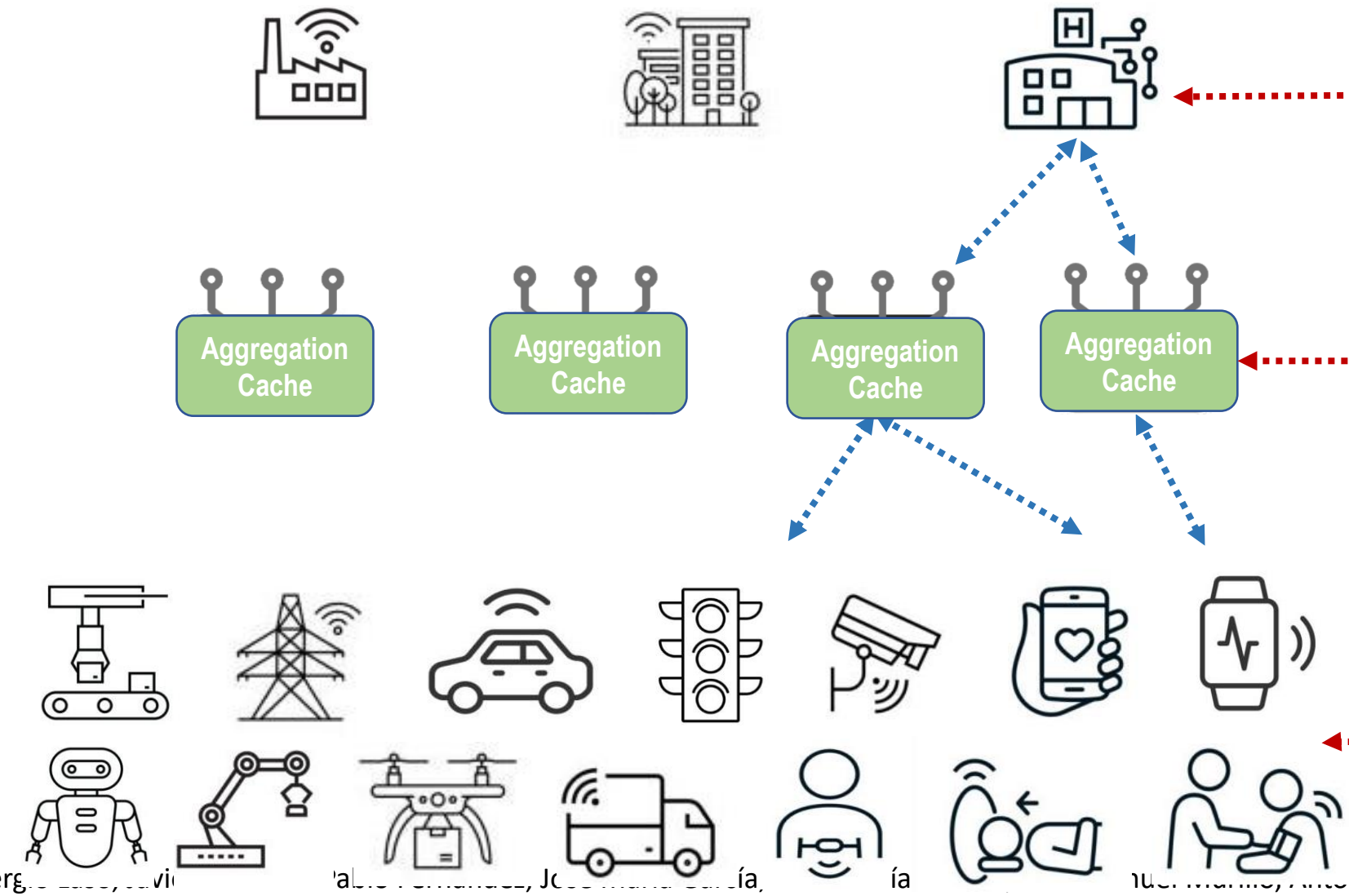

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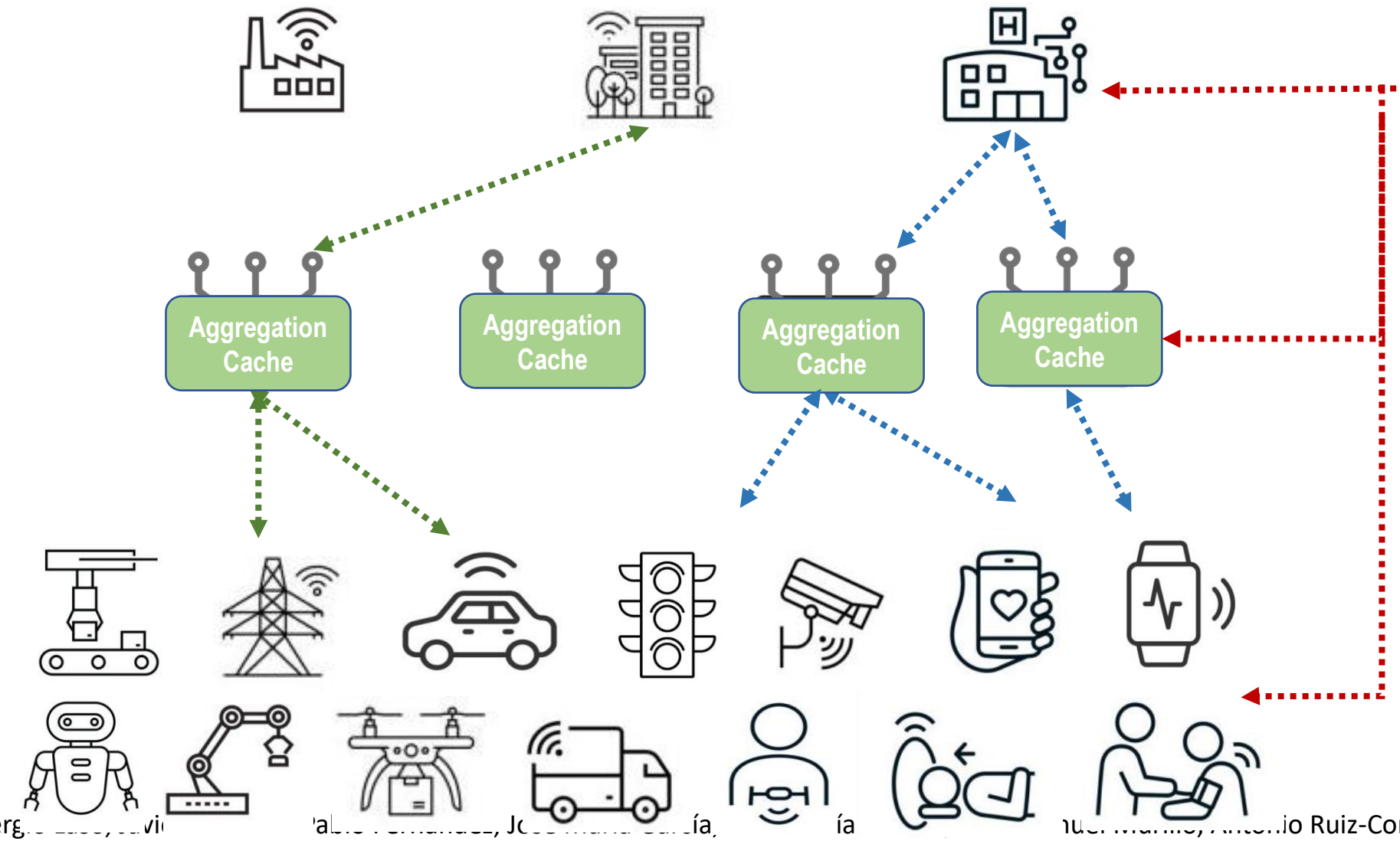

Operate

Orchestrator

Analytic - Hospital
