Alma Mater Studiorum – University of Bologna
CdS Laurea Magistrale (MSc) in
Computer Science Engineering

Mobile Systems M course (8 ECTS)
II Term – Academic Year 2021/2022

08 – Application Domains and Possible Scenarios for Project Activities

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http://lia.disi.unibo.it/Courses/sm2122-info/

Examples of Application Domains & Possible Scenarios for Project Activities

Examples of recent and relevant ***application domains*** for mobile services/systems and case studies towards ***possible project activities***:

- ***Social-aware*** resource sharing ***in spontaneous networks***
- ***ParticipAction***, crowdsensing and participatory task assignment in smart city environments
- ***Vehicular traffic management*** enabled by "traditional" and smartphone-based sensing (vehicle2vehicle and vehicle2RSU communications)
- ***Middleware for Machine-to-Machine (M2M) communications***, ***fog computing oriented***, for efficiency, locality optimizations, batching/aggregation, edge/fog computing, industrial cloud, and container optimizations (e.g., migration)

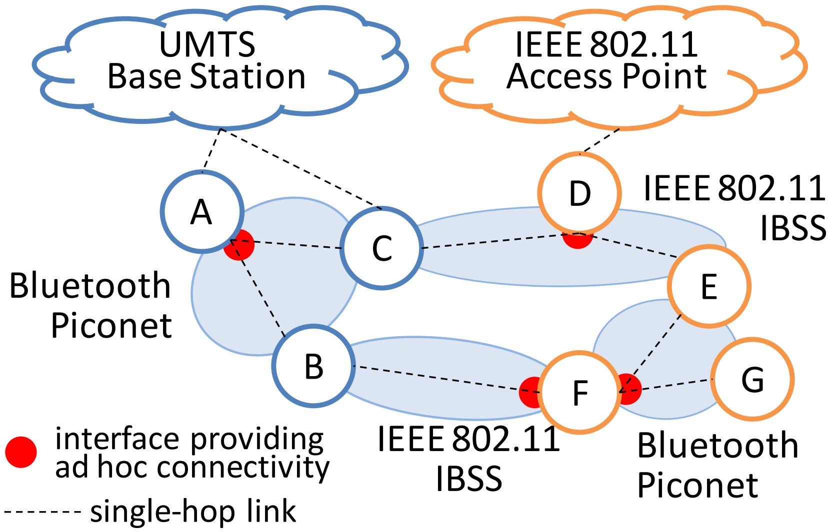
Real Ad-hoc Multi-hop Peer-to-peer (RAMP)

Impromptu interconnection of fixed and mobile nodes

- Not only to achieve Internet connectivity (Always Best Connected - ABC), but also to support users' willingness to ***share contents, resources, and services***
- Packet dispatching at application level over ***het platforms***
- Management of ***non-coordinated IP address spaces***

RAMP supports creation and mgmt of ***spontaneous networks***

- ***multi-hop*** end-to-end connectivity
- Users invoke and offer services (peer-to-peer)
- ***APIs*** to support development of ***new services*** in a simplified way



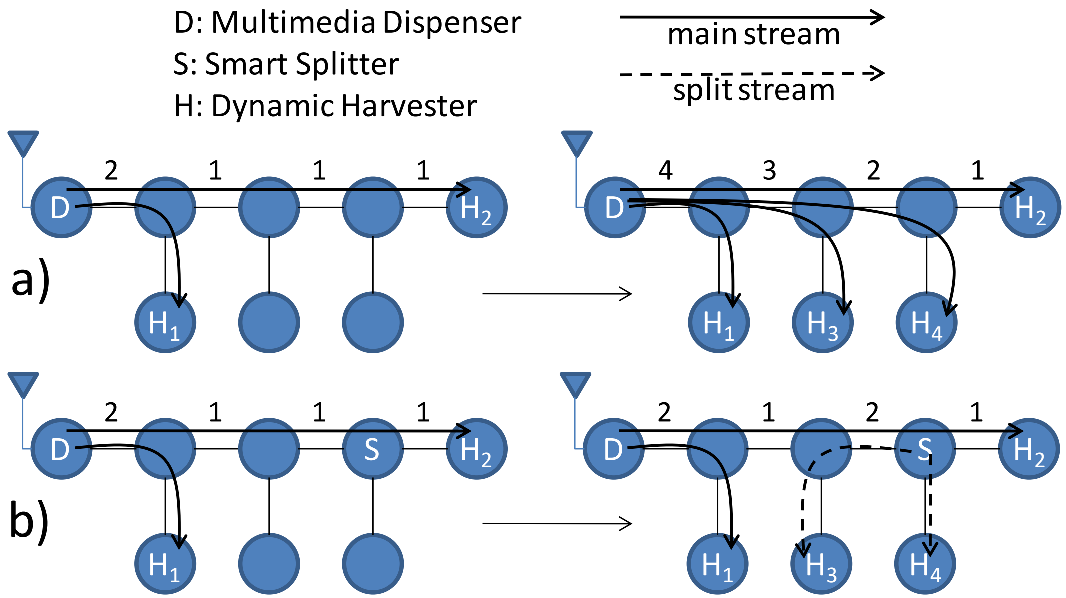
Example: Application-layer Multimedia Re-casting

1) Nodes perform end-to-end ***cooperative splitting*** of multimedia paths into differentiated segments

- Lower traffic on intermediate nodes

2) Nodes perform ***cooperative monitoring of stream quality*** (packet loss, jitter, …) and ***dynamically adapt*** flows (priority-based video frame dropping)

- ***fine-grained and per-segment*** management to reduce needed throughput close to bottlenecks that are identified at runtime



But also example of federation of ***UPnP localities***, …

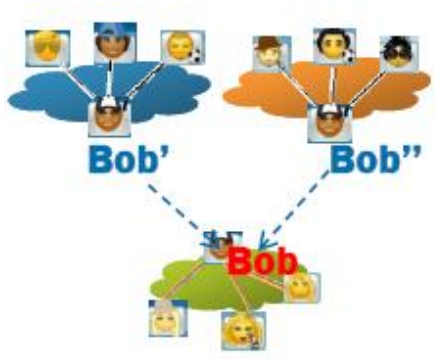
From Social Network Aggregation to Federated Social Networks

Social network aggregation

Some aggregation services already start to emerge: ***aggregate messages, status feeds, content, and friends*** from different and heterogeneous standalone social apps

- For instance, significant feature of ***cross-posting***

In this approach, ***users should have multiple accounts*** to the different social netw apps



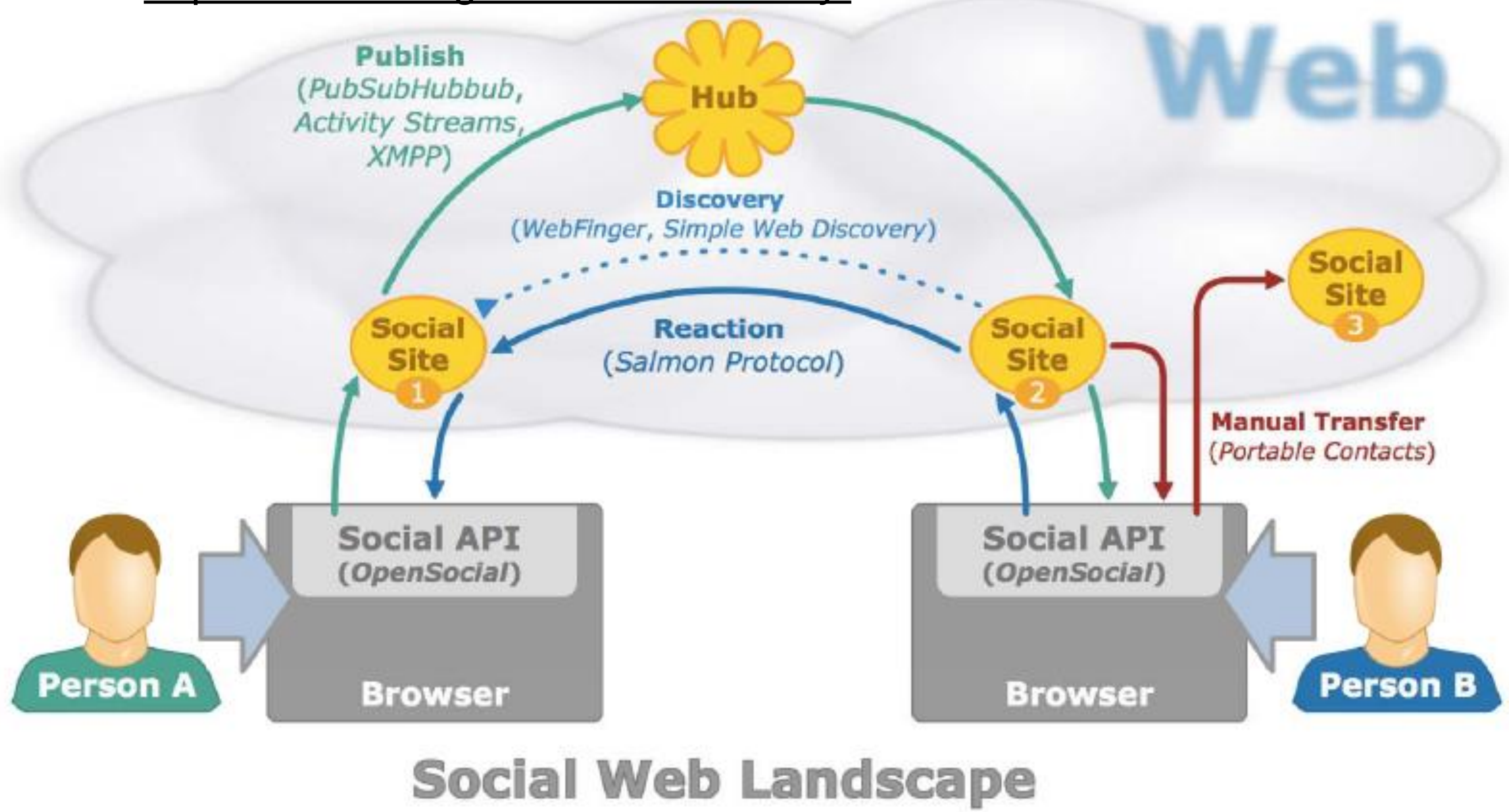
Federated social networks

- Users can communicate ***across domains*** with ***globally unique identifiers*** (one single account for all social netw apps)
- ***User data portability*** (as for number portability in cell comms, favors competition and migration between social netw app providers)
- ***Greater scaling and robustness*** of the overall Social Web
- Important industrial and "strategic" trend supported by relevant players (industries, governments, communities, …)

Federated Social Networks

Many ***related technological standards under discussion and definition***: OpenSocial, WebFinger, Salmon, ActivityStreams, PubSubHubbub, XMPP, …

See also http://www.w3.org/Talks/Deck/identity/



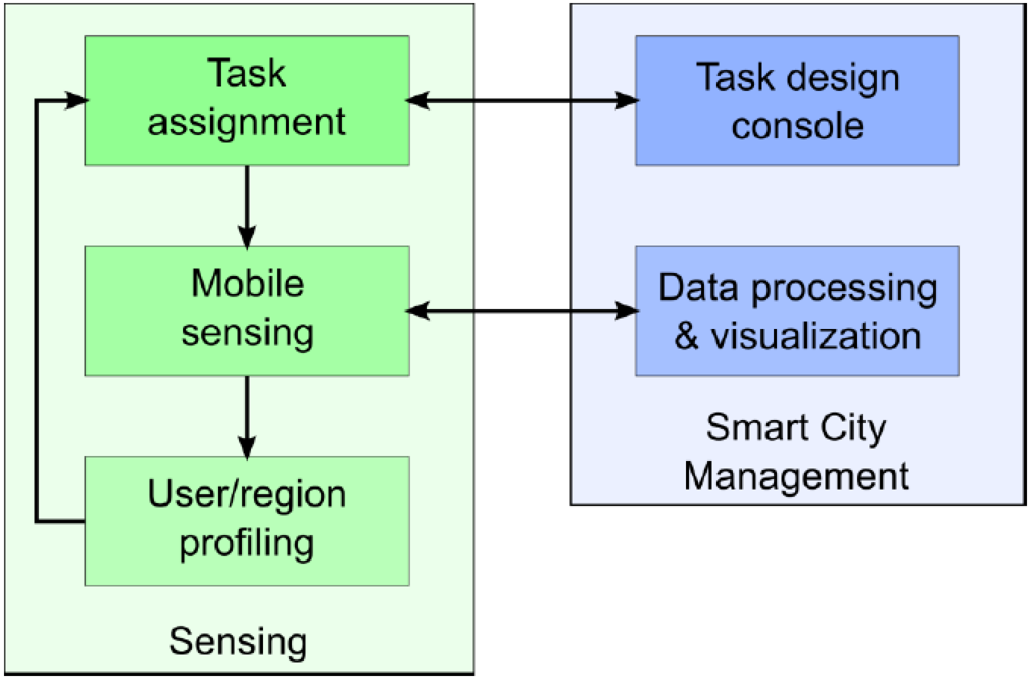
Social-aware Resource Sharing in Spontaneous Networks

Based on the scenarios and technologies sketched above, ***to contribute to enable resource sharing*** (typically multimedia contents) among ***different localities***

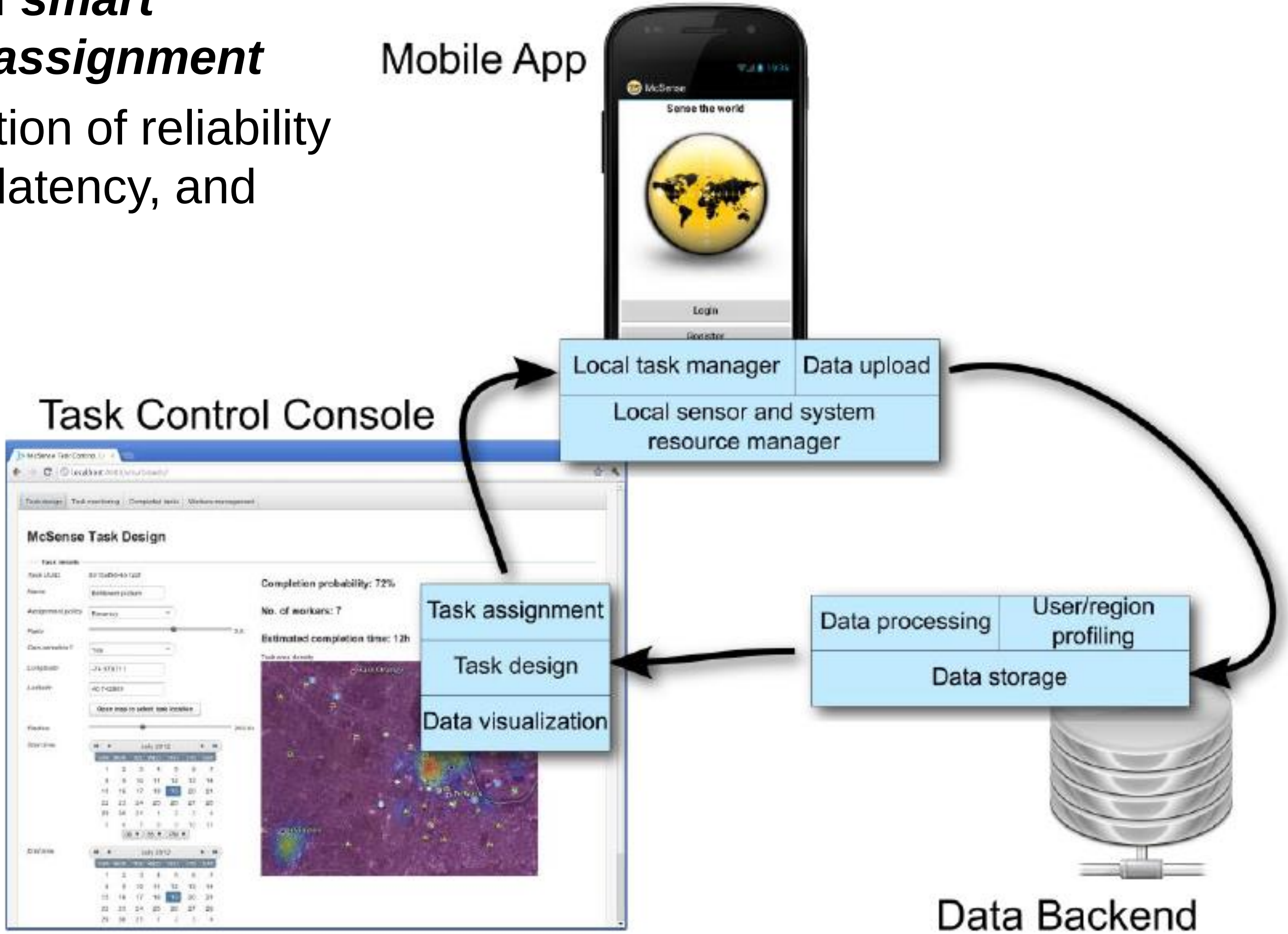
- Localities as ***domestic islands*** (UPnP and DLNA devices, experimental home gateways by TIM and CISCO, WiFi Direct connectivity, …)
- ***Island federation*** as automated federation based on ***social metadata*** dynamically extracted from primary social networking applications via standard protocols
- ***Unique identity*** for users
- ***Content filtering*** offered based on context and social profile
- …

ParticipAction: Crowdsensing

- Collaboration with NJIT and several Brazilian Universities
- Availability of a good set of Android devices and users for wide-scale living lab (300)
- Monitoring and crowdsensing for smart city
- "Smart" assignments of participatory tasks, also with economic incentives



- Determination and experimentation of ***smart policies for task assignment***
- (pseudo) optimization of reliability in task execution, latency, and economic cost



ParticipAction: CoVID-19?

