Industrial IoT and Cloud

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Version 1.1

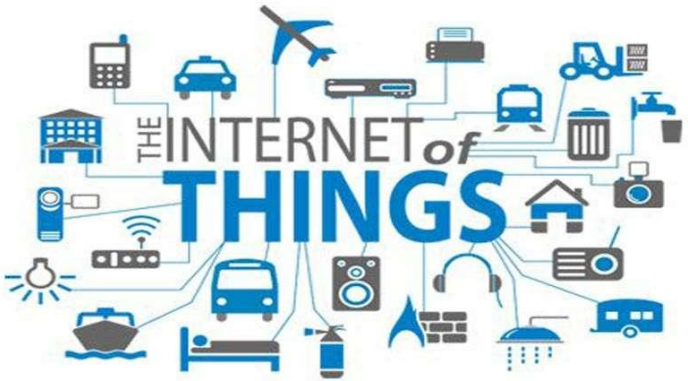
Outline

- Internet of Things
- Industry 4.0 and the communication
- IoT vs Industrial IoT
- (I)IoT Stack
- Commercial solutions
- An exemplification case: ICE Laboratory
- A cloud-native data collection architecture

INTERNET OF THINGS - IOT

What is Internet of Things? (IoT)

- A system composed of different actors:
  - computing devices
  - mechanical and digital machines
  - objects



- Key features:
  - autonomous => must generate information without human interaction
  - network access
    - compliant to TCP/IP
    - specific protocols (e.g.: Lora-r) => most promising protocol for IoT right now is 5G -> huge number of devices per square kilometer, more IBs than 4G
      - low power transmission protocol
  - a unique identifier for each actor

For indoor situations: zigbee is connected to a gateway and then pass to TCP/IP

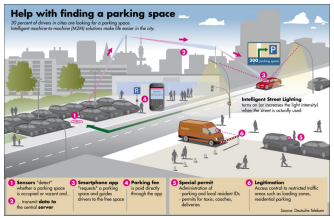
IoT Scenarios - I

IoT can be used in different scenarios:

1. Smart Healthcare
   - measures pulse, steps, blood pressure, …

2. Smart Home
   - controls home heating, lamps, locks, …

3. Smart Mobility
   - smart parking, connected cars, …



4. Smart Grid efficient usage of power
   - smart meters, smart tuning of deliver… systems, …

IoT Scenarios - II

5. Smart Agricolture (specific information for watering)
   - raise the quality, waste less, optimize, …

6. Smart Cities
   - smart buildings, mobility, water, energy, …

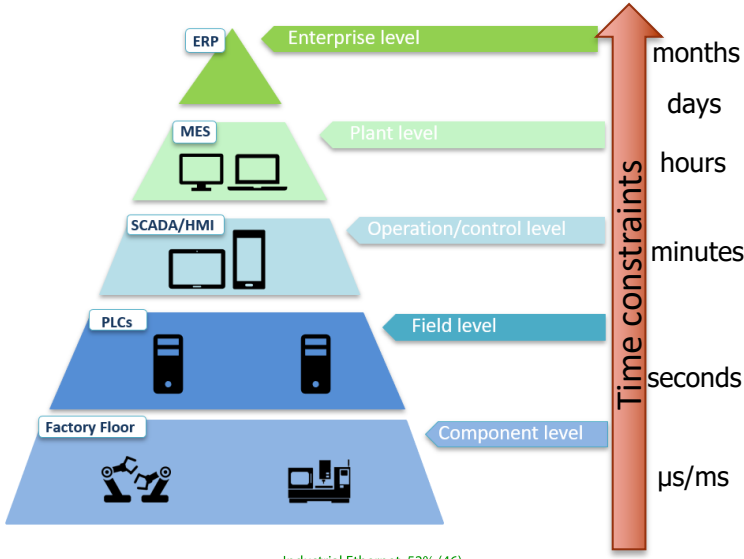
7. Smart Manufacturing
   - improve operational efficiency
   - increase production
   - exploit intelligient technologies

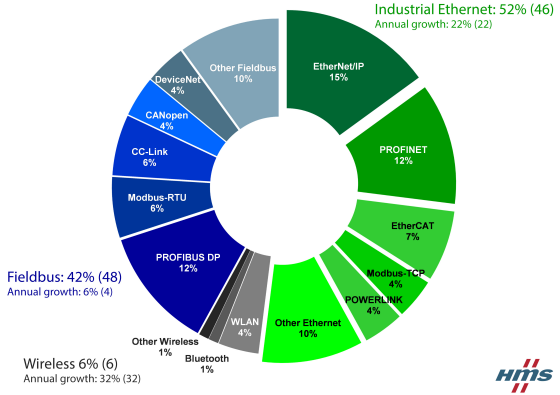
Industrial Internet of Things
IIoT

INDUSTRY 4.0 AND THE COMMUNICATION

Industry 4.0 and the communication

- Standard automation pyramid
  - from actuators and sensors to enterprise systems
  - result of the Third industrial revolution
- At the lowest level, different vendors provide different fieldbus protocols
  - Fielbuses like `Profibus DP`, `Modbus-RTU`
  - Industrial Ethernet networks like `PROFINET`, `EtherCAT`, `Modbus TCP`, `EtherNet/IP`
- **Challenge**: communication technology for all the levels of the pyramid.



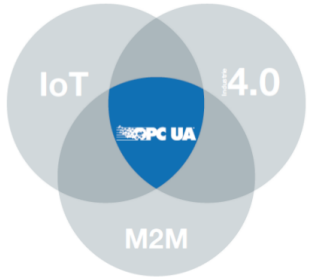


Solution: OPC Unified Architecture

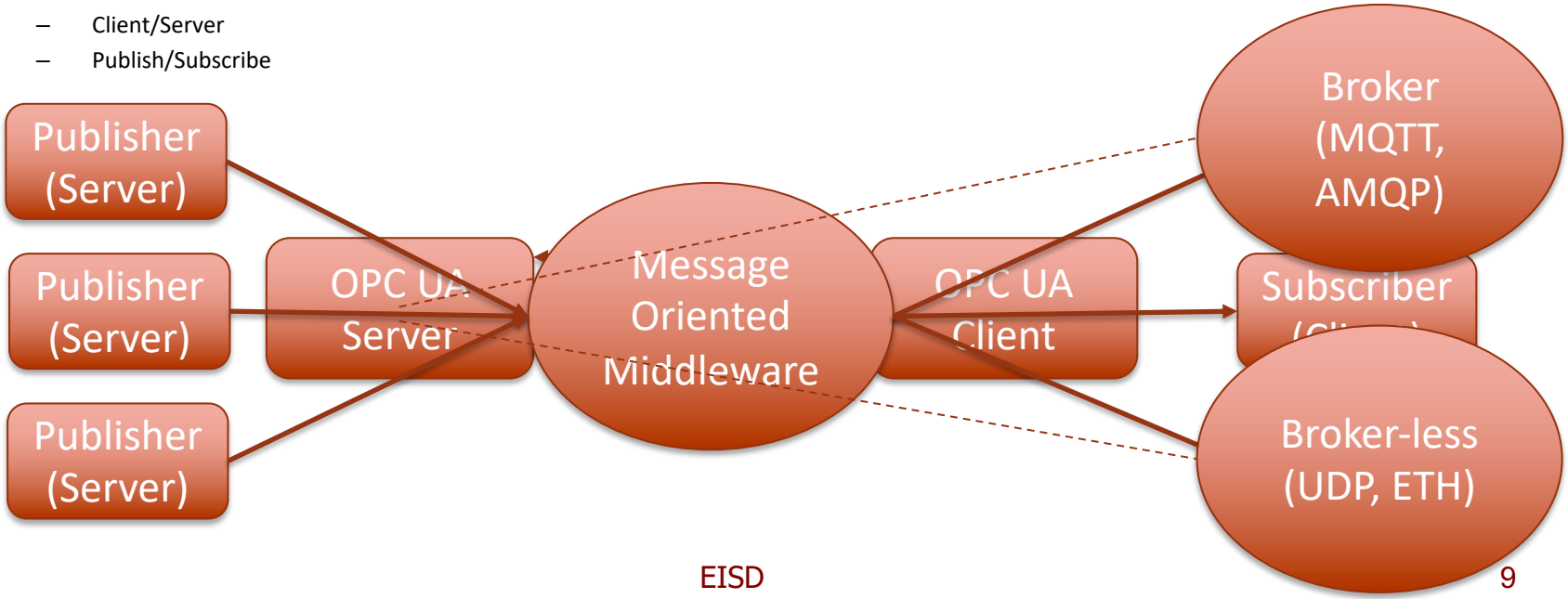
Designed for secure, reliable and interoperable M2M communication
Service oriented architecture (SOA) follows the request/response paradigm.