Accuracy: LOW
Freshness: HIGH

Analytic – City Council
Accuracy: LOW
Freshness: LOW

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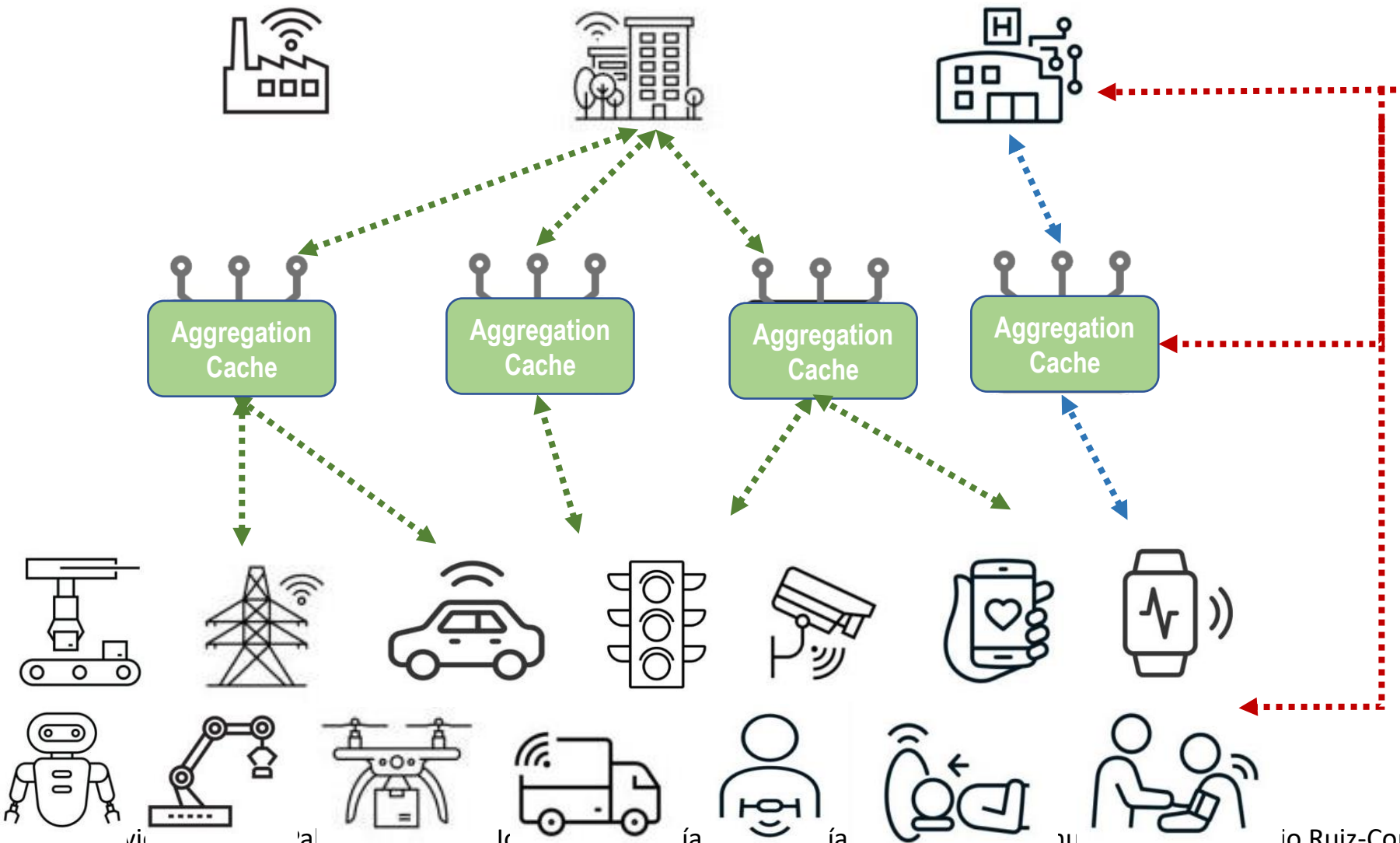