- Determination and experimentation of smart policies for task assignment
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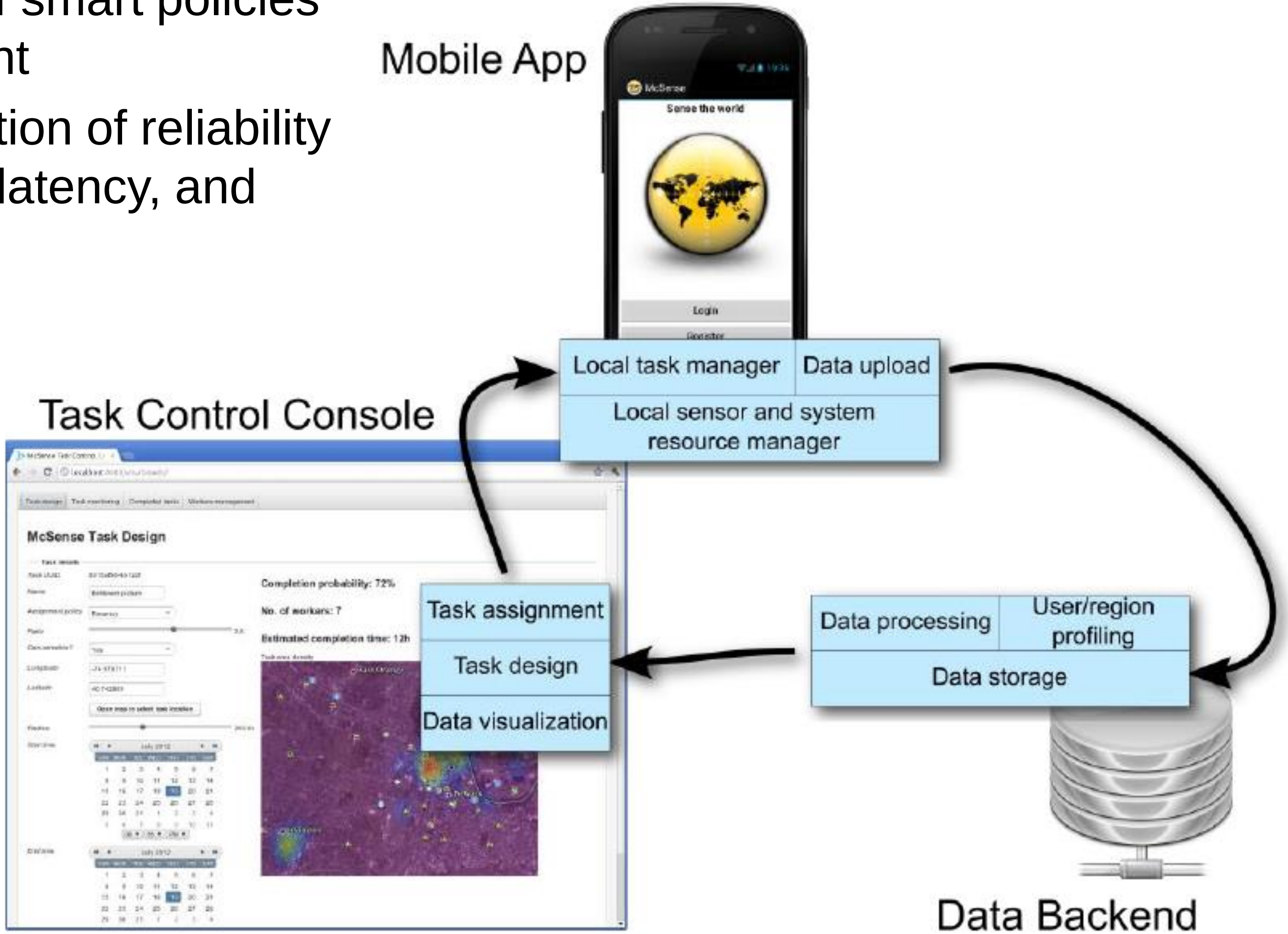
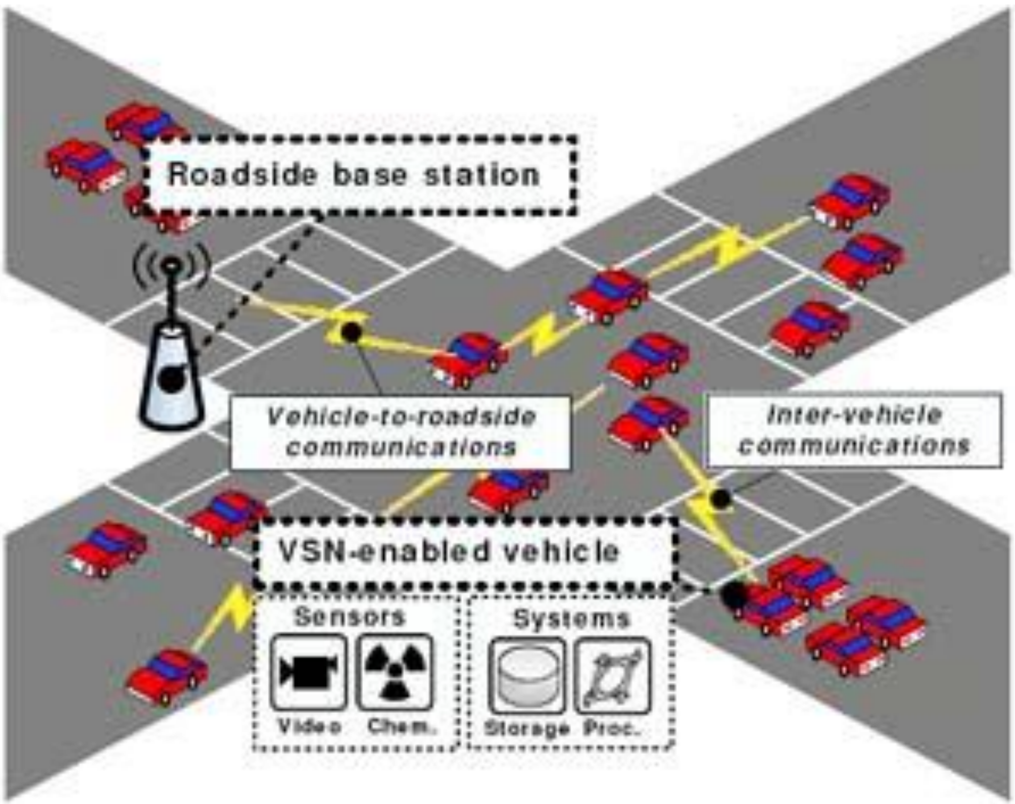


Vehicular Traffic Management

Cars are relevant example of ***mobile autonomous sensors*** and they can ***coordinate themselves lazily*** by exploiting wireless communications



- Cars perform ***opportunistic sensing*** in urban environments and maintain local data
- ***Collaborative dissemination of metadata*** based on local decisions
- Possibility of ***emerging behaviors*** to satisfy ***application-specific requirements*** (e.g., query completeness, response time, overhead, …)

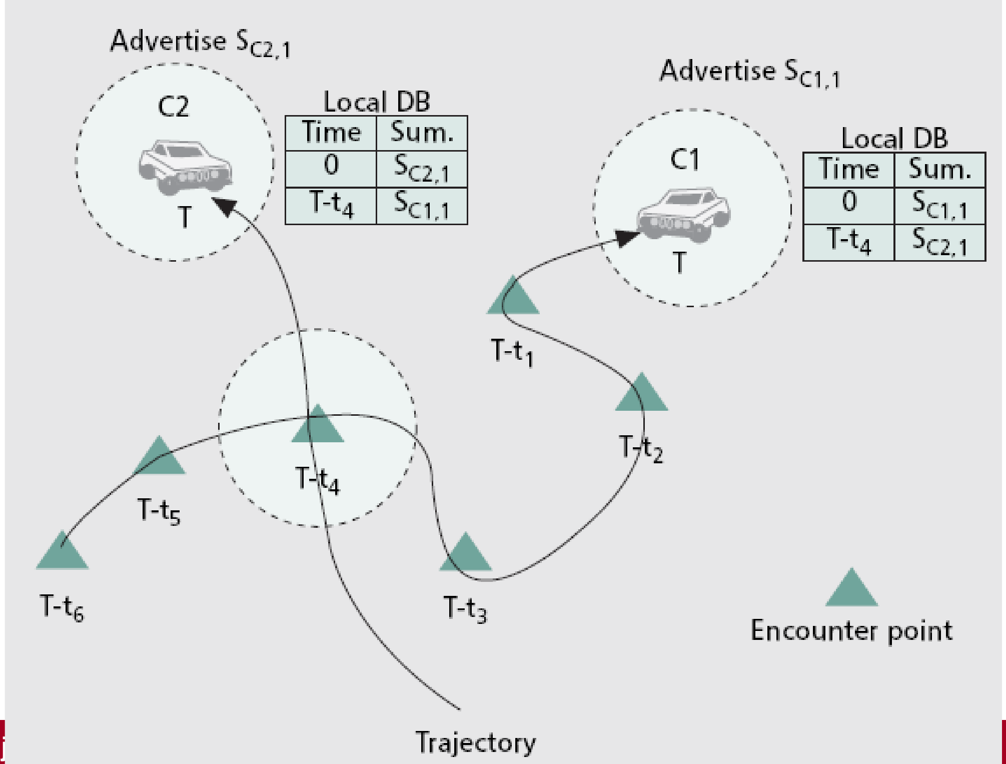
Previous Experience with MobEyes (UCLA)

Urban monitoring via vehicular sensor networks that are opportunistic and autonomous

- Opportunistic encounters of "regular" cars equipped with sensors and P2P wireless connectivity
- Sensor mobility is of course ***«not-directed»***

Differences wrt WSN:
- Less stringent constraints on memory, storage, and power consumption
- Wide-scale deployment

<u>Application scenario:</u>
- Post-crime investigation (e.g., after terroristic attack)
- Cars with A/V sensors
- ***Metadata summaries***



Vehicular Traffic Management

Idea of ***using the same "regular" citizen cars*** to monitor urban vehicular traffic, in areas with ***relatively high density*** (in integration and synergy with existing monitoring systems)

Goals:

- Minimization of traffic jams and global travelling time
- Minimization of pollutant emission
- Maximization of traffic fluidity and municipality-level utility functions

Approach: to exploit sensors already available at vehicles, standard frameworks emerging in automotive area, but ***also onboard sensors by passengers' smartphones***…

Vehicular Traffic Management

Possible directions for project activities:

- Study, analysis, and simulation tests about ***standards for vehicle2vehicle or vehicle2infrastructure*** (towards road side units) ***communications***
- ***Exploitation and integration of smartphones*** (sensors + peer2peer communications + comm. towards infrastructure) to the purpose of vehicular traffic estimation
- Employment of ***peer2peer communications*** (rather than to a centralized infrastructure server) to ***harvest, aggregate, and process*** monitoring data ***in a decentralized way***
- Exploitation of ***locality principle***, evolution of geo-tagged historical data, trust level obtained at runtime by participants, …
- …

M2M Middleware

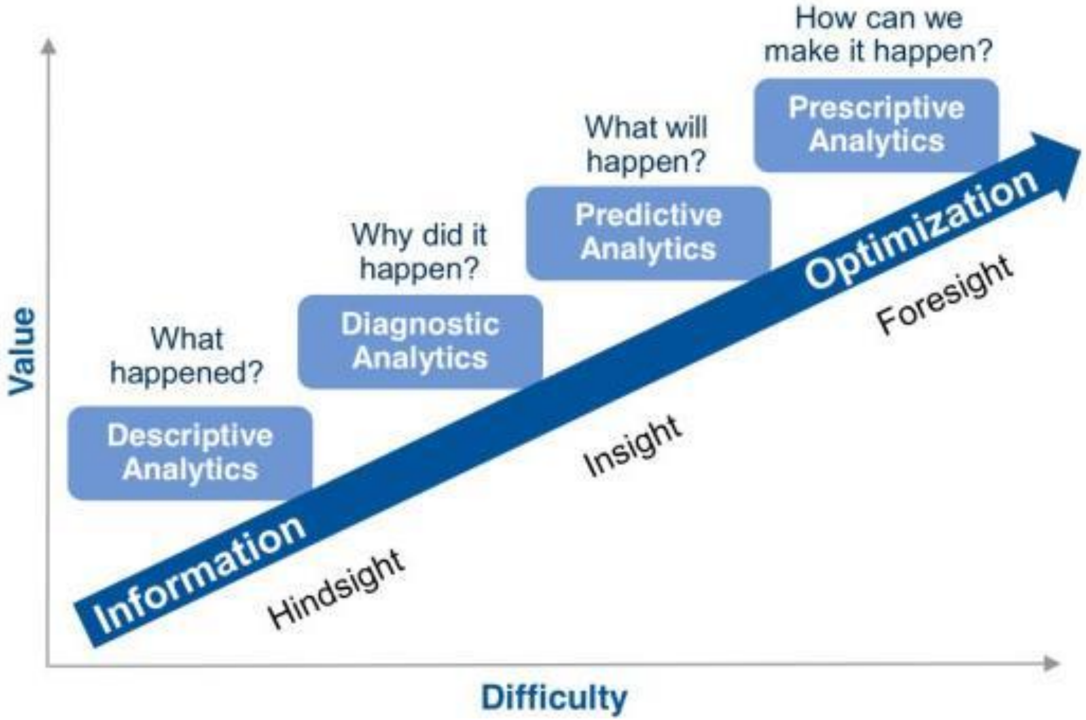
Middleware for efficient communication in Machine-to-Machine (M2M) applications

- Internet of Things and Cyber-Physical Systems (sensors+actuators) scenarios
- Dynamic identification of localities (clustering)
- Data batching/aggregation
- Efficient integration with (virtualized, global) cloud computing resources
- ***Edge cloud computing***
- ***Fog computing***
- Distributed machine learning, reinforcement learning, federated learning, …