Doesn't manage low-level

High-level manager for different protocols



- OPC UA offers two communication patterns:
  - Client/Server
  - Publish/Subscribe

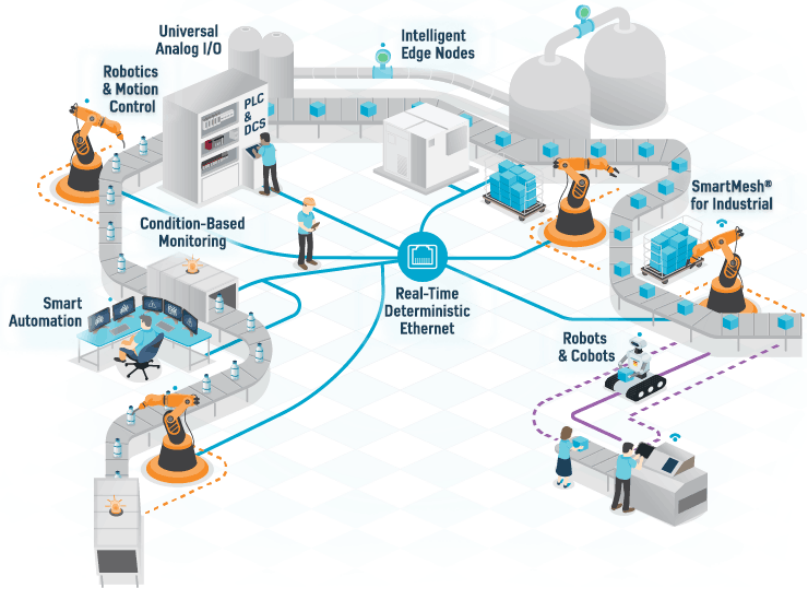


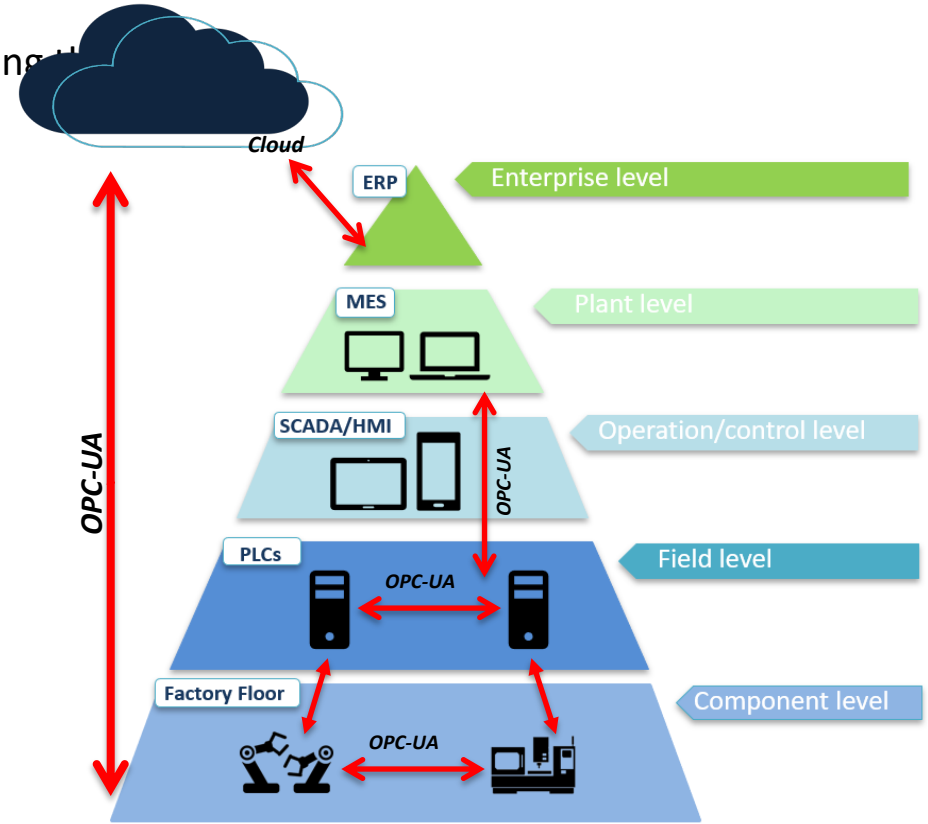
Problems to be faced

1. Role of OPC UA PubSub in Industry 4.0
2. Best communication model for a specific industrial scenario.
3. Best OPC UA PubSub configuration to meet the requirements of the scenario.
4. Integration of OPC UA PubSub with new technologies.
5. Automatic configuration of PubSub environment.

Client/Server VS PubSub

- Different aspects and possible applications
  - **Cloud** scenarios
  - **Real-time** scenarios
    - Information **fan-out**





IoT vs Industrial IoT

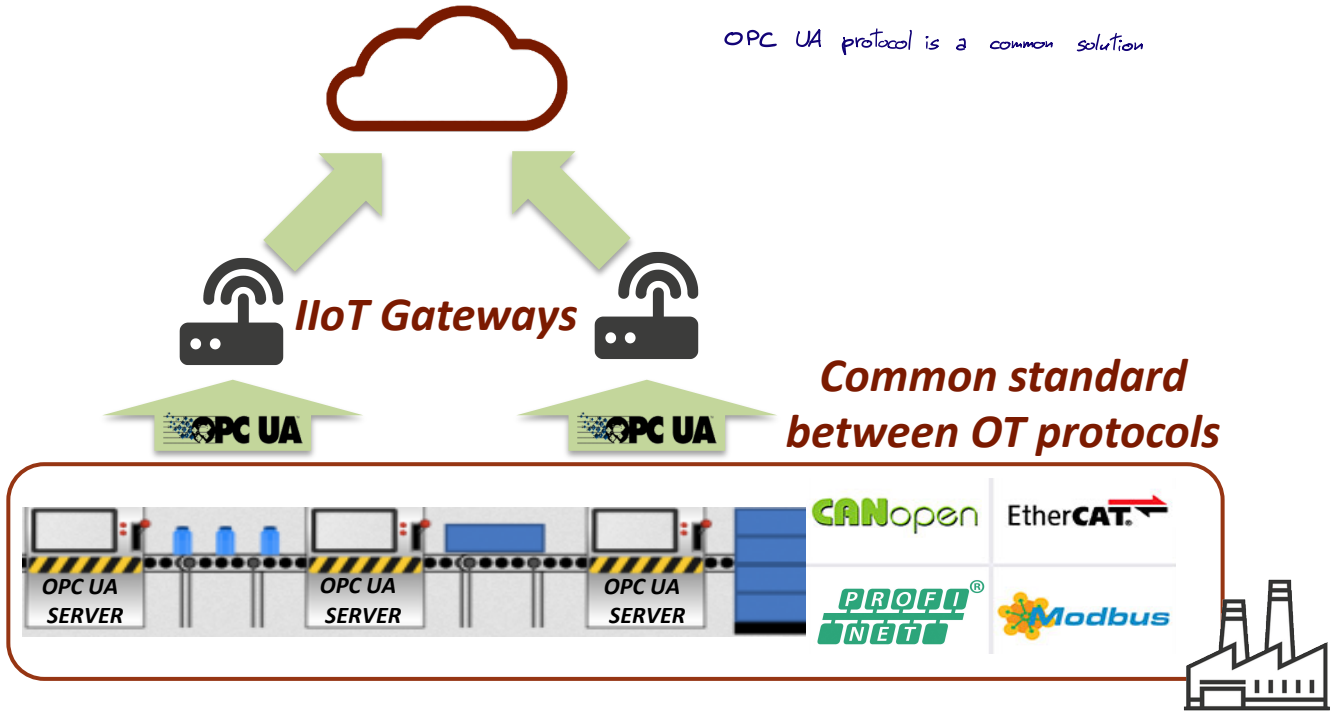
IoT vs Industrial IoT - I

1. *Communications*:
   - IoT devices use *standard IT protocols* like *Wi-Fi*, *Ethernet*, …
   - IIoT devices must support *industrial protocols* like *Profinet*, *Ethercat*, …
2. *Safety and Security*:
   - IoT devices *access the Internet* directly, so they must be *secured*
   - IIoT devices live in the *OT network*, so they must take care of *safety rather than security*
3. *Reliability*:
   - it is *not so critical* for IoT devices
   - IIoT devices must guarantee *high reliability* to *keep safe the production plant*