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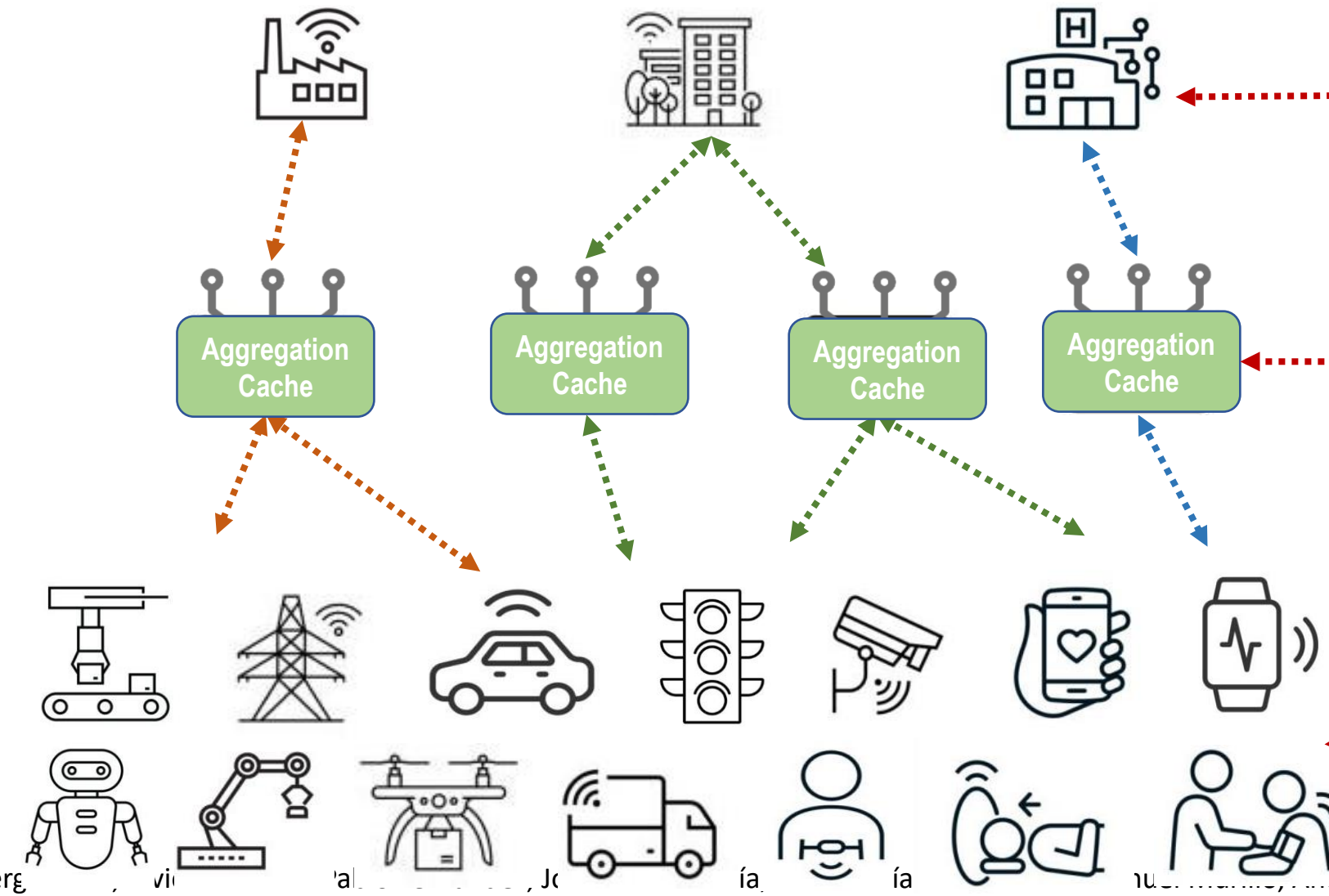