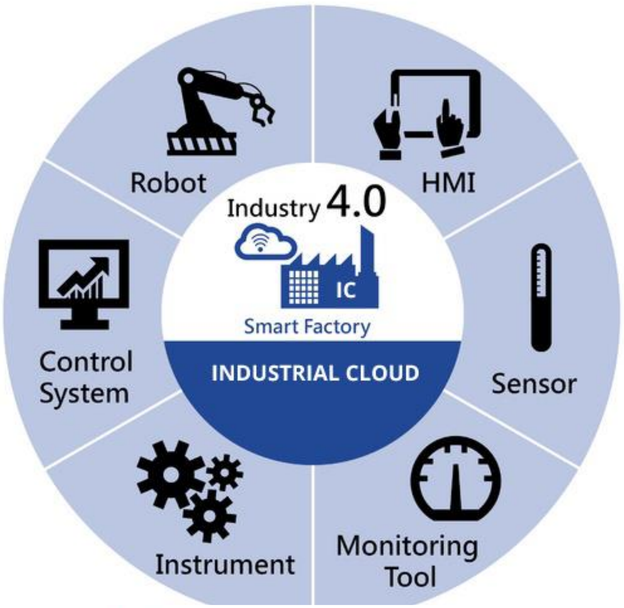
Use Case #1: Predictive Diagnostics and Optimization of Manufacturing Processes

Failure prevention/prediction and planning of efficient maintenance operations through Machine Learning-enabled techniques

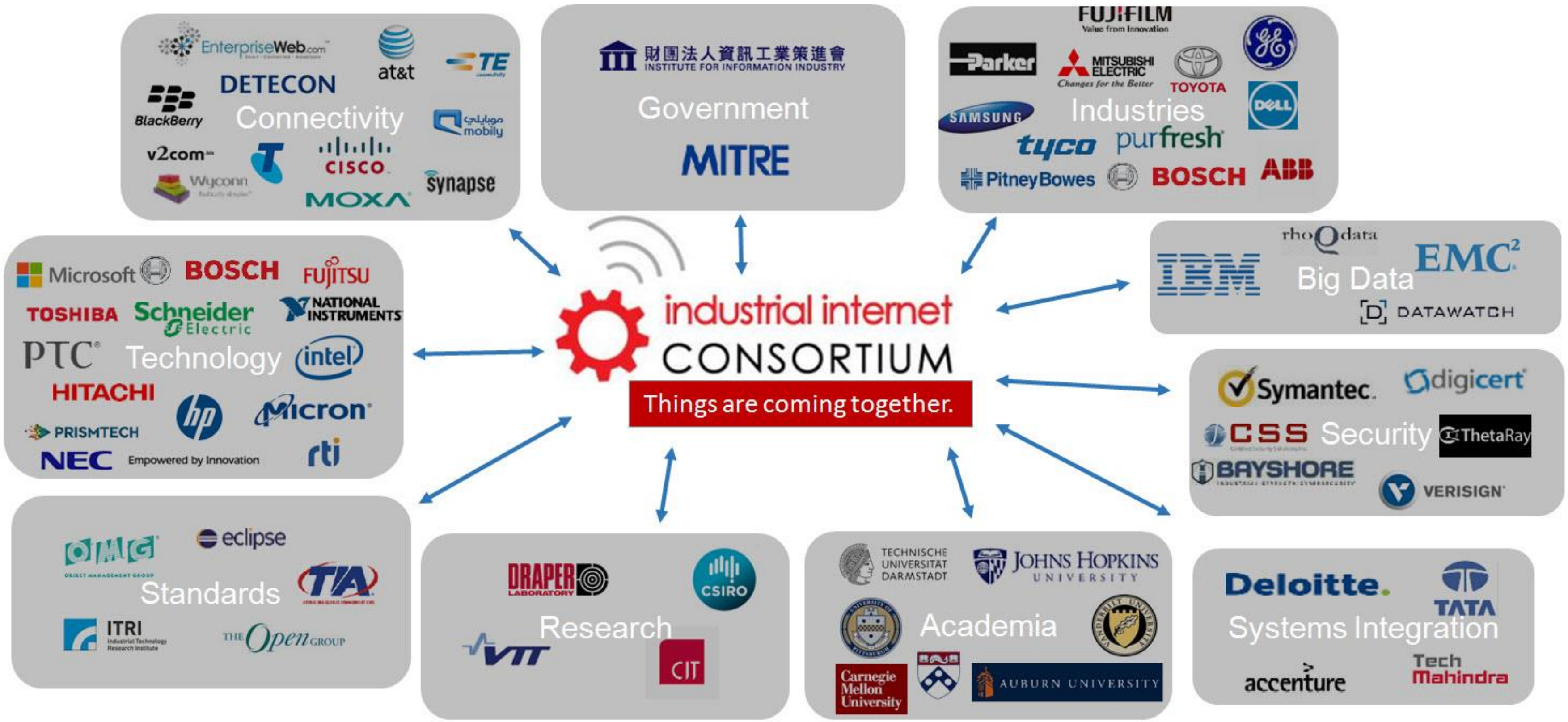
- Not only AI…
- Efficiently interconnected IoT
- Industrial cloud and compliance with standards + best practices
- Edge cloud computing
- …



Use Case #1:
Predictive Diagnostics

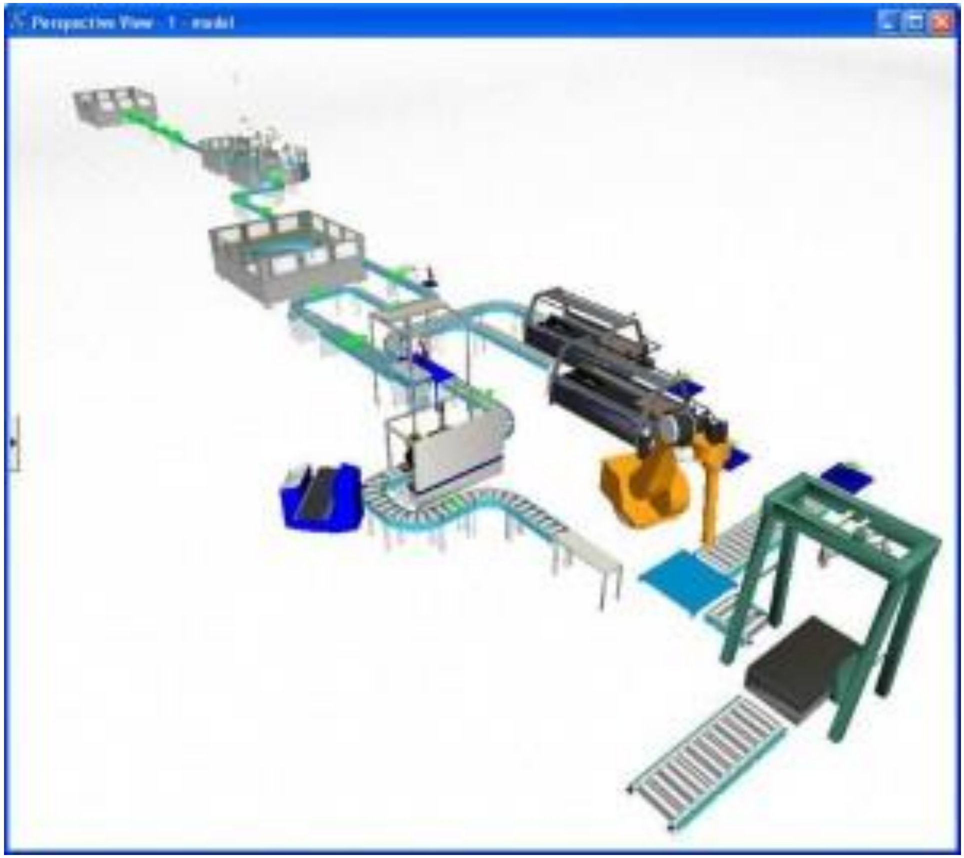


- Industrial cloud
- Compliance with industrial standards and best practices



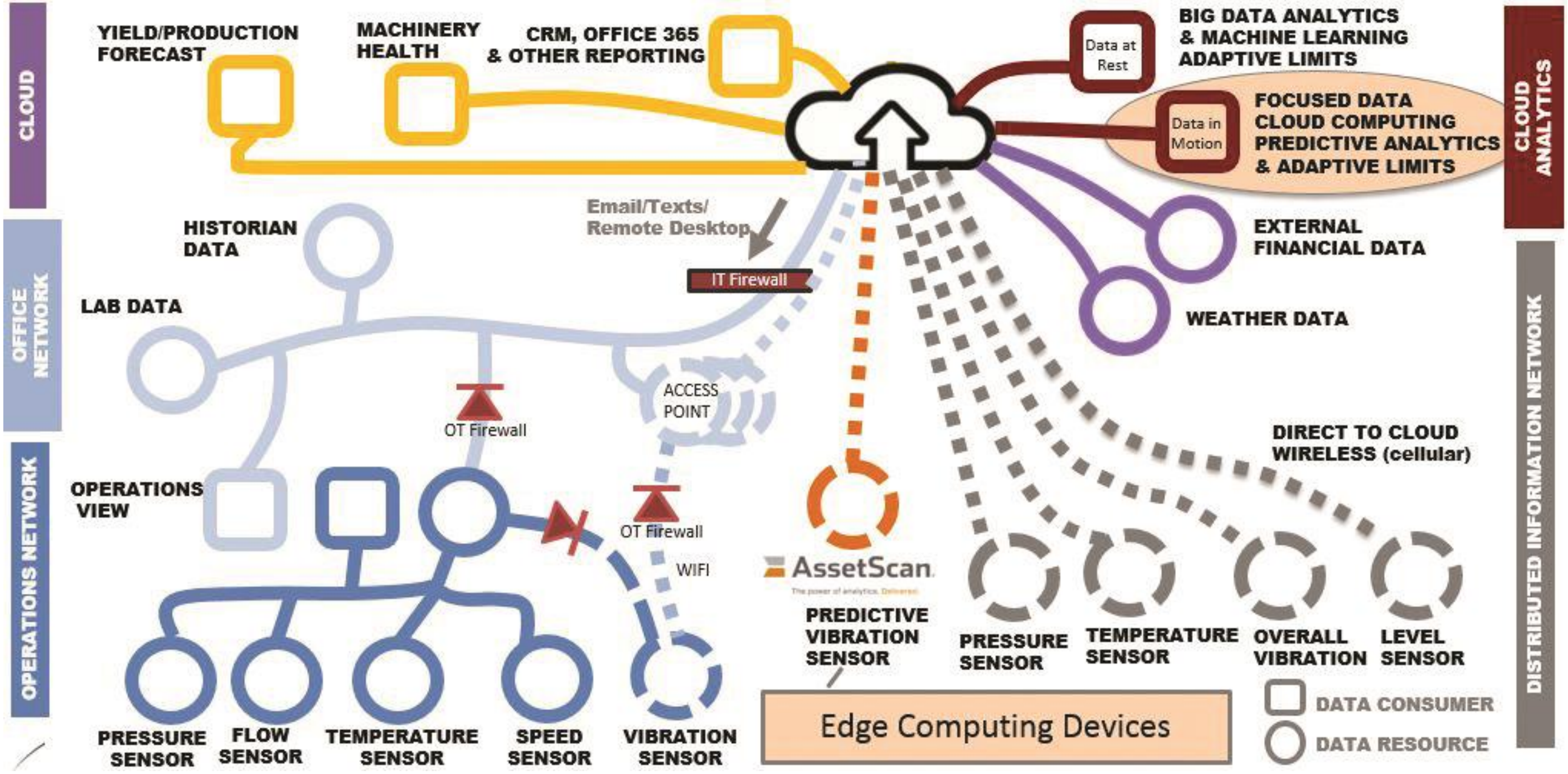
Use Case #1: Prescriptive Analytics and Optimization of Manufacturing Processes

- ***Digital Twins*** of production plants
- ***Automated configuration of manufacturing production lines*** (system of systems)
- ***Dynamic reconfiguration*** of production lines

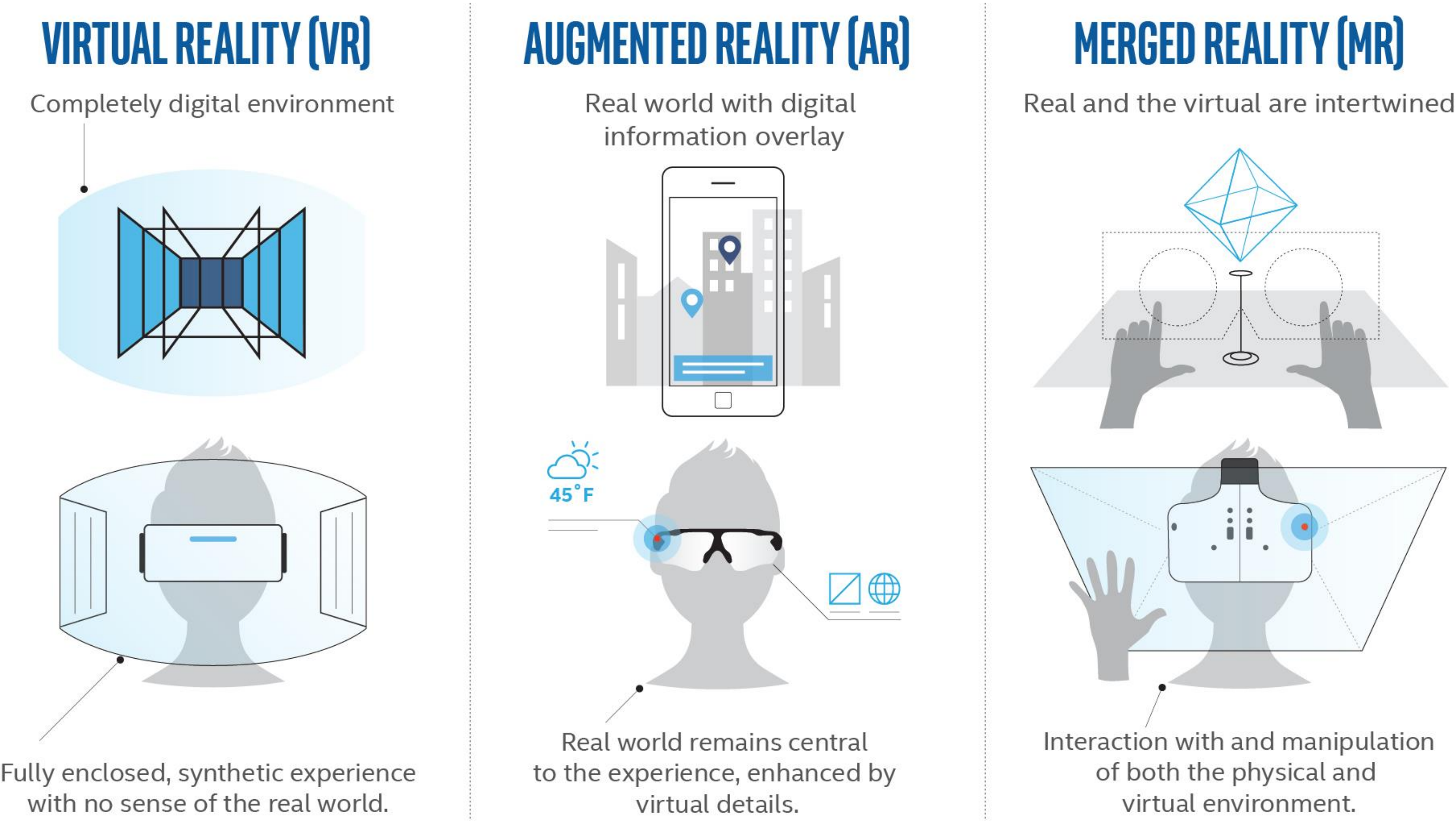


Use Case #1: Prescriptive Analytics and Optimization of Production Processes

- **Optimization of product quality and process efficiency** based on soft/hard real-time IoT monitoring and machine learning