IoT vs Industrial IoT - II

4. *Architecture*:
   - IoT devices communicate with a *public cloud* to access user information
   - IIoT devices uses a *private* or hybrid *cloud* which contains *company data*
5. *End devices:* very few aspects in common between IoT and IIoT end devices
   - IoT devices *sense data* (like steps, blood pressure, …) for a consumer-type ecosystem
   - IIoT devices provide *precise measures* to both *cloud and PLCs*
6. *Costs*:
   - IoT devices must be *as cheap as possible*
   - IIoT devices need to be *certified* so their cost can be slightly higher

Industrial IoT Architecture



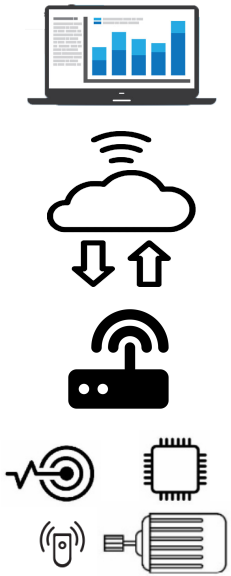
(I)IoT Stack

(I)IoT Solution - Layers

An IoT solution is composed of many layers:

- Security
- Management

4. analytics platform
3. core platform
2. communication protocols / device gateway
1. device layer



(I)IoT Solution - Device Layer

Devices are the *things* of the (I)IoT

– small devices with a microcontroller and one or more sensors / actuators

Sensors

- are programmed to *sense environmental parameters*
- low power



Actuators

- act with the *physical world* according to the input received
- motion, lighting, emitting sound, controlling power, …


Tagged Devices

- communicate wireless
  - *RFID* (Radio Frequency Identification)
  - *NFC* (Near Field Communication)
  - *Beacons* w/ Bluetooth LE

(I)IoT Solution - Communication Layer - I

Two *communication strategies*:

Direct Internet Access

- device has the capabilities to access directly the Internet
- using *wireless or wired* protocols:
  - Wifi
  - Ethernet
  - Cellular (2G, 3G, LTE, 5G)

Internet access *through gateway*

- device cannot access directly the Internet
- a *gateway/smartphone* is needed
- protocols between node and gateway:
  - Bluetooth / Bluetooth LE
  - RFID
  - NFC
  - Zigbee

(I)IoT Solution - Communication Layer - II

Two main *application protocols*:

difference is size → short but frequent msgs / larger msgs

MQTT/AMQP protocols

- *small* payload
- machine-to-machine (*M2M*) protocols
- client - server / publisher - subscriber
- needs a *broker* that handles message delivery
- work over a *TCP* connection

MQTT.ORG

AMQP Advanced Message Queuing Protocol

OPC UA protocol

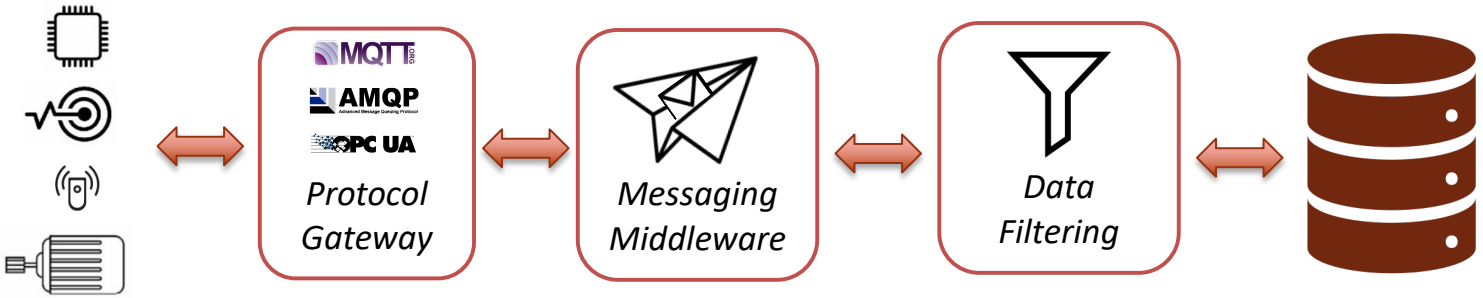
- industrial automation standard (*IEC 62541*)
- *interoperability* between industrial pyramid layers
- client - server / publisher - subscriber
- well defined *data model*
- works over any kind of transmission

OPC UA

(I)IoT Solution - Core Platform - I

Located in the cloud, provides a set of capabilities to monitor and control IoT devices and to process incoming data

All operations are completely implemented on the cloud



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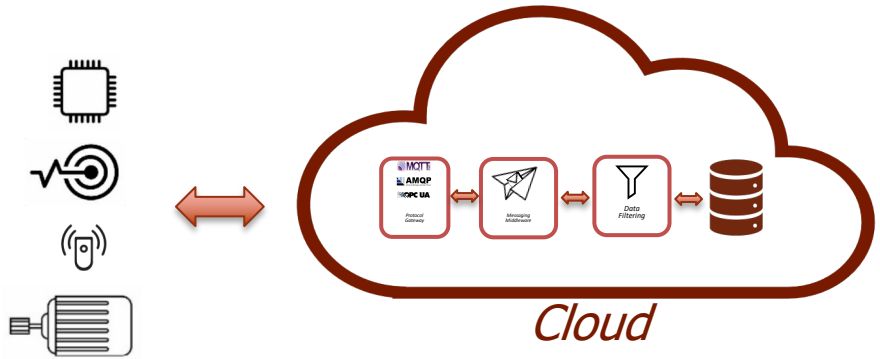
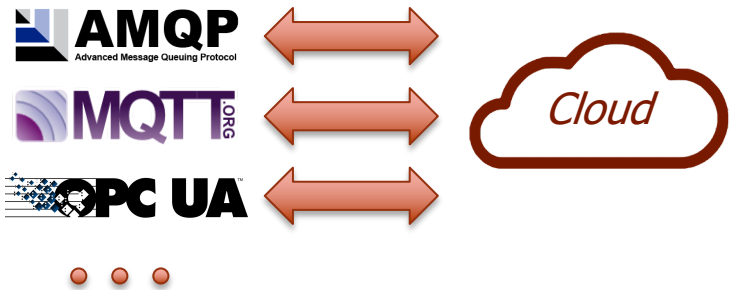


(I)IoT Solution - Core Platform - II

Protocol Gateway

- enables the core to support *different protocols* from devices
- the platform internally uses *one single protocol*



(I)IoT Messaging Middleware

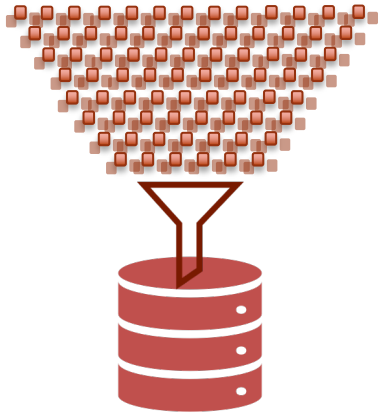
- *distributes messages* across core and devices
- *highly scalable* (*buffering* incoming data)
- provides *secure connectivity*

(I)IoT Solution - Core Platform - III

Data Aggregation and Filter

- provides *rules* and *complex conditions* to filter out data
- provides *mapping techniques* to extract *models* from *raw data*
- device *data contextualization*