Operate

Orchestrator

Analytic - Hospital
Accuracy: LOW
Freshness: HIGH

Analytic – City Council
Accuracy: LOW
Freshness: LOW

Analytic – City Council
Accuracy: HIGH
Freshness: HIGH

Analytic – Industry
Accuracy: HIGH
Freshness: HIGH

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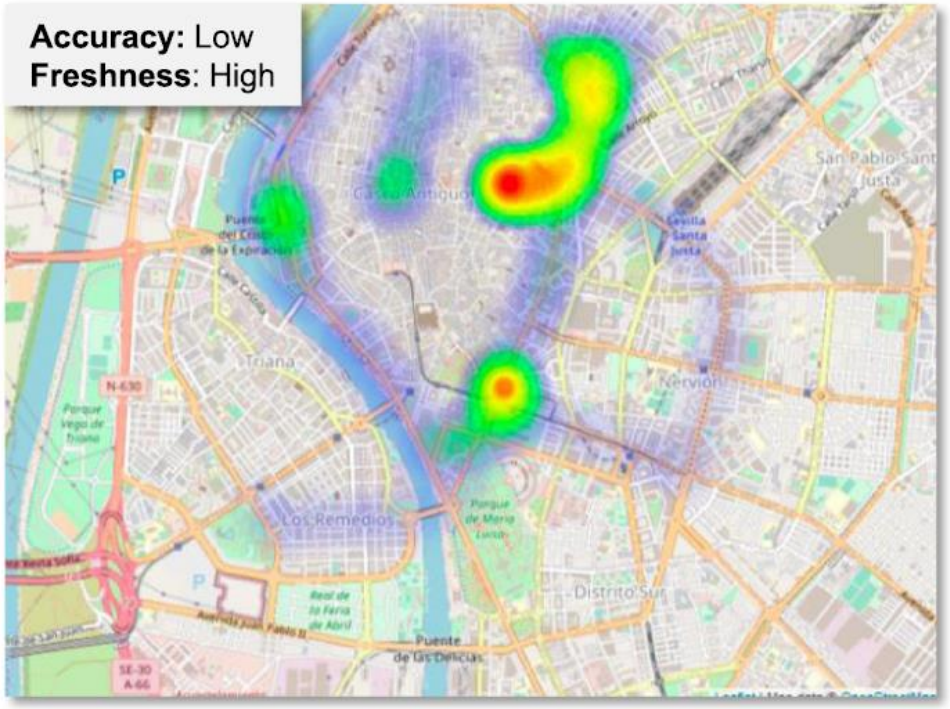
Elastic Computing Continuum

Operate

Smart-city case study



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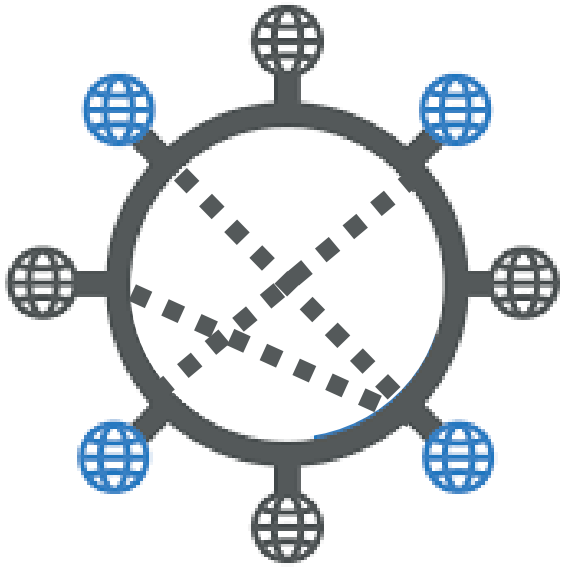
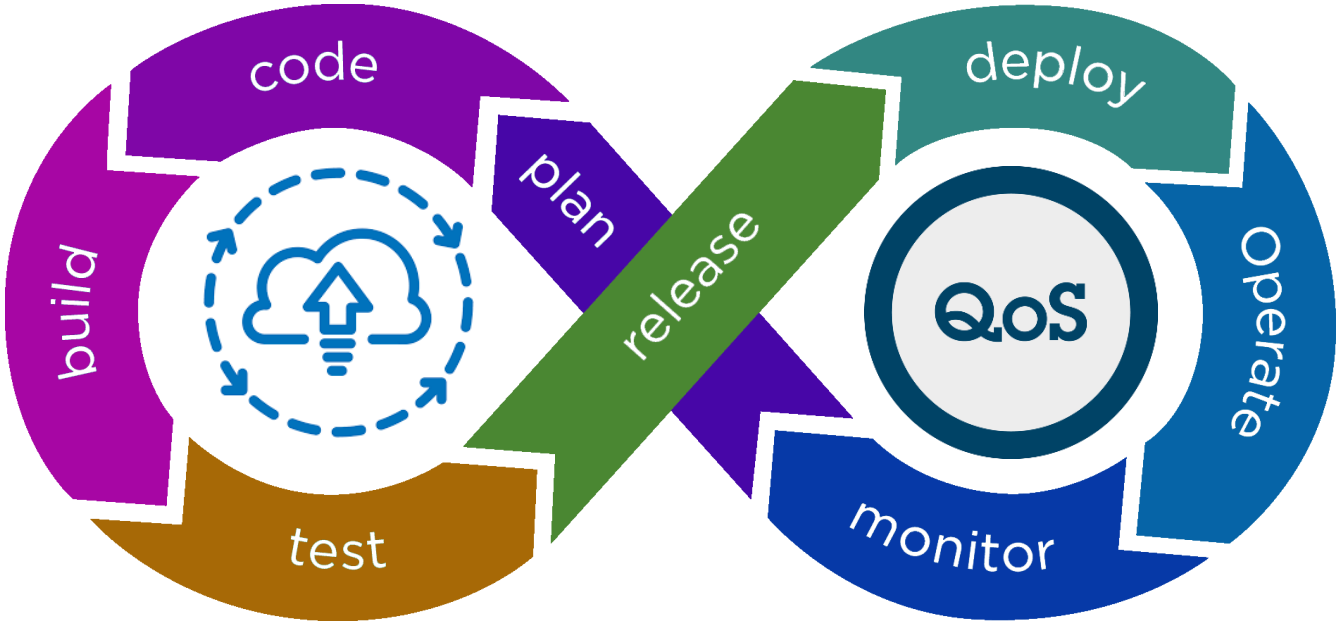
Elastic Computing Continuum