Use Case #2: Virtual and Augmented Reality

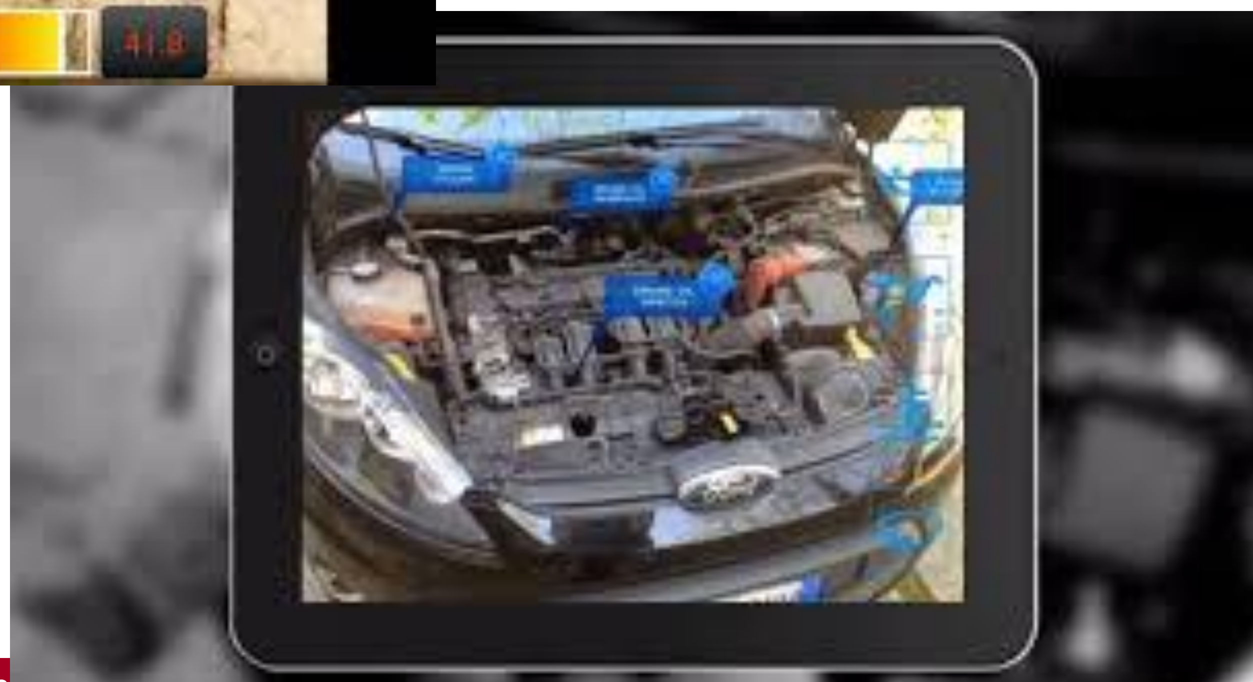


Virtual and Augmented Reality for Logistics

Virtual and Augmented Reality for Maintenance

Models visualized to integrate knowledge about the «real system» in real-time

Also storage and tracking of previous history of maintenance interventions



IoTwins

BIG DATA OPTIMIZE INDUSTRY AND SERVICES

TYPE OF ACTION
INNOVATION ACTION

PROJECT REFERENCE
857191

START/END
SEPTEMBER 2019 – AUGUST 2022

TOTAL COSTS
€ 20,029,818.75

EU CONTRIBUTION
€16,422,552.01

CALL IDENTIFIER
H2020-ICT-2018-2020

TOPIC
ICT-11-2018-2019 - HPC AND BIG DATA ENABLED LARGE-SCALE TEST-BEDS AND APPLICATIONS

COORDINATOR
BONFIGLIOLI RIDUTTORI

Concept and approach.

- IoTwins is an EU project that will work to **lower the barriers for the uptake of Industry 4.0 technologies** to optimize processes and increase productivity, safety, resiliency, and environmental impact
- IoTwins approach is based on a **technological platform** allowing a simple and low-cost access to **big data analytics** functionality, **AI services**, and **edge cloud** infrastructure for the **delivery of digital twins in manufacturing and facility management sectors**
- The approach is demonstrated through the development of **12 large scale testbeds**, organized in three application areas: **manufacturing**, **facility management**, and **replicability**/scale up of such solutions

20	16	23	1	12	3
M€ total value	M€ EU Funding	Partners	Platform	Testbeds	Application areas

IoTwins

Platform and services.

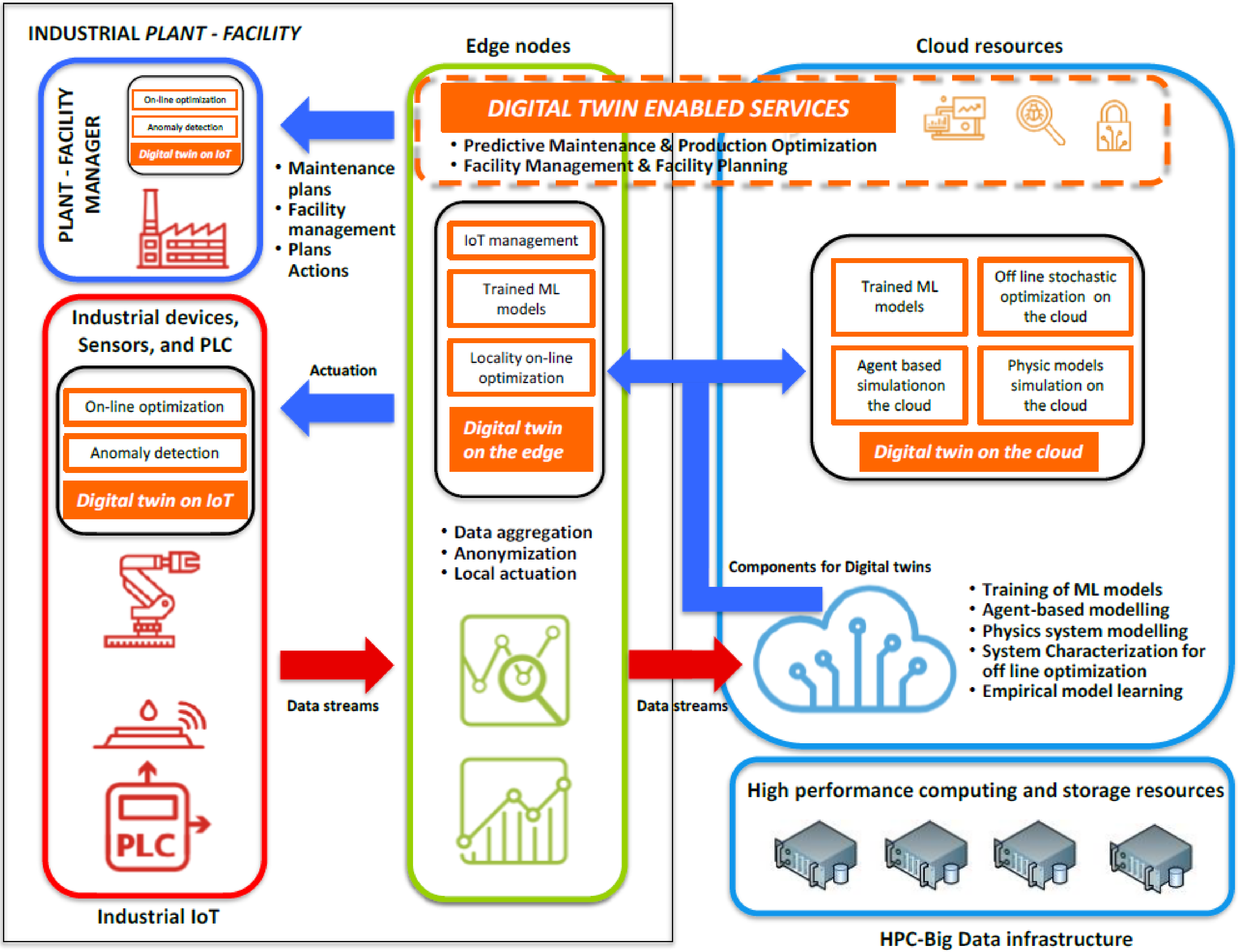
All the IoTwins testbeds share the same methodology, grounded on the concept of **distributed IoT-/edge-/cloud-enabled hybrid twins, to replicate complex systems**, with the ambition of predicting their dynamics and temporal evolution

Key elements:

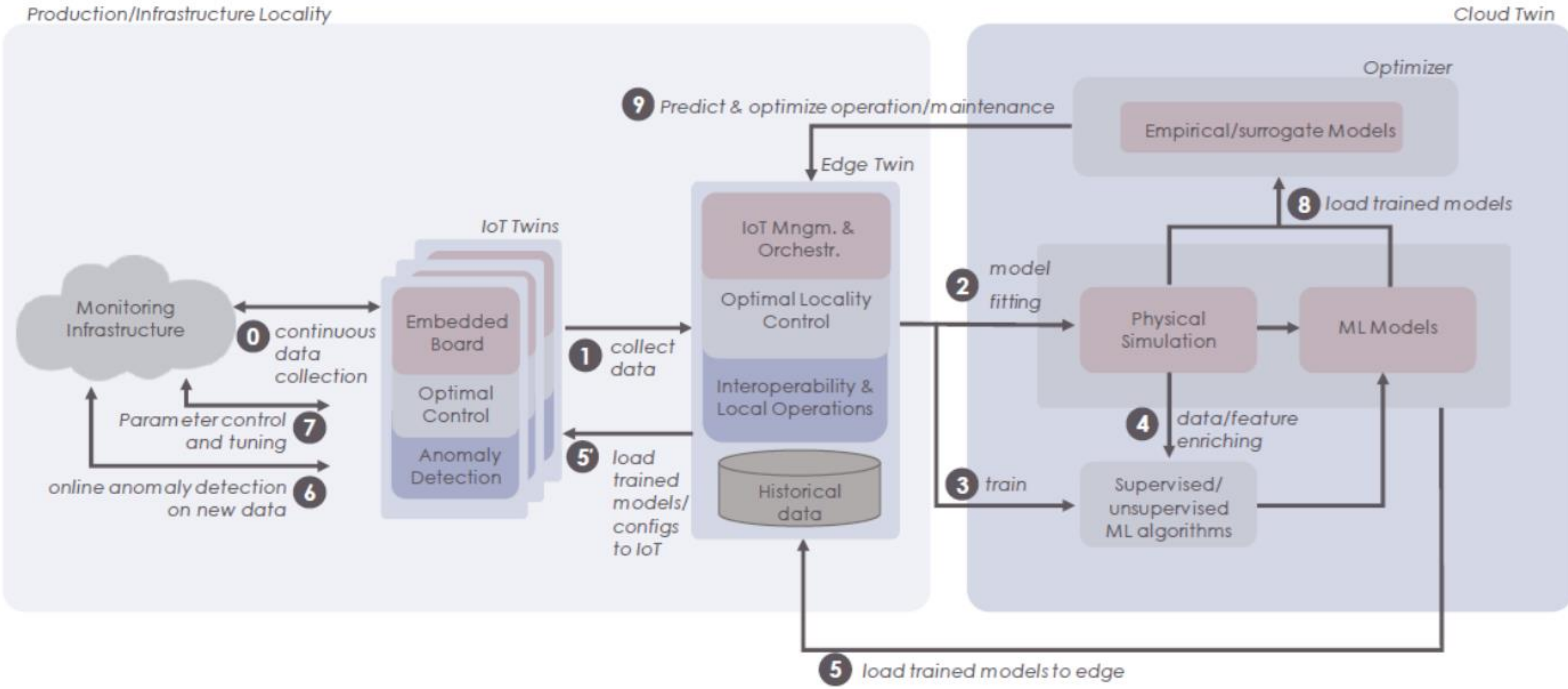
- A full-fledged platform enabling **easy and rapid access to heterogeneous cloud HPC-based resources** for advanced big data services
- **AI services** to simplify and accelerate the integration of **advanced Machine Learning algorithms, physical simulation, on-line and off-line optimization** into distributed digital twins
- **Advanced edge-oriented mechanisms, tools, and orchestration** to support **Quality of Service** in the runtime execution of the distributed digital twins

IoTwins

Digital Twins concept in IoTwins



Distributed Training and Control in IoTwins



IoTwins

manufacturing

4 industrial testbeds calling for predictive maintenance services (time to failure forecasting and generation of maintenance plans to optimize costs)

- Wind turbine predictive maintenance | Bonfiglioli Riduttori, KK Wind Solutions
- Machine tool spindle predictive behavior | FILL
- Predictive maintenance for a crankshaft manufacturing system | ETXE-TAR
- Predictive maintenance and production optimization for closure manufacturing | GCL International

facility management

3 testbeds calling for identification of criticalities, optimization techniques to provide efficient facility management plans, operation optimal schedules, and renovation/maintenance plans

- NOU CAMP - Sport facility management and maintenance | **Futbol Club Barcelona**
- EXAMON - Holistic supercomputer facility management | **CINECA**
- Smart Grid facility management for power quality monitoring | **SIEMENS**

replicability

5 testbeds to demonstrate the replicability and scalability of both IoTwins solutions and the former manufacturing and facility management testbeds

- Patterns for smart manufacturing for SMEs | **Centre Technique des Industries Mécaniques**
- EXAMON replication to other datacenters facilities | **Istituto Nazionale di Fisica Nucleare, Barcelona Supercomputing Center**
- Standardization/homogenization of manufacturing performance | **GCL International**
- NOU CAMP replicability towards smaller scale sport facilities | **Futbol Club Barcelona**
- Innovative business models for IoTwins PaaS in manufacturing | **Marposs**

Partners.