Synchronize the incoming data



Data Storage

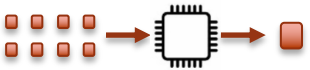
- stores *continuous data stream* from devices
- provides *redundancy*
- *Time Series* database (NoSQL) like MongoDB, CouchDB, …

(I)IoT Solution - Analytics Platform

Allows to analyze data to derive insights and actions

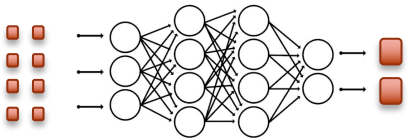
Stream Processing

- *analyzes* all incoming data
- *fault tolerant*
- *scalable*
- supports interactive queries
- triggers *events*



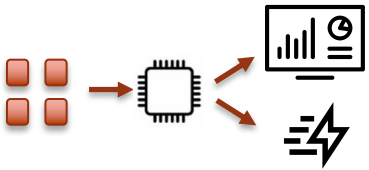
Machine Learning

- makes computers learn from data without explicitly programming them
  - *supervised learning*
  - *unsupervised learning*
  - *reinforcement learning*



Events and Reporting

- services that allows the connection between data and actions
  - *trigger events*
  - *call external services*
  - *update dashboards in real time*



COMMERCIAL SOLUTIONS

Commercial Solutions - Common Features

IIoT solutions are composed of *two parts*

1. access to a *cloud dashboard* to
   - *configure* the service
   - *pair* the IIoT gateways
   - *visualize* stored data
   - perform *data analysis*

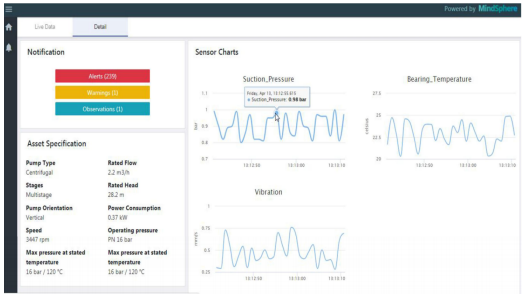
2. a set of *IIoT gateways*
   - *data collection* from PLCs
   - small local data buffer
   - data is sent to cloud

Commercial Solutions - Siemens MindSphere

IoT operating system from **SIEMENS**

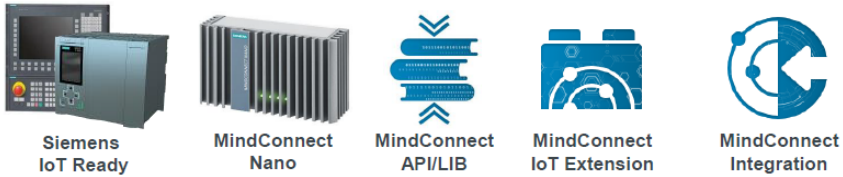
Cloud dashboard

- concept of *apps* executed in the cloud
- advanced *data analytics*
- *fast develop* of industrial solutions
- data *visualization*
- *machine learning* app



Many data sources

- MindConnect Nano
- MindConnect IoT2040
- MindConnect Lib
- MindConnect IoT Extension



Commercial Solutions - eWON

A HMS Connecting Devices™ company, has its own solution

M2Web

- provides secure access to PLCs, HMI, …
- pc, mobile, tablet supported
- access through Vpn
- Monitor and control PLCs

Flexy M2M Data Gateway

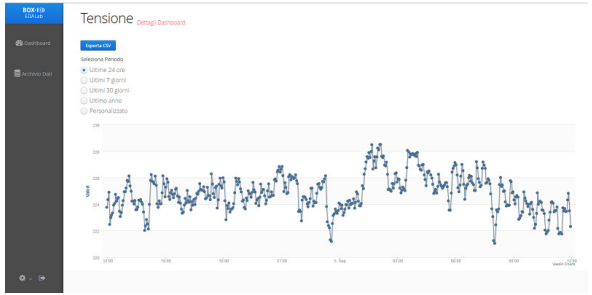
- PLC form factor
- support for *many PLC brands* to collect data (Siemens, ABB, Omron, …)
- support for *many cloud services* to store data (MindSphere, AWS, Azure, …)

Commercial Solutions - BOX-IO

IoT monitoring solution from EDALAB Networked Embedded Systems

Cloud dashboard

- *monitor and control* IoT devices
- can also *aggregate* data
- *customizable* solution

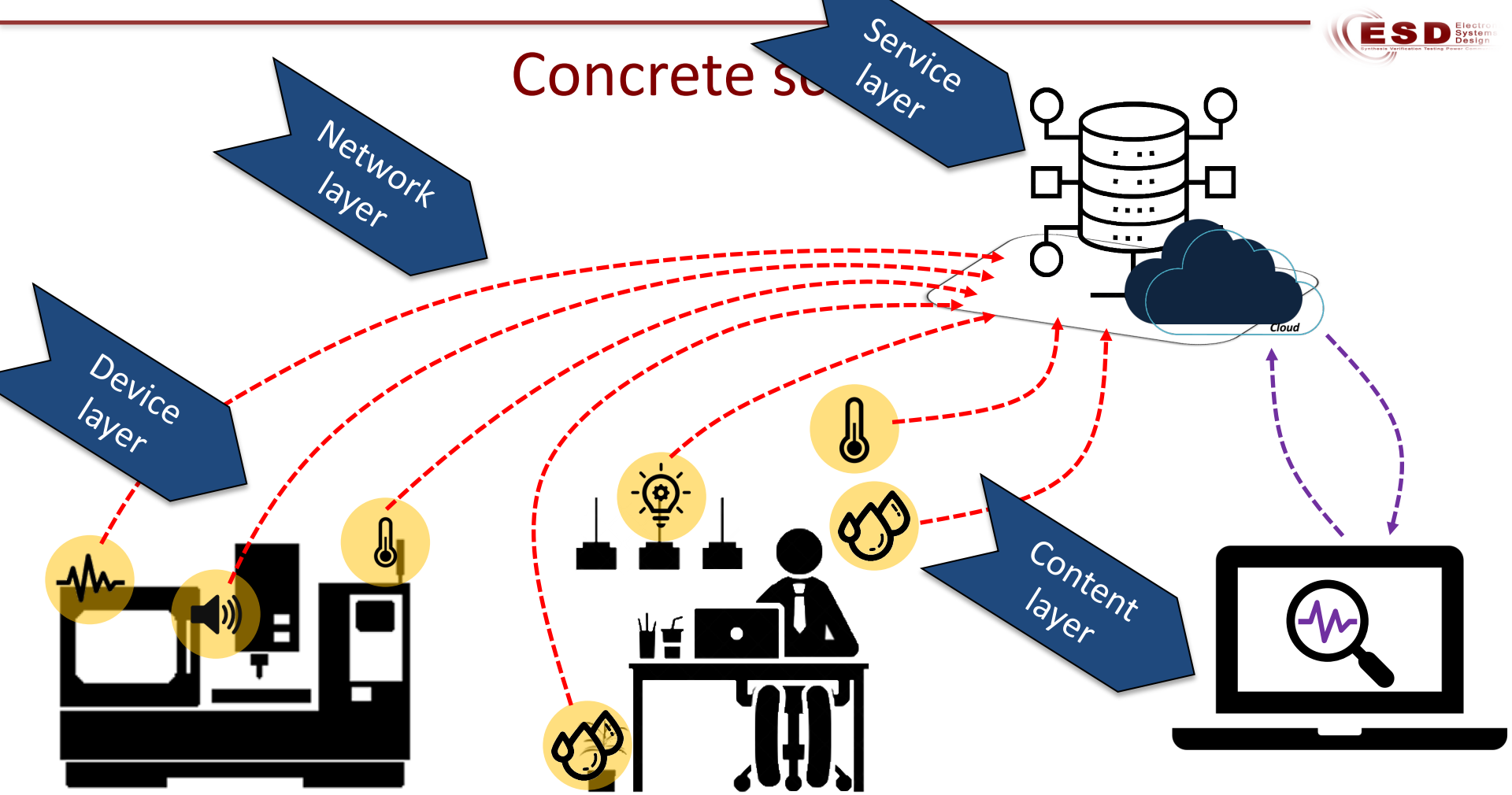


BOX-IO Gateway

- various *IT/OT protocols* supported
  - zigbee, modbus, ethernet, wifi
- broad range of *sensors/actuators* supported
- *local* buffering storage
- easily *extensible*
- embedded *gateway* or embedded *software*