Smart orchestration



Smart Choreography

Continuous Adaptation



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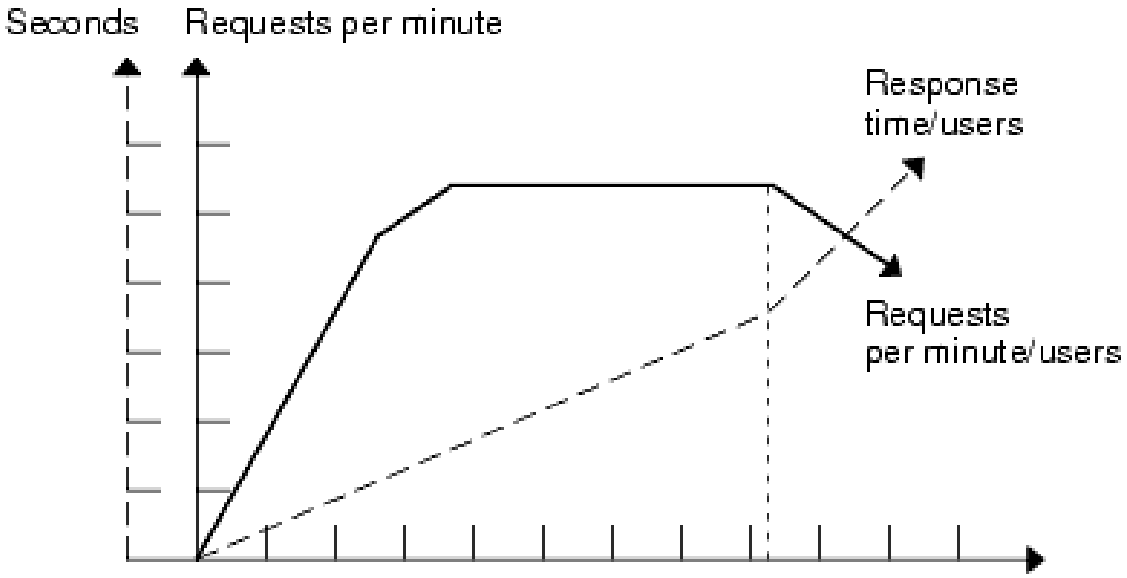