IoTwins

Bonfiglioli

Coordinator

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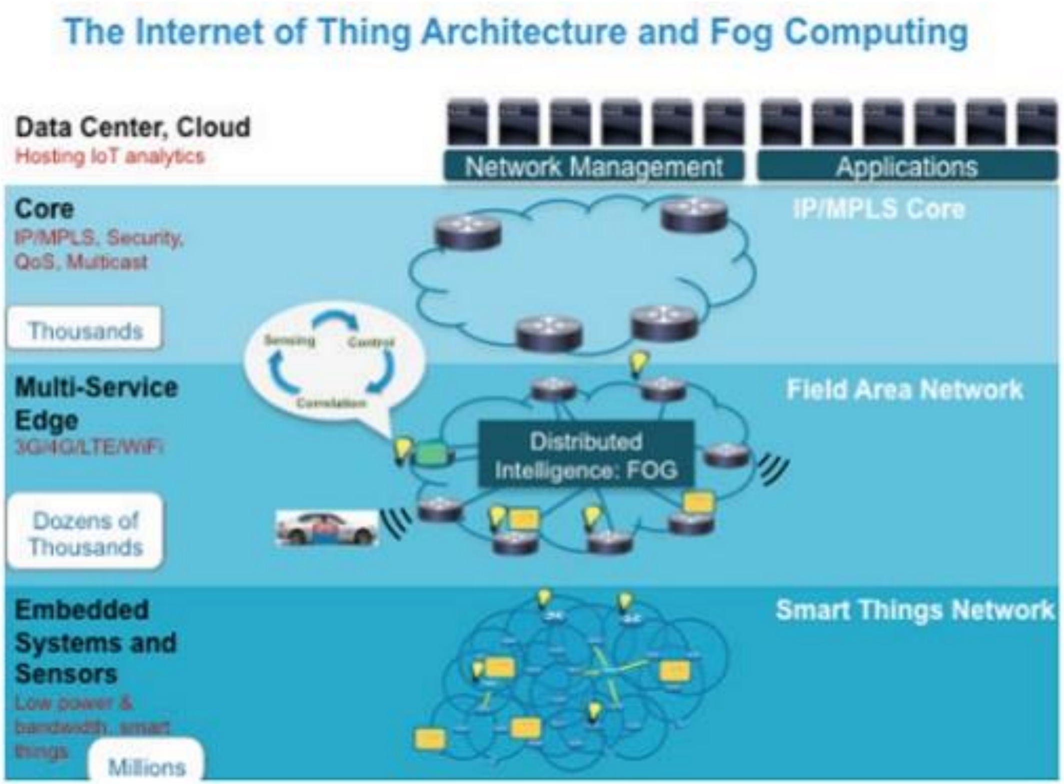
Edge Computing for IoT Apps: Quality Requirements

Towards the vision of ***efficient edge computing support*** for ***“industrial-grade” IoT applications***

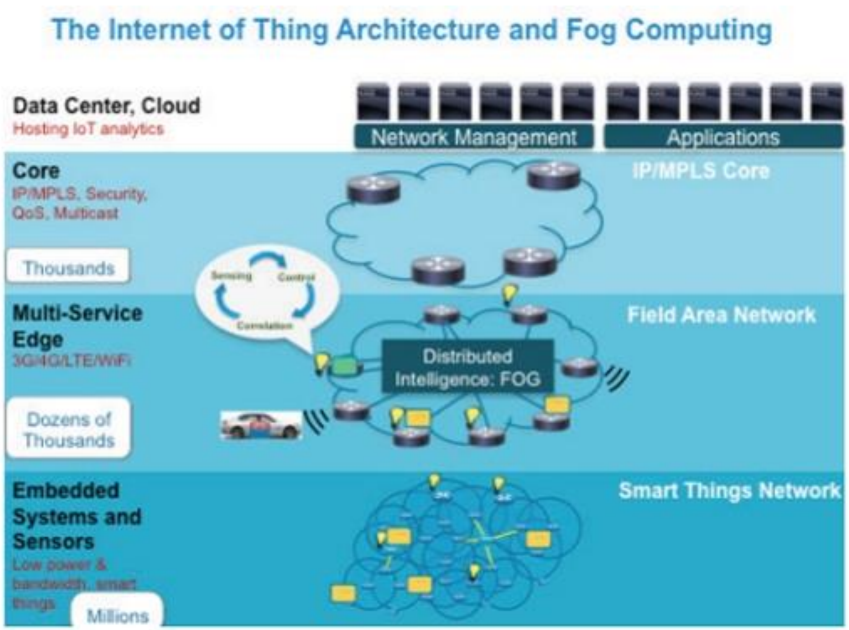
- ***Latency constraints***
- ***Reliability***
- ***Decentralized control***
- ***Safe operational areas***
- ***Scalability***



1. Architecture modeling
2. ***Quality support even in virtualized envs***
3. ***Scalability via hierarchical locality management***
4. ***Distributed monitoring/control functions*** at both cloud and edge nodes ***to ensure safe operational areas***

But also:

- Data aggregation
- Control triggering and operations
- Mgmt policies and their enforcement
- …



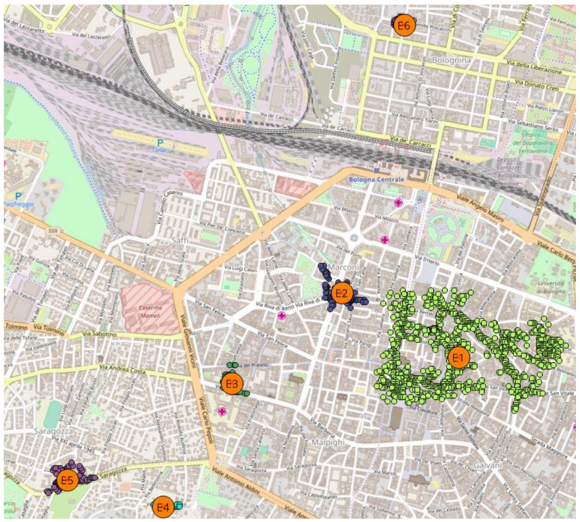
Human-driven Edge Computing (HEC)

- HEC as a new model to ease the provisioning and to extend the coverage of more traditional MEC solutions
- How to exploit MCS
  - to support ***effective deployment of Fixed MEC*** (FMEC) nodes
  - to further extend their coverage through dynamic introduction of ***impromptu and human-enabled Mobile MEC (M^2EC) nodes*** for serving local MCS computing/storage needs

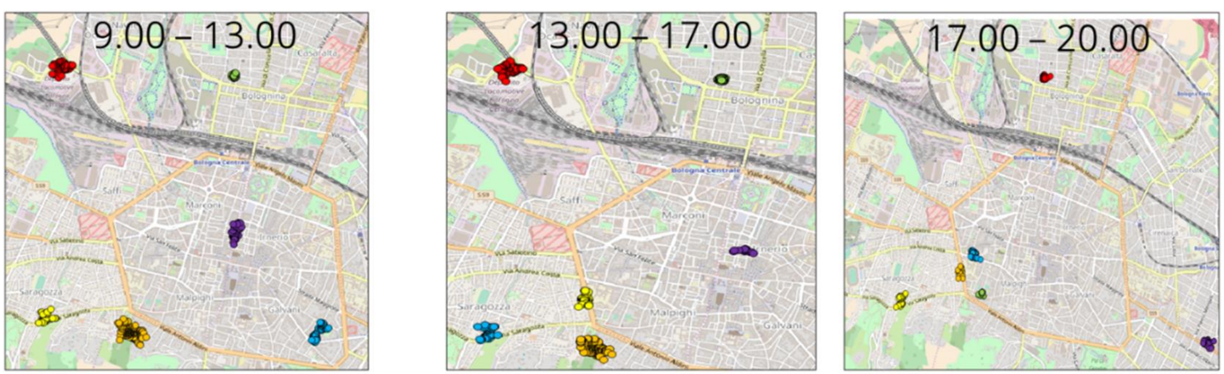
- Ongoing implementation in the ***MCS ParticipAct*** framework through the integration of the ***MEC Elijah (OpenStack++)*** platform

Human-driven Edge Computing (HEC)

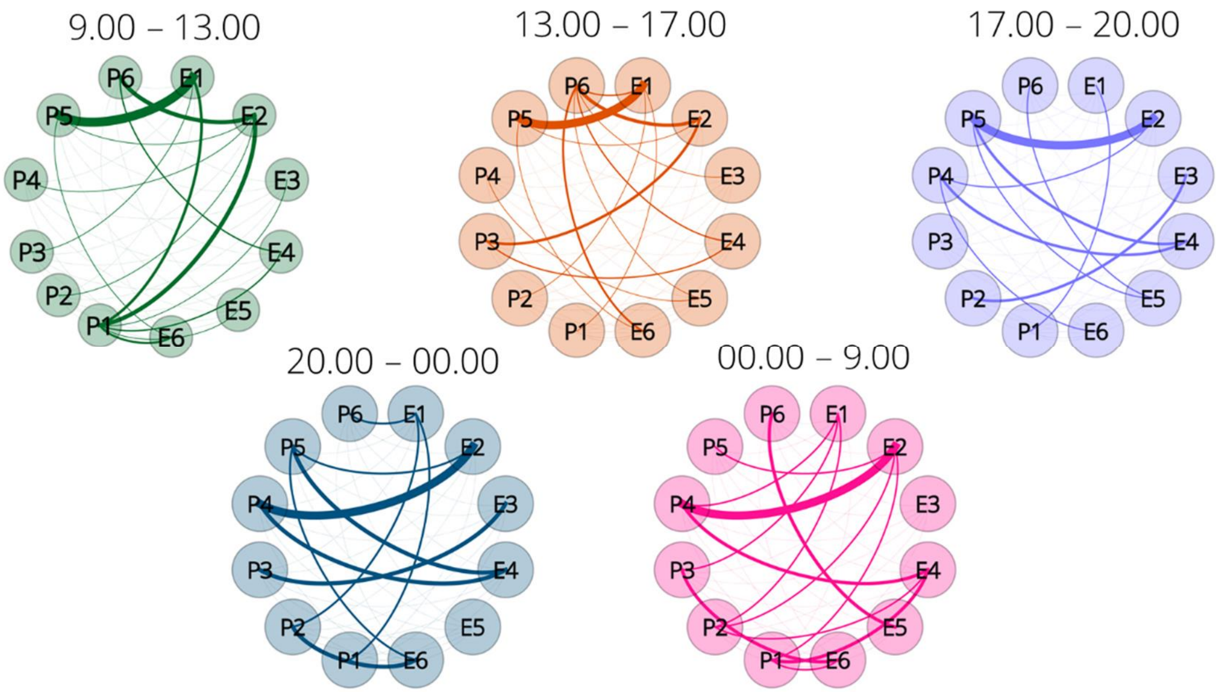
- HEC potentially mitigates weaknesses of having only Fixed MEC entities (FMEC) by exploiting MCS
  - to continuously monitor humans and their mobility patterns
  - to ***dynamically re-identify hot locations*** of potential interest for the deployment of ***new edges***
- Implementation and dynamic activation of ***impromptu and temporary Mobile MEC*** entities (M^2EC)
  - Leveraging resources of ***locally available mobile devices*** (in a logical bounded location where people tend to stay for a while in a repetitive and predictable way) -> ***participatory edge node***
- HEC exploits ***local one-hop communications and the store-and-forward*** principle
  - by using ***humans as VM/container couriers*** to enable ***migrations*** between well-connected FMEC and local M^2EC



FMEC nodes identified as DBSCAN clusters



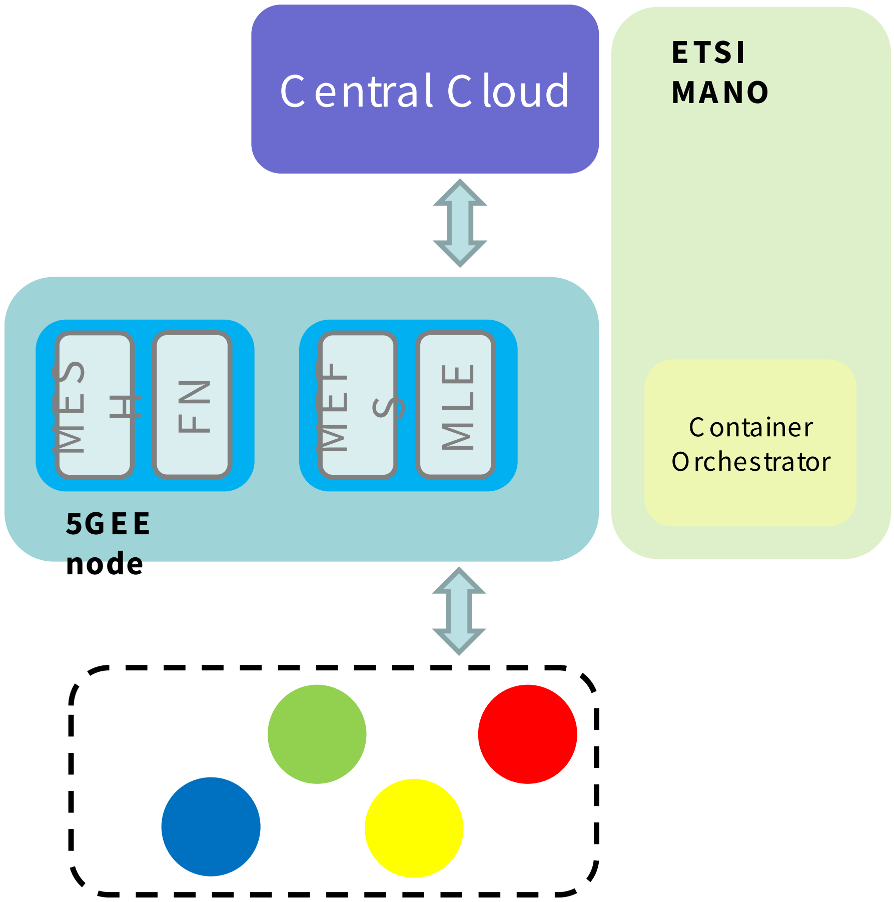
M^2EC nodes identified as DBSCAN clusters



measurement of connectivity as temporal graphs between FMECs (E_i) and M^2EC (P_i)

4) Advanced Management Operations at the Edge

- Architectural solution called 5G-Enabled Edge **(5GEE)** that aims at converging MEC and Fog while maintaining quality awareness and orientation
  - **Combination** of all the main MEC and Fog functions
  - Dynamic **management/(re-) configuration** of 5GEE entities
  - Implementation based on **ETSI MANO**