AN EXEMPLIFICATION CASE: ICE LABORATORY

Concrete se


Service layer
Network layer
Device layer
Content layer
Cloud

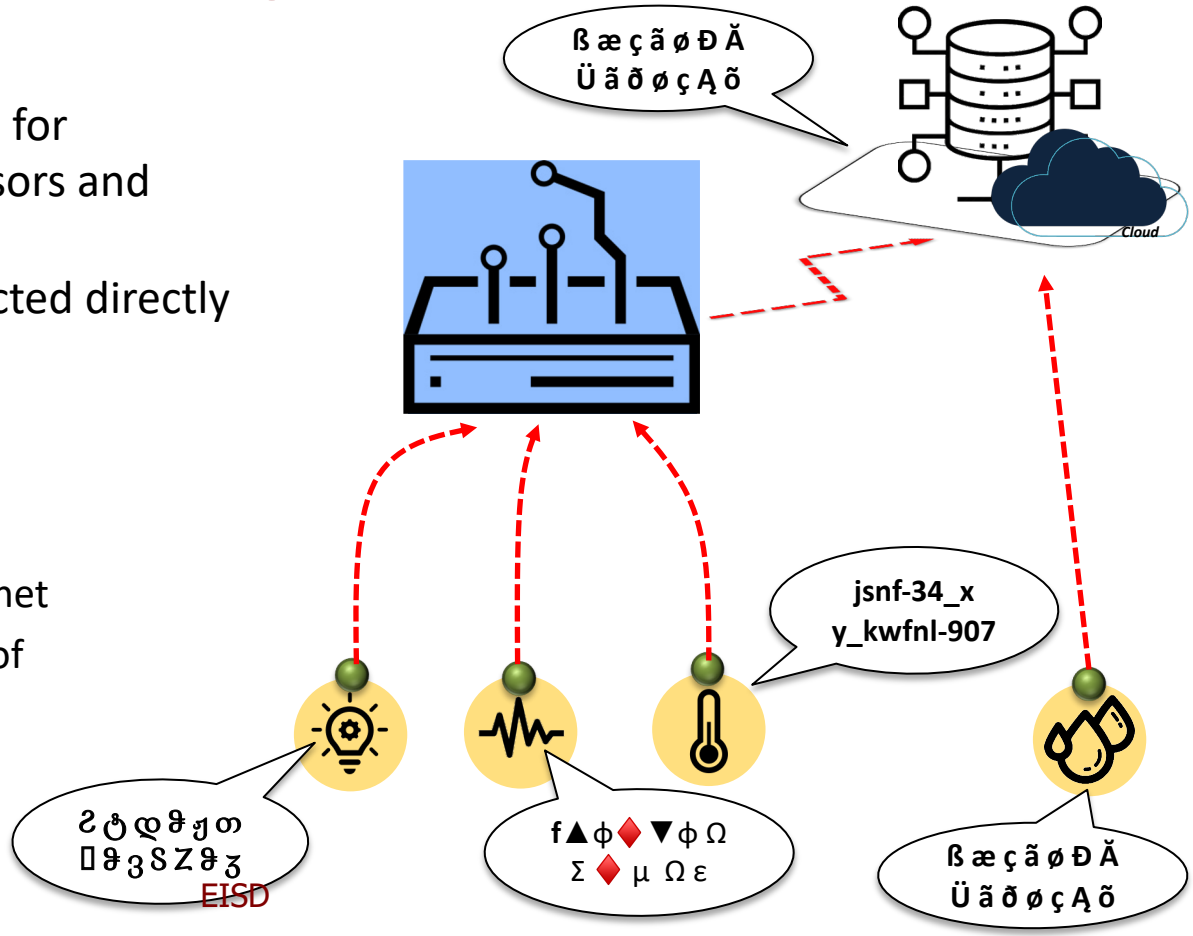
Connecting devices

PROBLEM

- Absence of a unique standard for communication between sensors and central processing
- The sensors cannot be connected directly to the IP/internet network

SOLUTION: Gateway

- Support different protocols
- Connect devices to the internet
- Provides an additional level of security
- Pre-process data
- Reduce transmission size

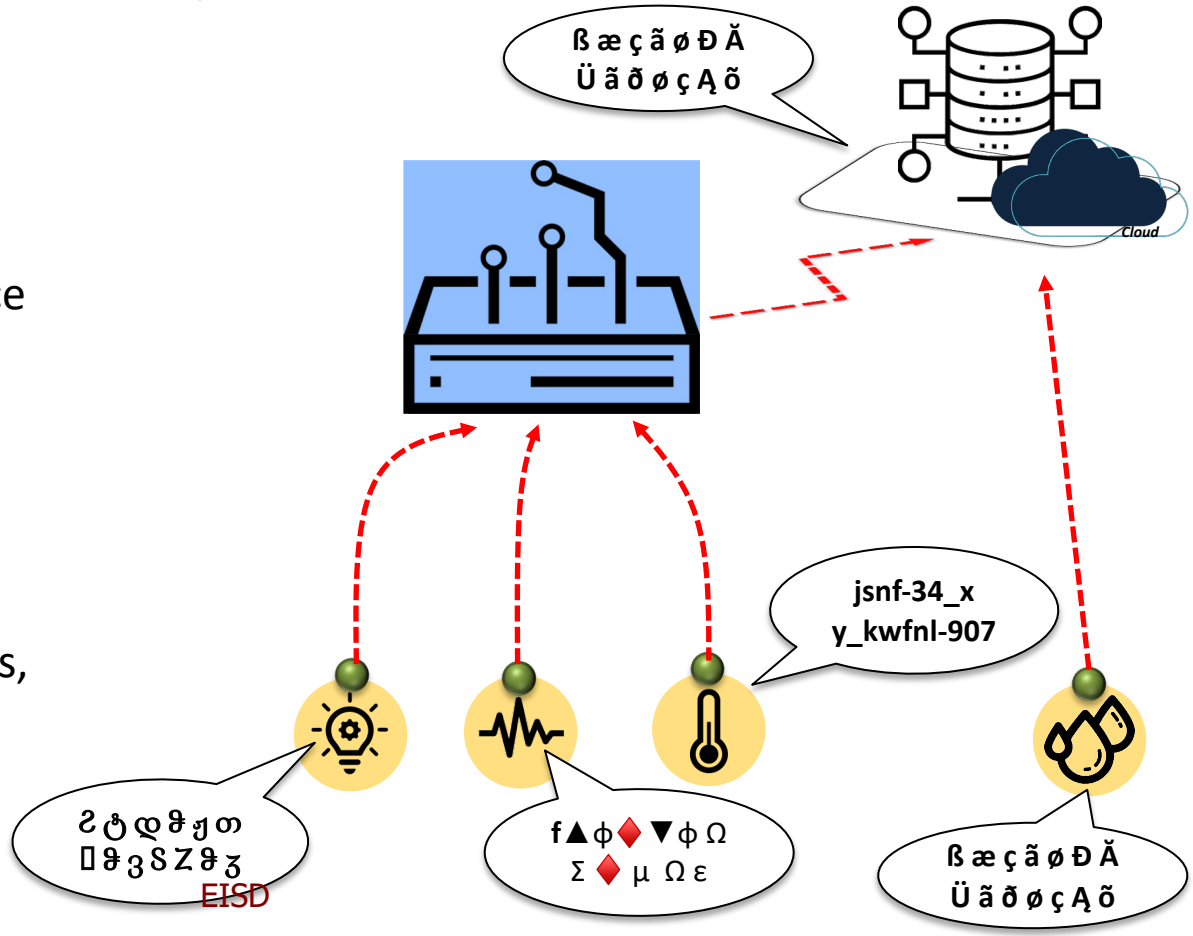


Which protocol?