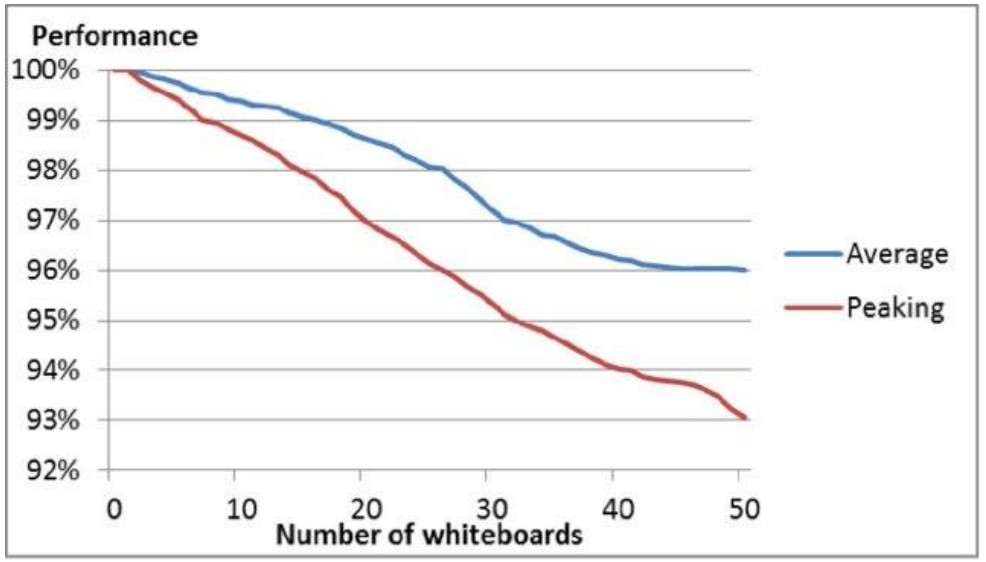

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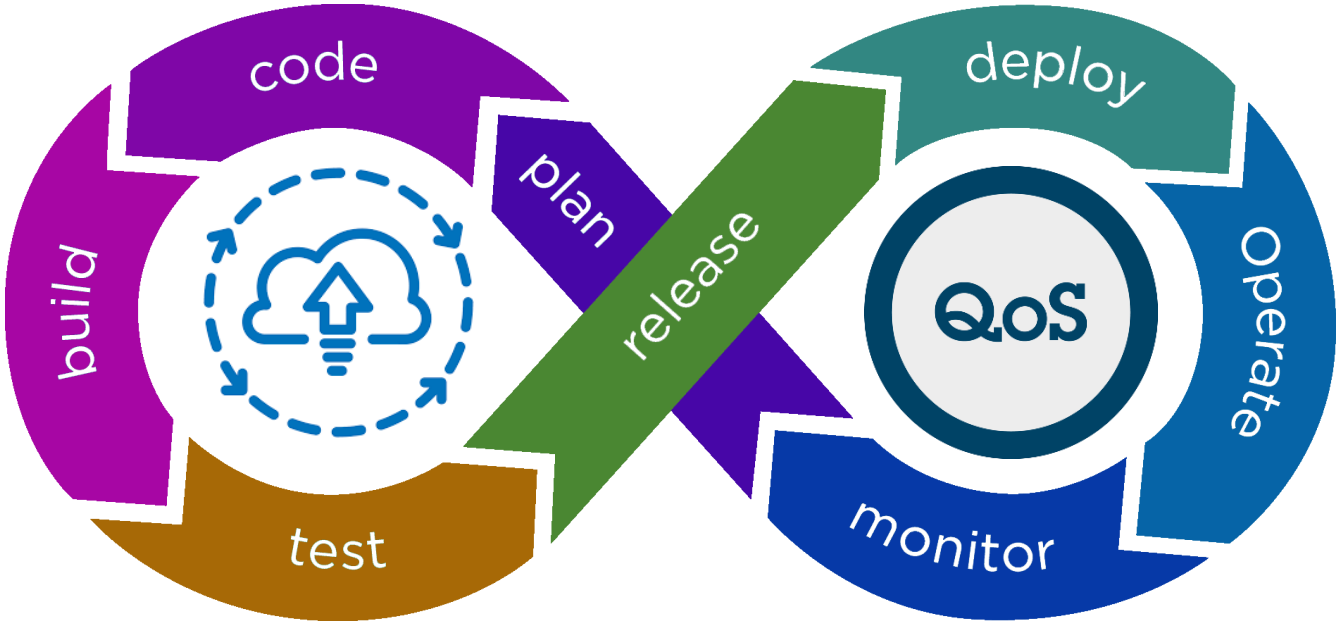
Sun Java System Application. Deployment Planning Guide

Continuous Adaptation



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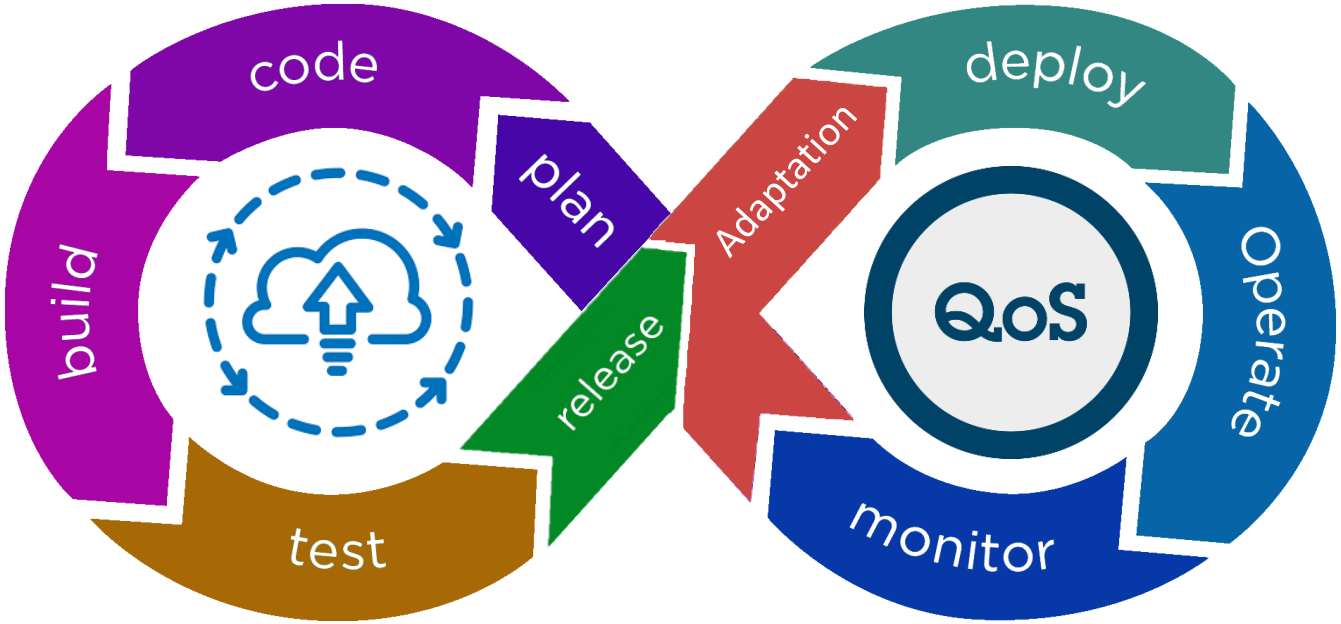