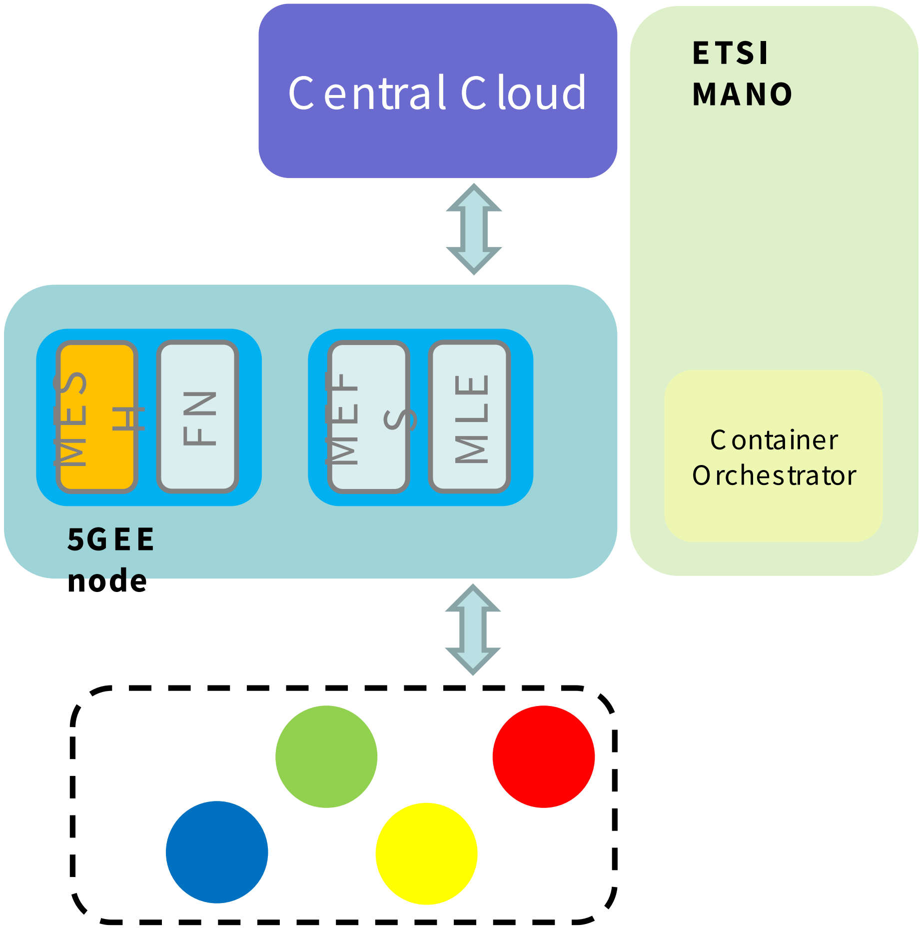


MEC Services Handoff (MESH) for Advanced Management Operations at the Edge

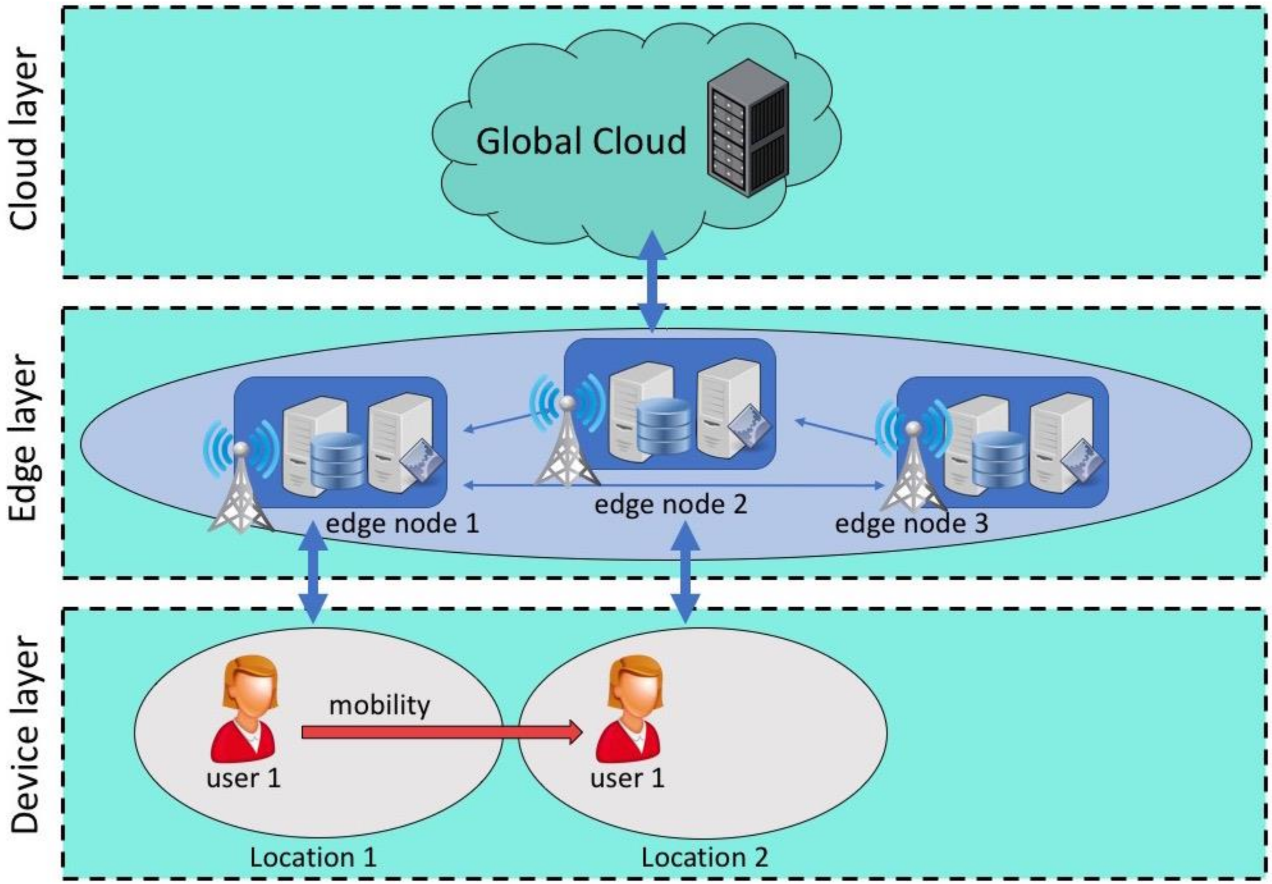
1. **MESH** is **proactive**
2. **MESH** enables either **application-agnostic** or **application-aware** handoff
3. **MESH** supports inter-edge migration of:
   - Virtual machine (VM)
   - **Docker container**
4. **MESH** runs on resource-poor edge devices such as **Raspberry Pi**
5. **MESH** is tailored on ETSI MEC specification

Edge-enabled Handoff

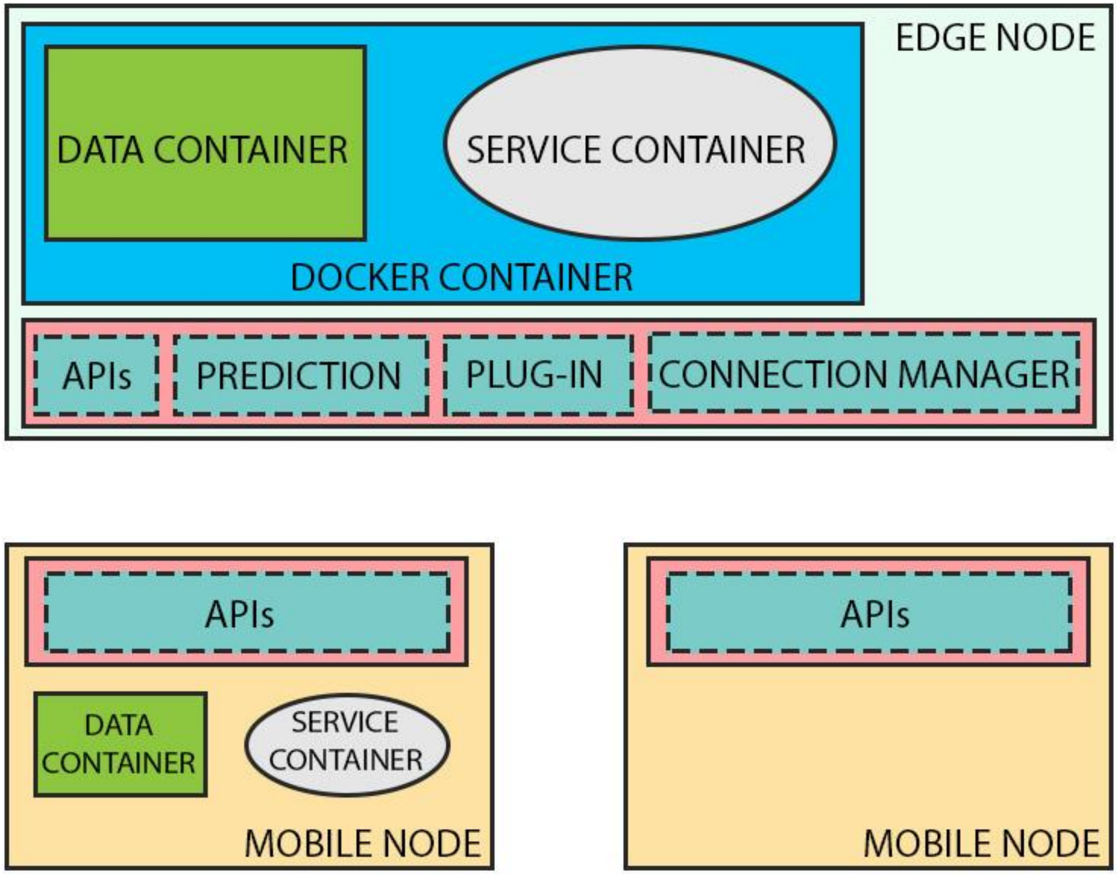
1. Background
2. Proposal of proactive application-aware service handoff protocol
3. Proposal of application-aware optimizations



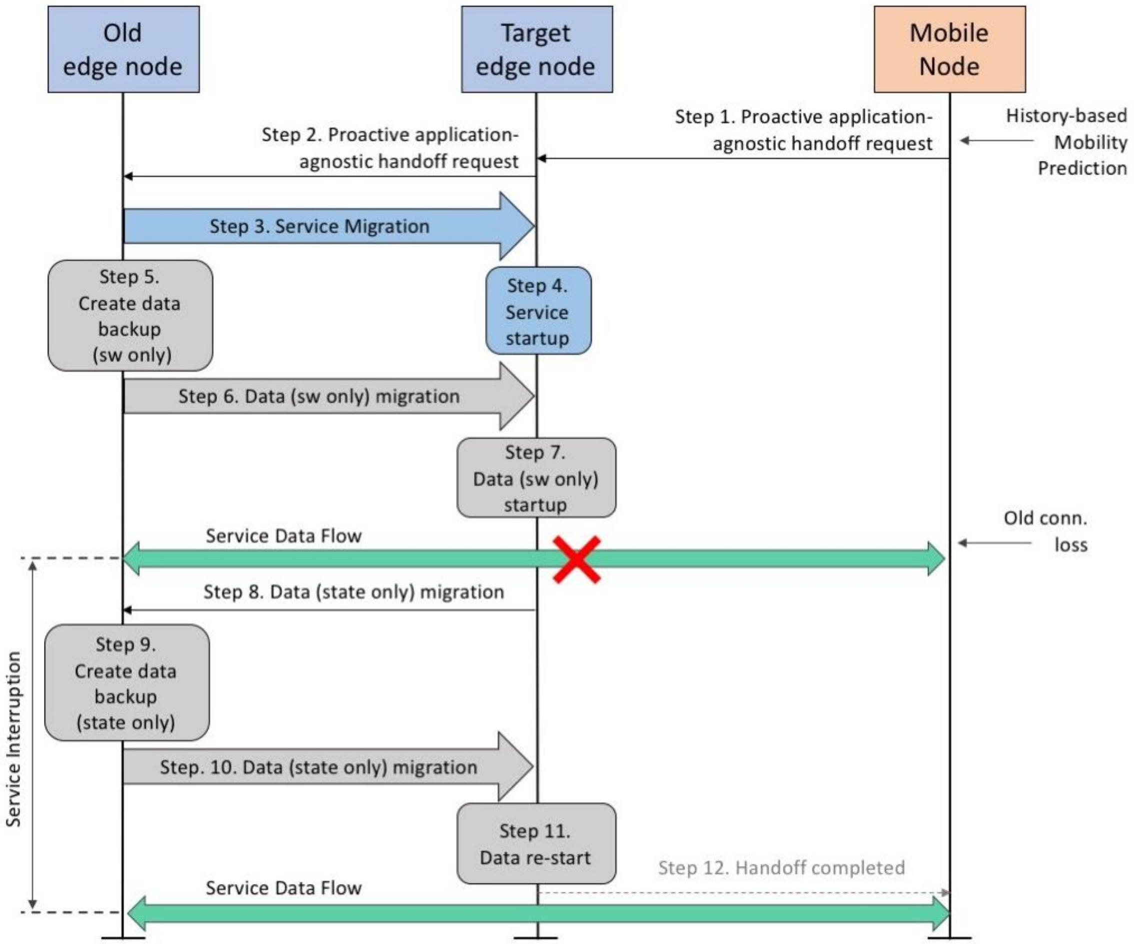
Edge-enabled Handoff



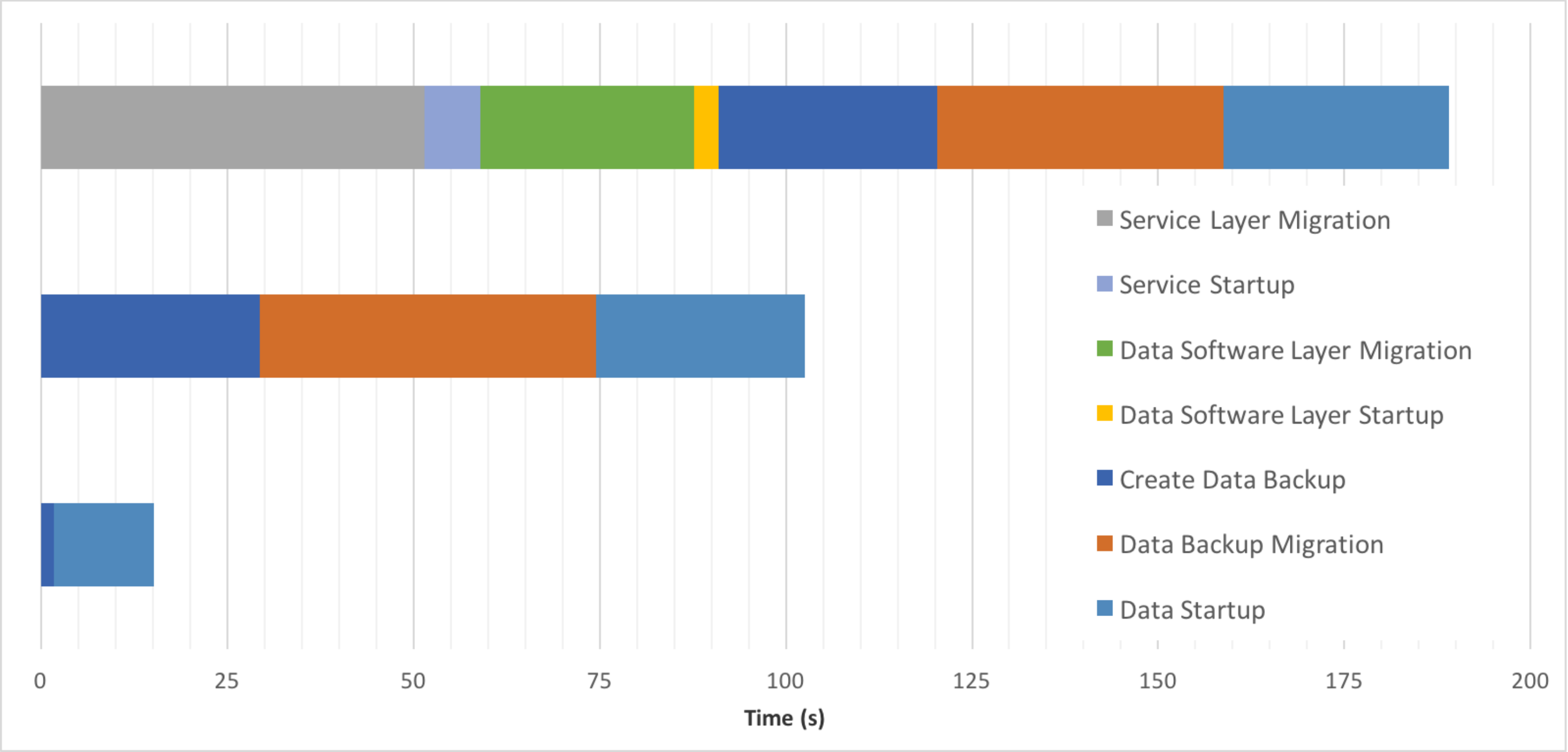
MESH – ARCHITECTURE



- **service layer**: the stateless application logic.
- **data software layer**: software parts for managing the data storage.
- **data state**: the data stored in the physical disk.