The choice of protocols depends on:

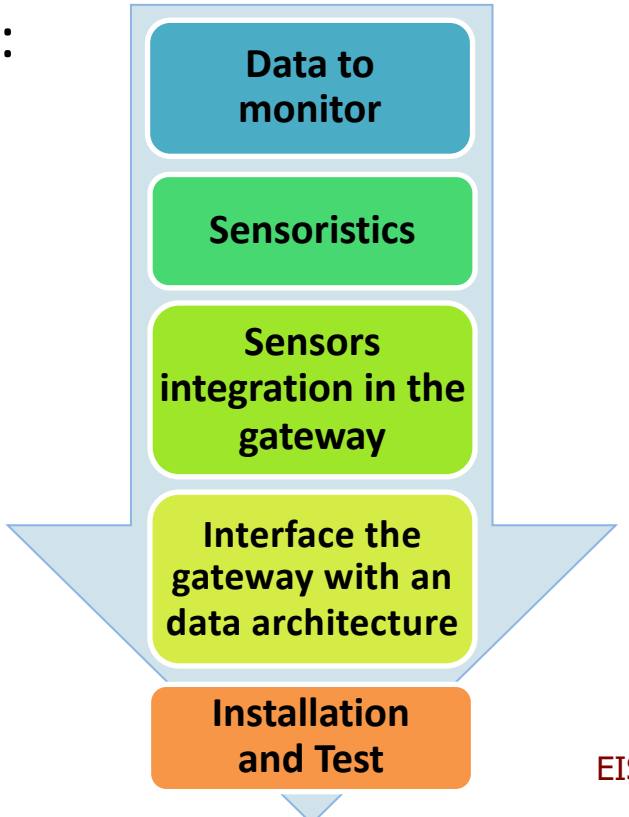
- Wired or wireless
- Sensor-gateway distance
- Bandwidth
- Latency
- Energy consumption

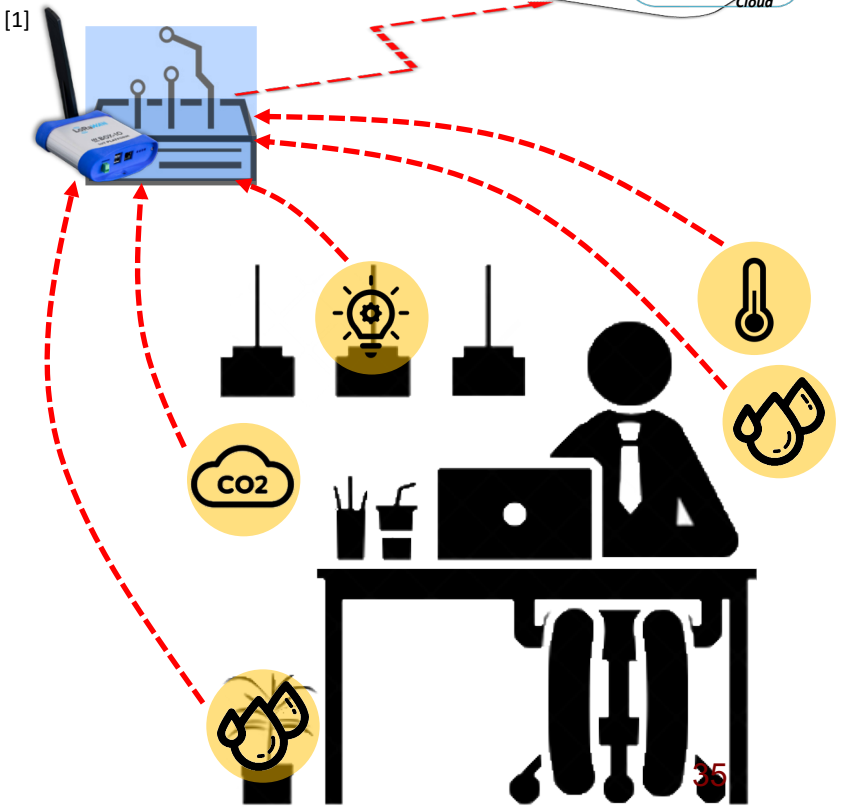
- (I)IoT protocols
  - Wi-fi, Ethernet, Modbus, Bluetooth, Zigbee, NFC, LoRaWAN, …



Data acquisition system implementation

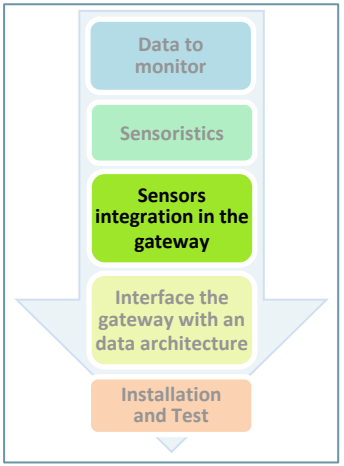
- **GOAL:** to monitor the working environment and equipment status
- Steps:





[1] https://www.box-io.com/

Sensors integration



Choose the data to collect

Sensor already installed

Sensor not installed

Protocol supported by the gateway

Protocol not supported by the gateway

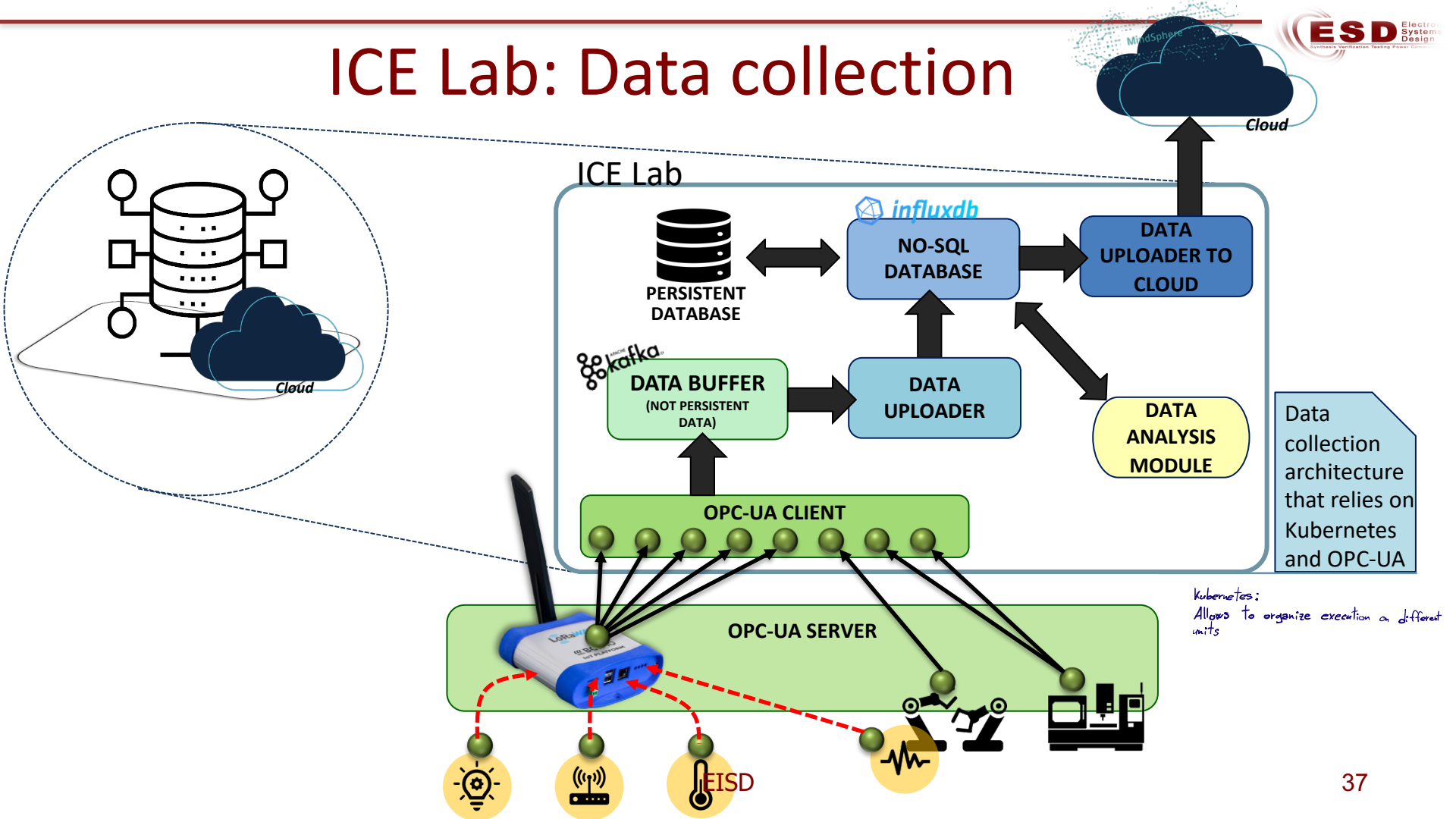
Choose the most suitable sensor

Add protocol to the gateway

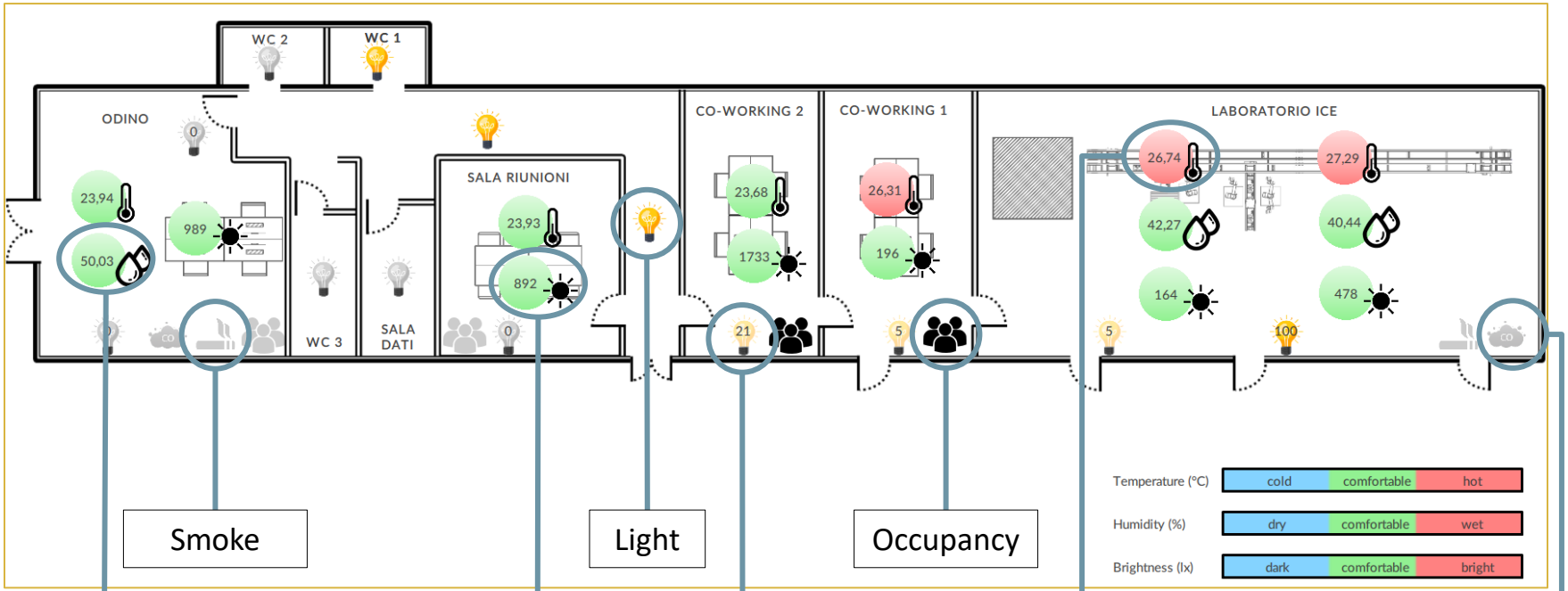
Integration of the sensor to the gateway

Test phase

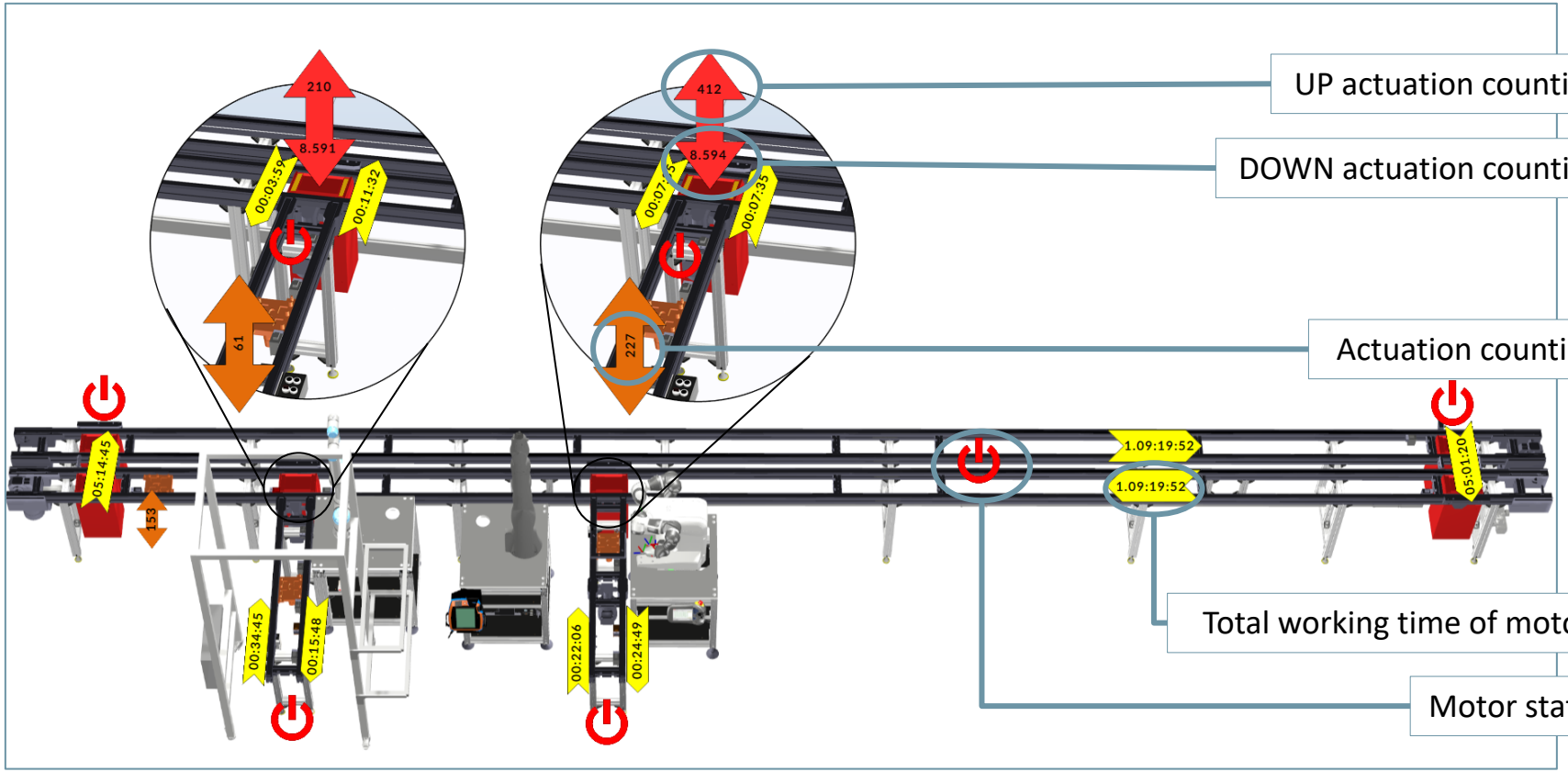
ICE Lab: Data collection



ICE lab: IoT Data Viewer



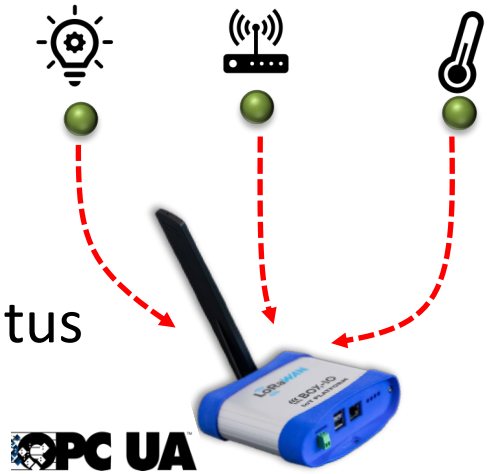
ICE lab: IIoT Data Viewer



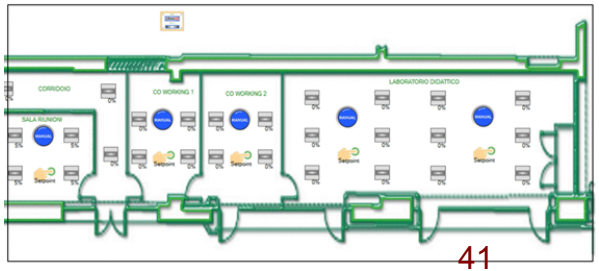
Data Collection Architecture – based on Kubernetes and OPC-UA