Herrera, J. L., Berrocal, J., Forti, S., Brogi, A., & Murillo, J. M. (2023). Continuous QoS-aware adaptation of Cloud-IoT application placements. *Computing*, 1-23

Continuous Adaptation

- *Broken deployments* are situations in which the existing application placement cannot be used successfully after a change in the environment.
- *QoS violations* are subtler than broken deployments and represent dependability issues.

Once detected, the application placement needs to be adapted to the new environment.

Continuous reasoning is aimed at finding which microservices of the application placement need to be migrated (i.e., moved between nodes) after a change.

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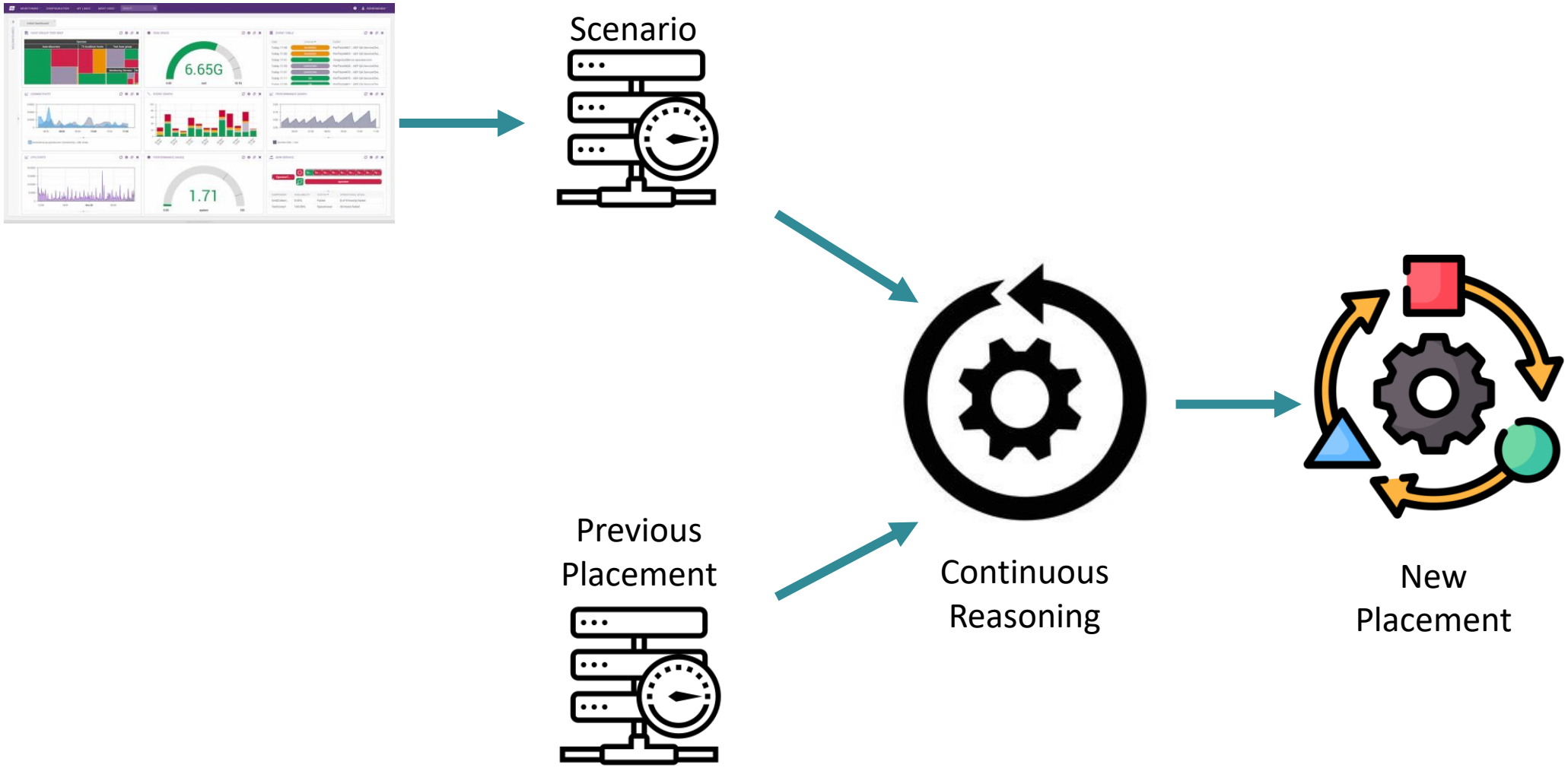