MESH – EXPERIMENTAL RESULTS



- **Raspberry Pi 3**

Mobile Edge File System

- **OFS**: An Overlay File System for Cloud-Assisted Mobile Applications
- Systems designed to offload resource-demanding tasks to cloud
  - Task offloaded in the form of **Objects**

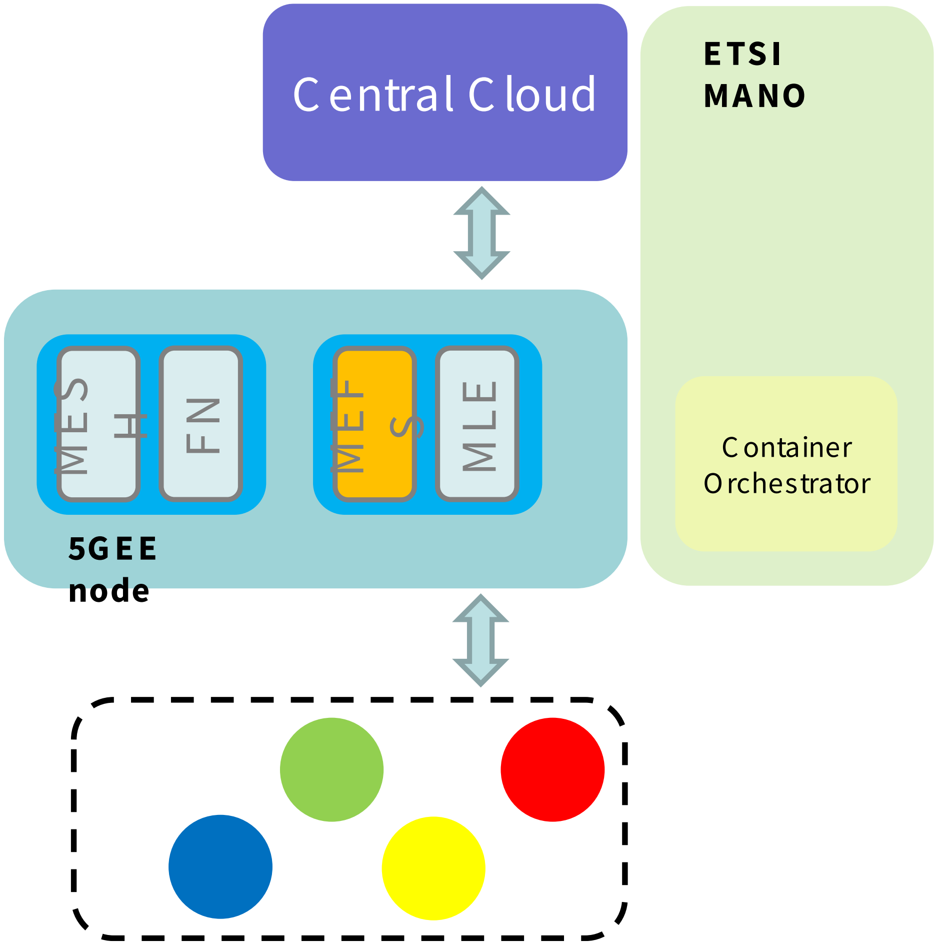
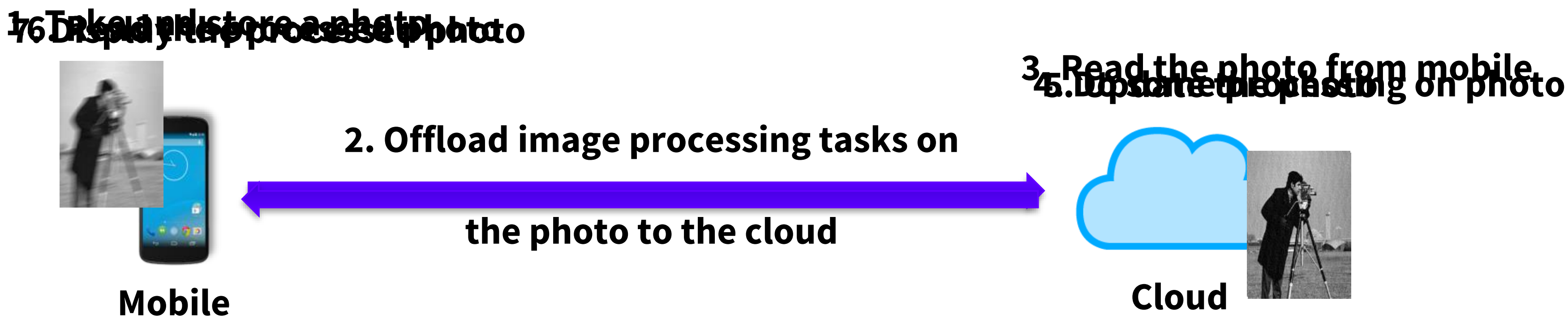
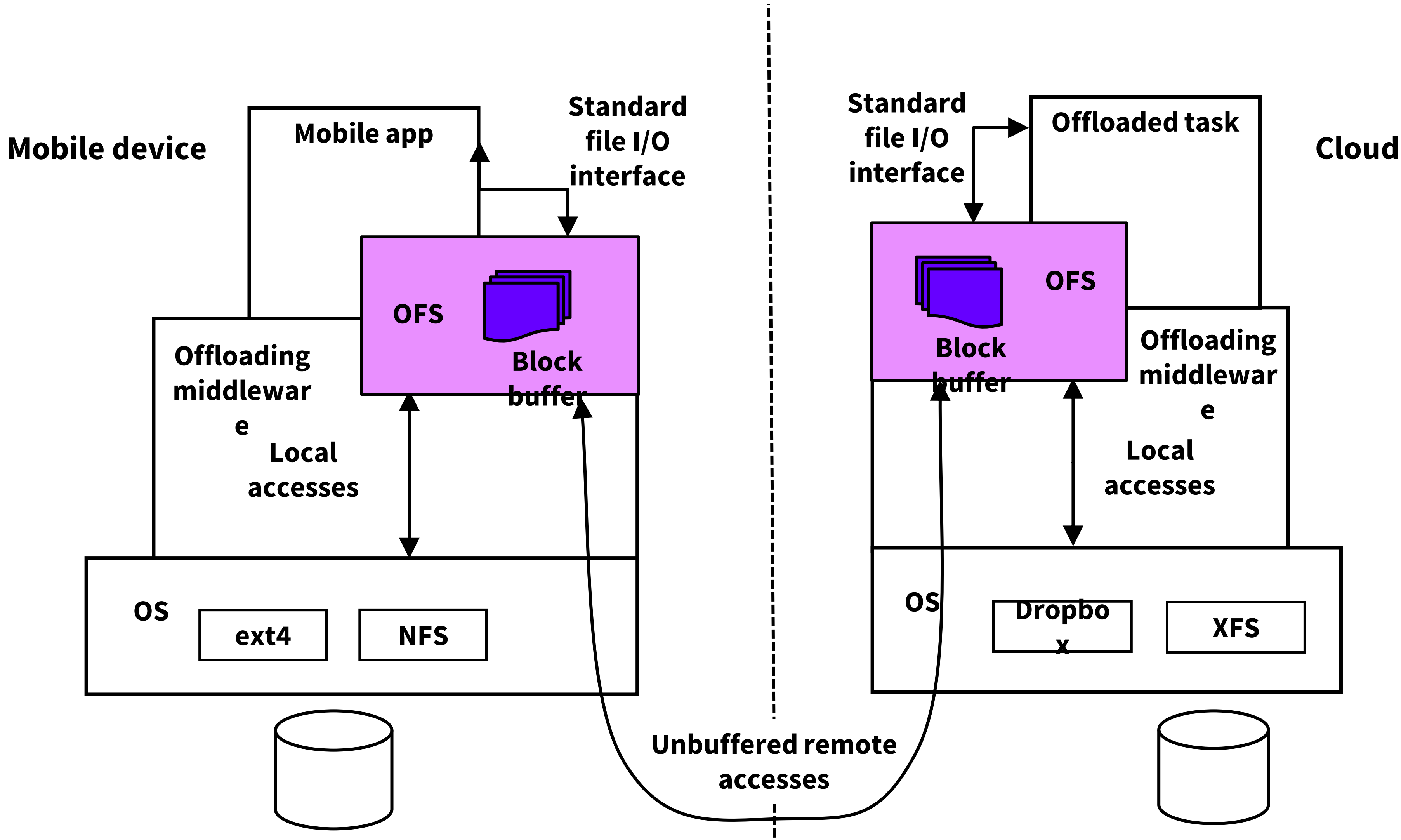


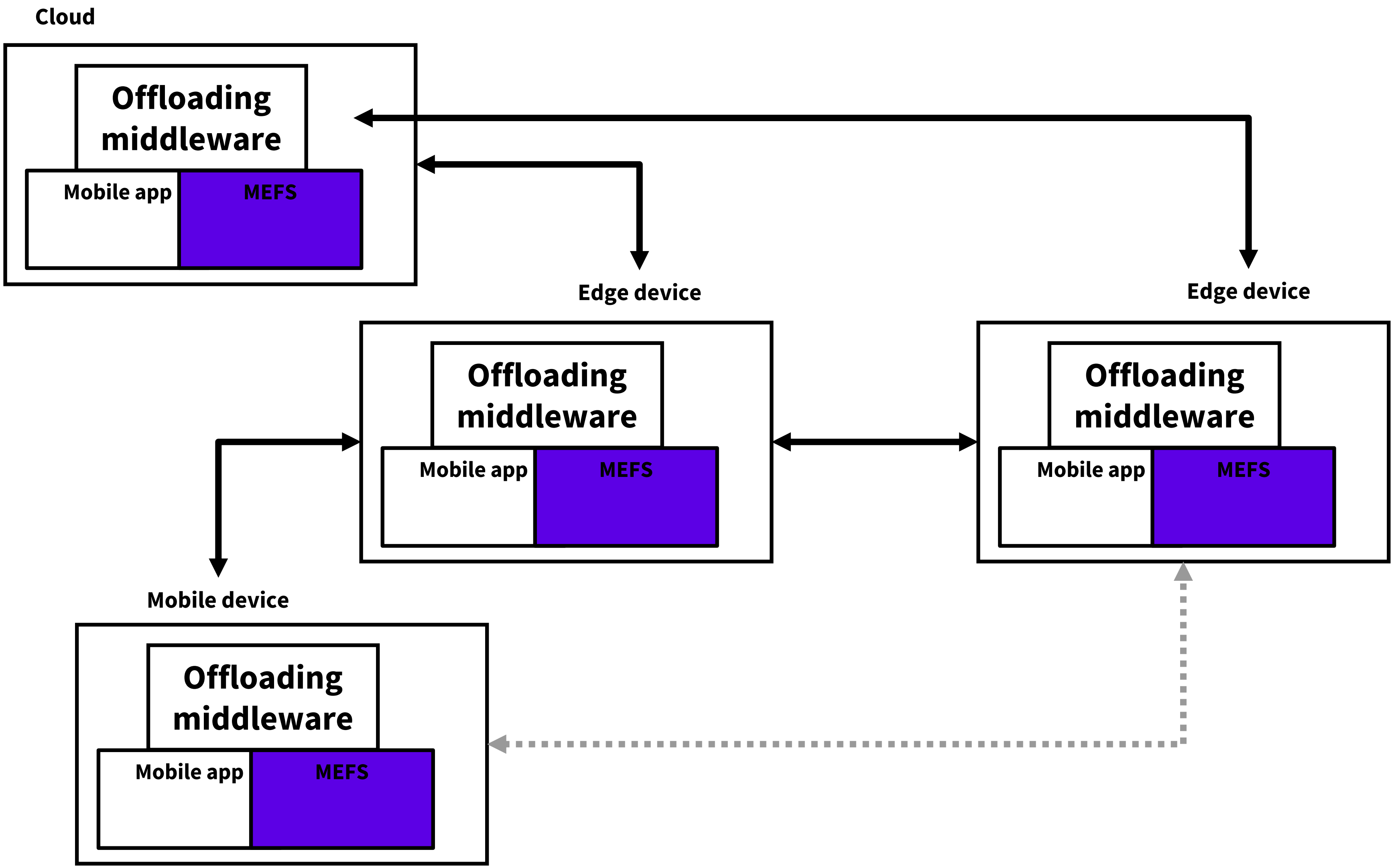
Photo Enhancement App



- **Characteristics of file I/O in cloud-assisted mobile apps:**
  - Read and write files on both mobile and cloud
  - Require strong consistency
  - Long I/O latency due to transferring the file over network

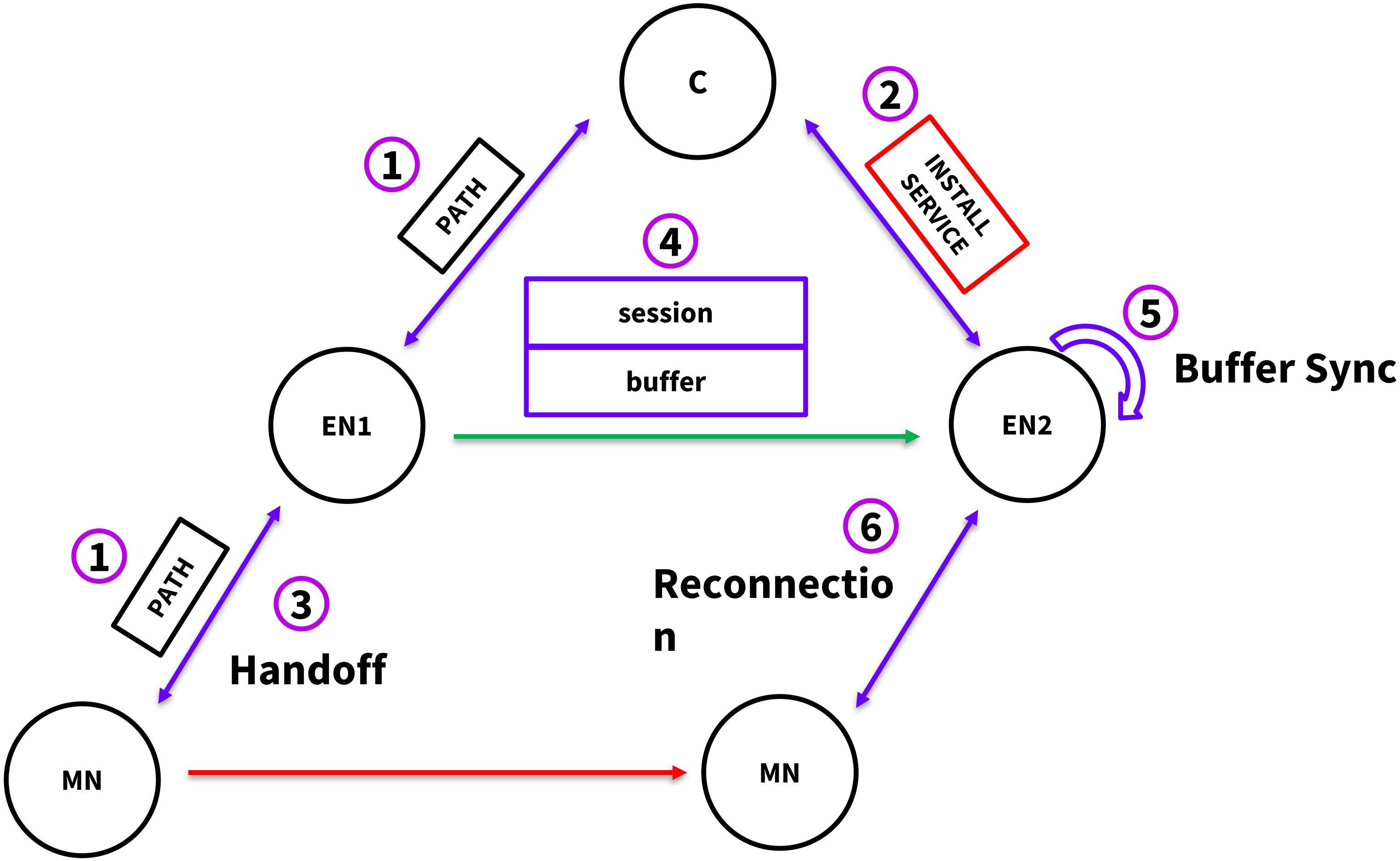
OFS Architecure




Cloud
Offloading middleware
Mobile app
MEFS
Edge device
Offloading middleware
Mobile app
MEFS
Edge device
Offloading middleware
Mobile app
MEFS
Mobile device
Offloading middleware
Mobile app
MEFS

MEC Technical Challenges

1. **Application portability**
   - Transfer apps between MEC servers
2. **Resilience**
   - Protect against node or communication failure