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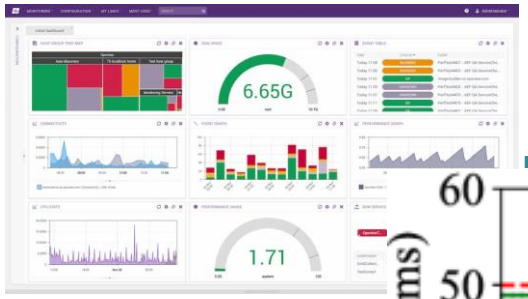
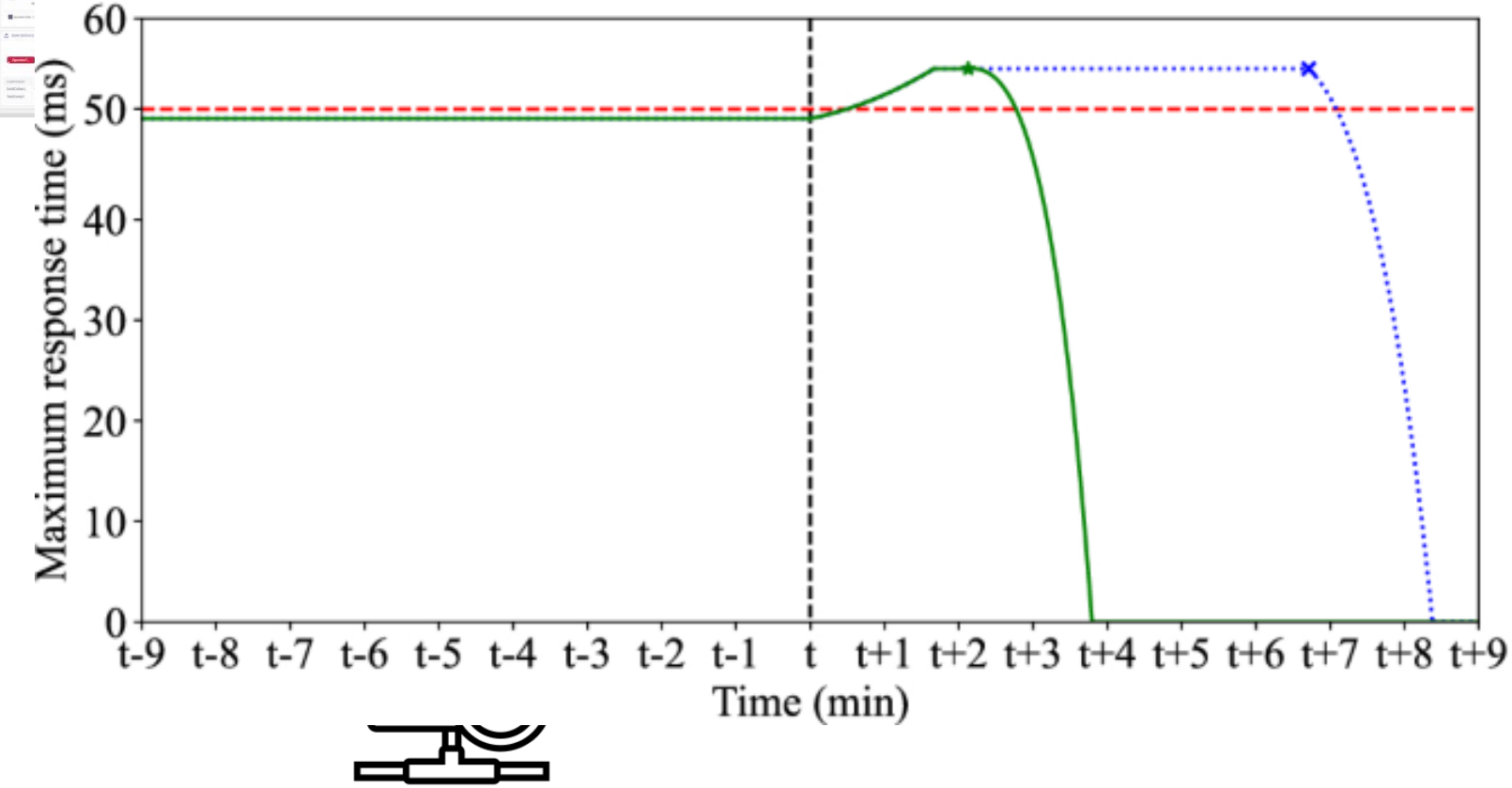


Current Scenario



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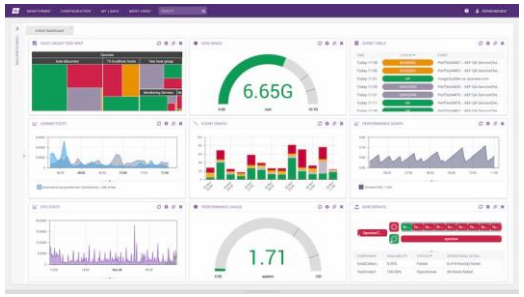


Current Scenario

Future Scenario

Previous Placement

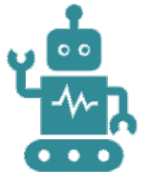
Continuous Reasoning

New Placement

Conlusion

Computing continuum allows developers to better control de QoS

It is a complex infrastructure that requires highly skilled workers



New methodologies and tools are required to improve how developers and operators interact with it.

AI can be used by these tools to automate part of the process and reduce the required skills

Javier Berrocal
University of Extremadura
Quercus Software Engineering Group
Social and Pervasive Innovation Lab

jberolm@unex.es
@jberolm

Thank you very much