C
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Buffer Sync
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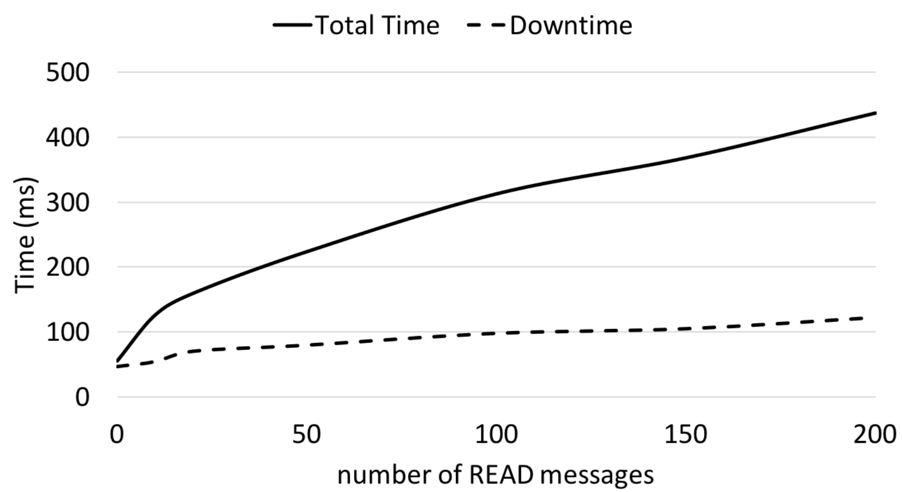
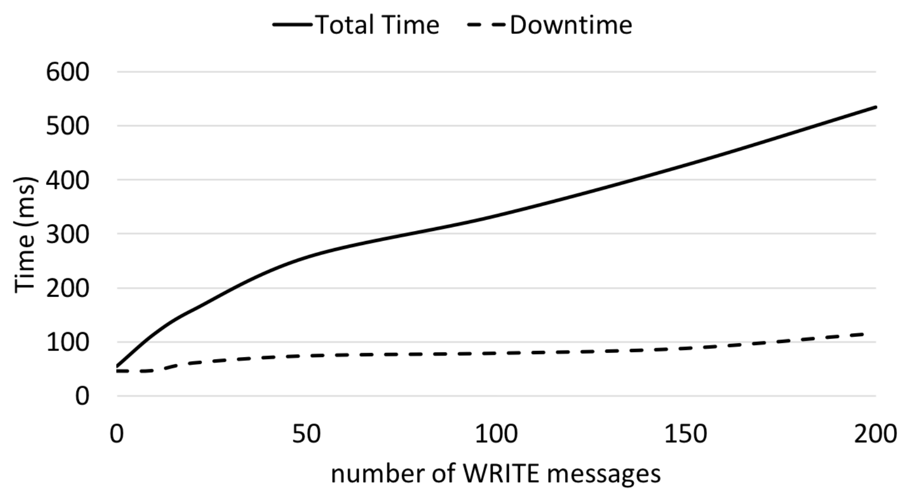
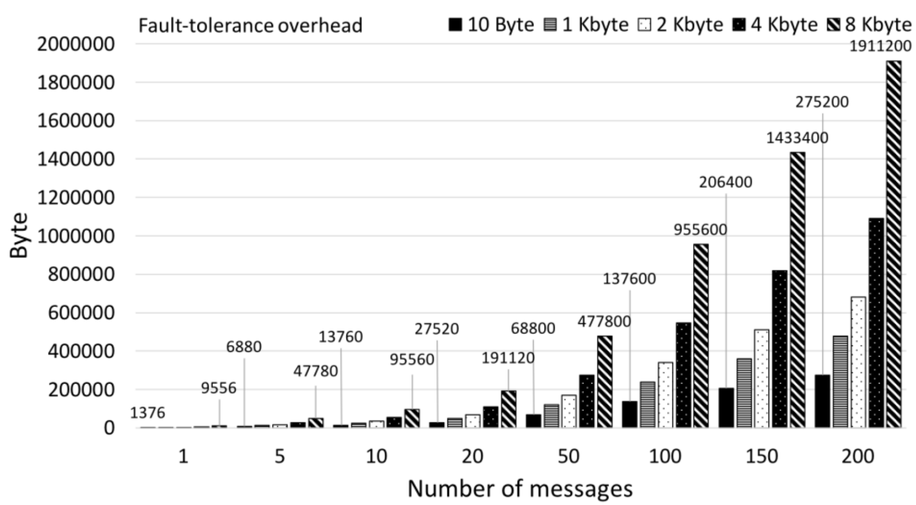
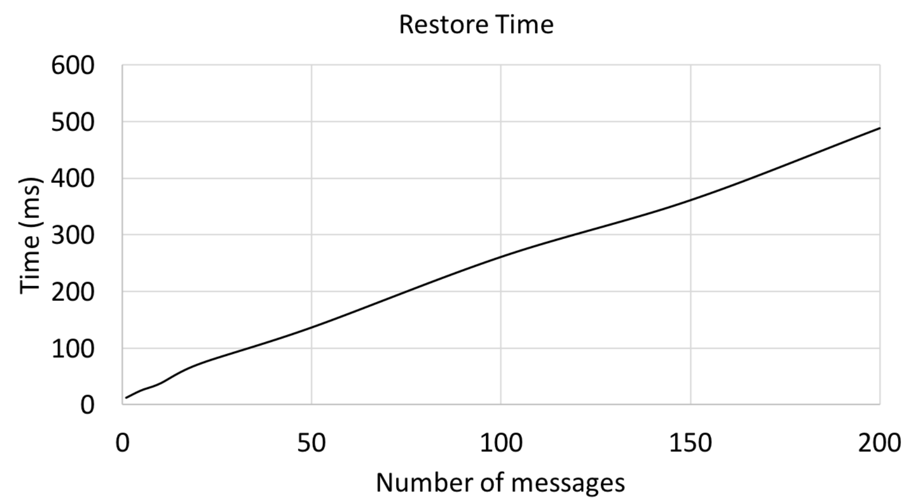
MEFS Performance



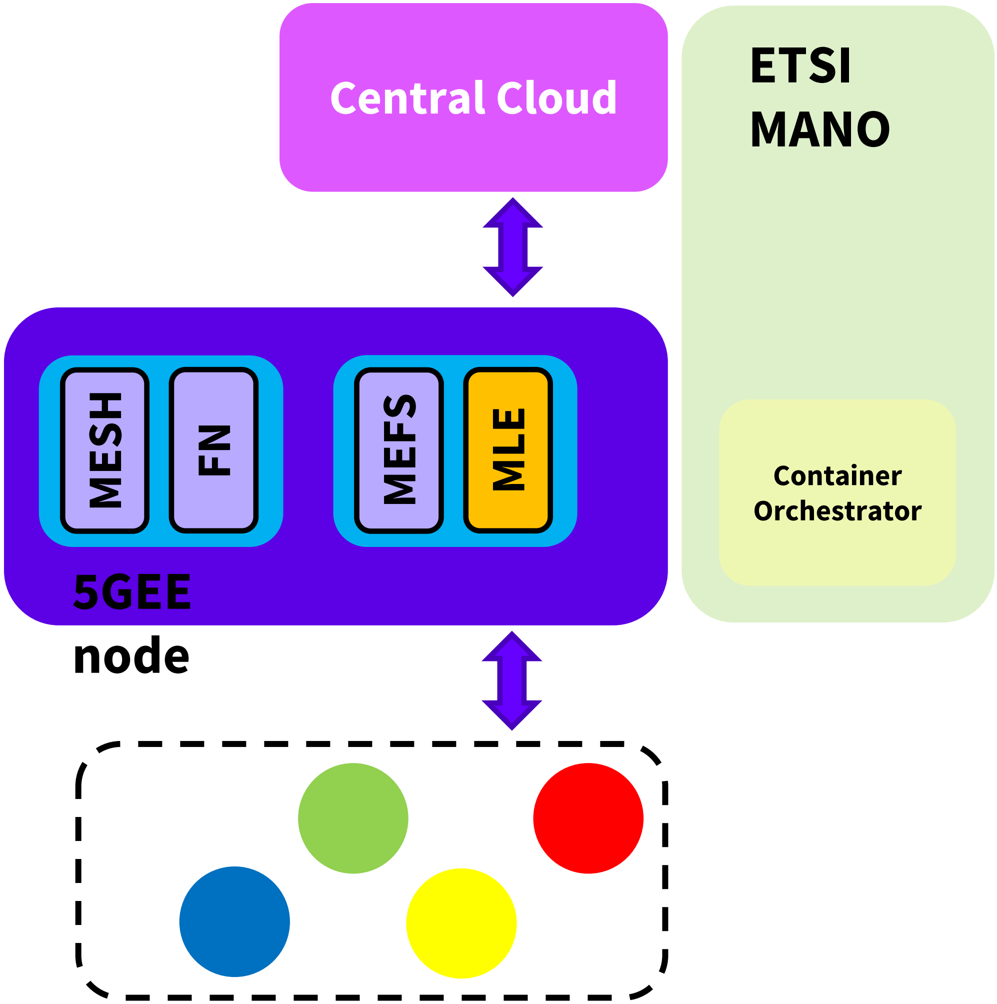




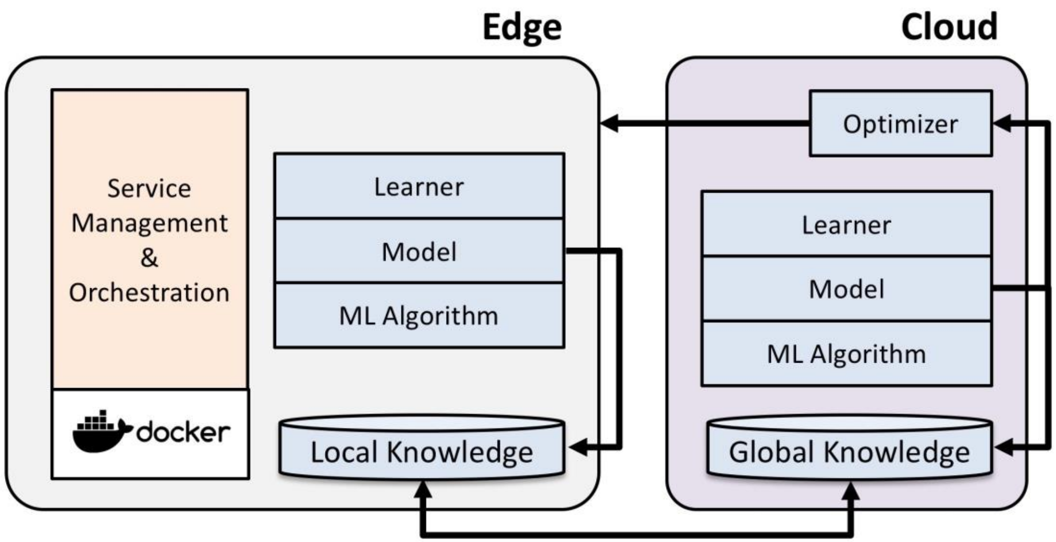


Machine Learning at the Edge

- IoT generates a huge quantity of data
- **Machine Learning** is often used to extract info from generated data
- Support infrastructure to perform ML on distributed EC

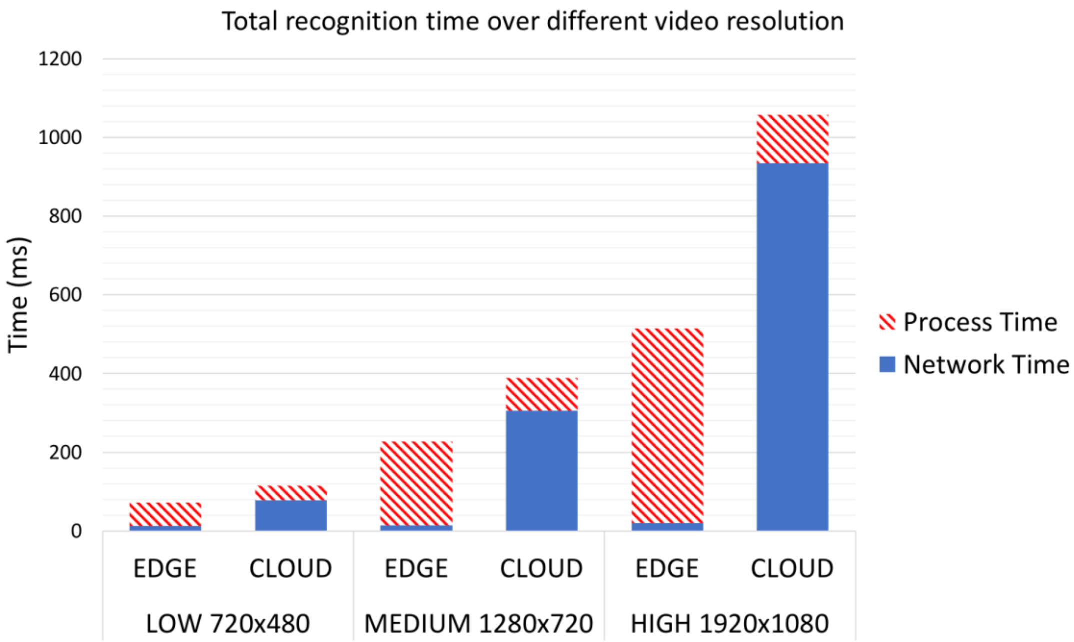


Support architecture for ML



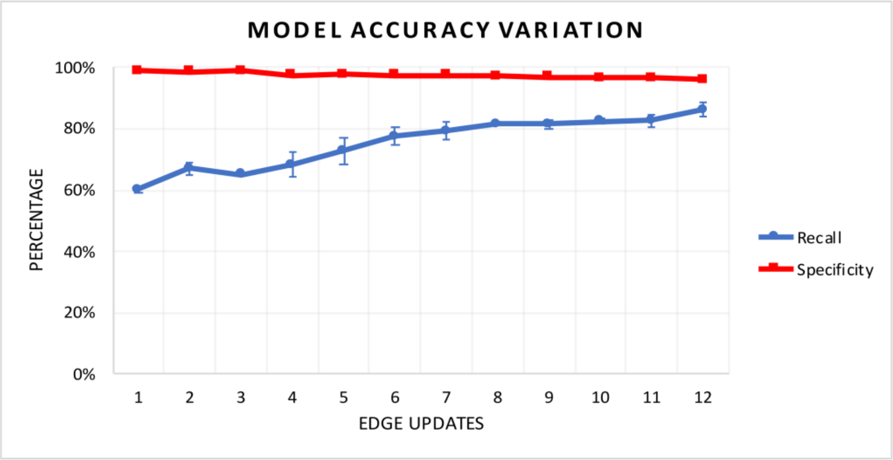
- A set of ML algorithms **run at the edge** for online analysis
- Learning module able to train model (**Digital Twins**)
- An **Optimizer** module that sends feedback to reinforce distributed models

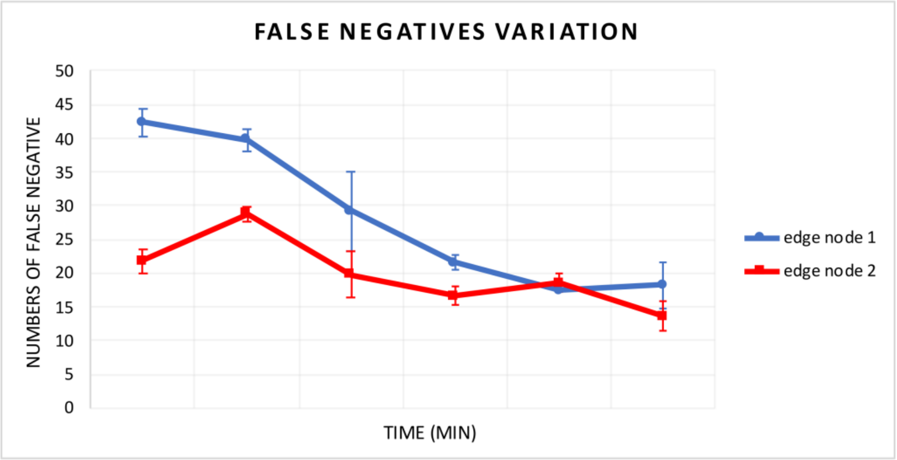
Experimental Results (Smart City scenario)



- **Compared performance of face recognition app in two scenario: mobile/edge and mobile/cloud when the video quality grows**
  - In the cloud the recognition time goes up rapidly as the video quality increases
  - Mobile/edge recognition performs better due to lower latency and higher throughput at the edge

Experimental Results (IIoT scenario)





- **By sending reinforced models from the cloud towards the edge:**
  - the total model accuracy is more or less the same
  - more accuracy to predict negative instances

Questions?
Also about the exam…