Overview

- Plant equipped with *OPC-UA servers* providing
  - *equipments status*
    - *by native or custom OPC-UA servers*
  - *environment data (*IoT and Industrial IoT*)*

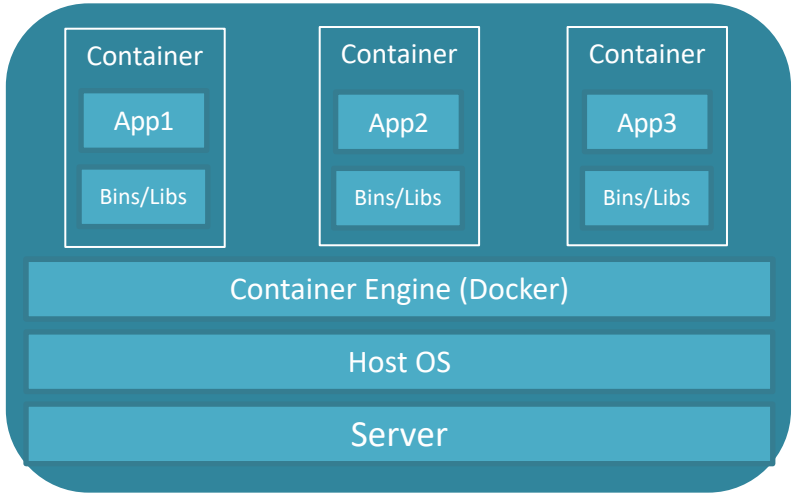


- Need to *monitor*, *log* and *analyze* the plant status
- Our solution:
  - *OPC-UA Data Collection Architecture that relies on Kubernetes*

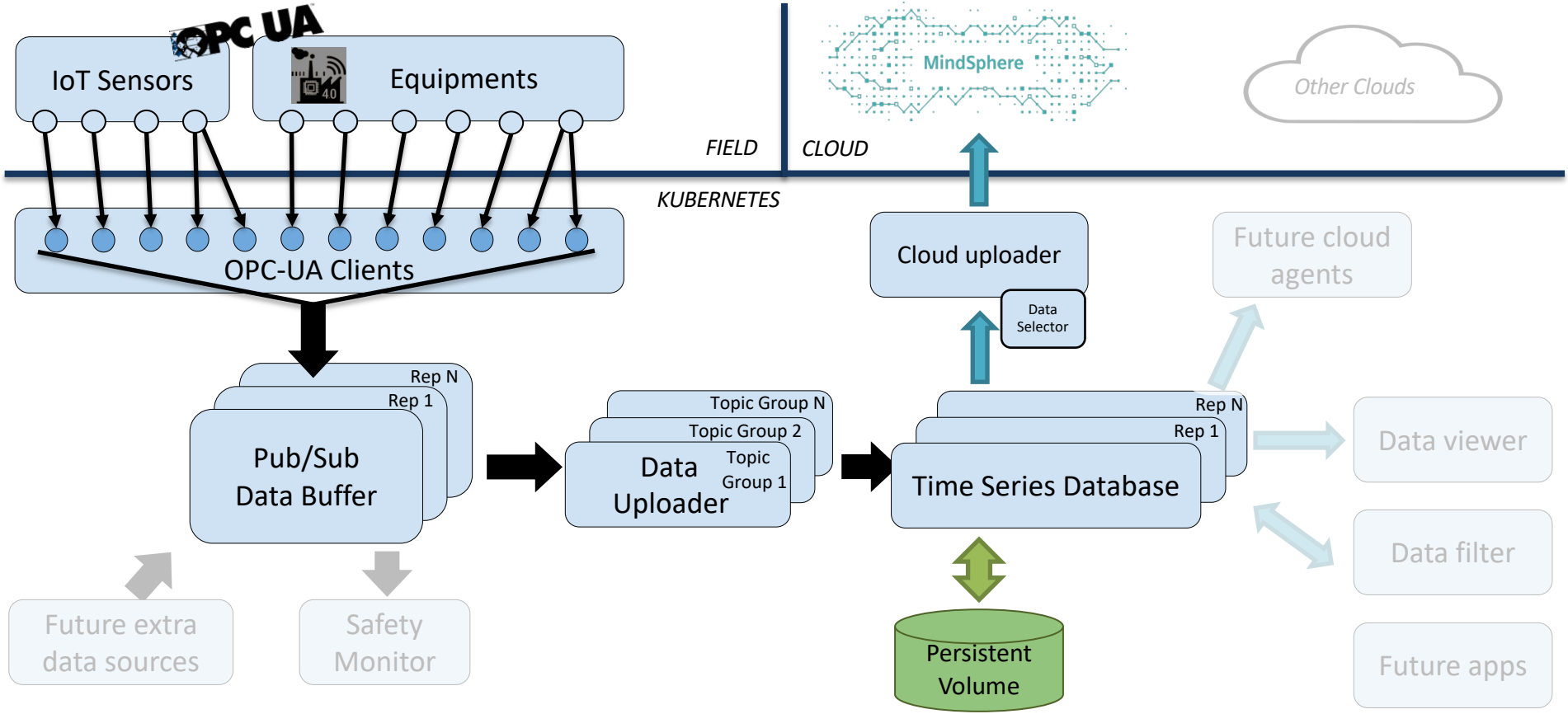


Containers and Kubernetes

- Each node of our architecture is bundled in a *container*
  - *"A container is an app abstraction that packages code and dependencies together"*
- Container orchestration tool: Kubernetes
  - Instantiate, monitor and manage
  - Scaling / Replication

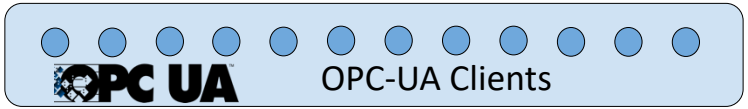


Architecture Overview



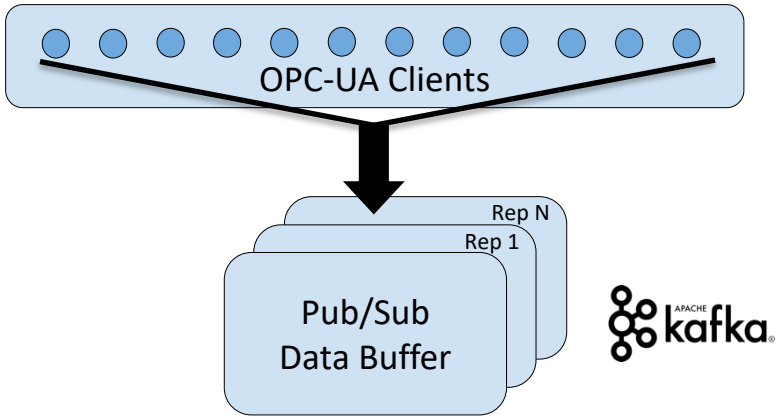
OPC-UA Client

- *Data ingress node*
- Reconfigurable:
  - *OPC-UA server* to connect to
  - variable list to subscribe, for each:
    - *sampling interval*
    - *datatype* and *unit*
    - custom static fields
  - *topic name* to publish data to
- Optimized for *high data throughput*
- *At least* one instance per machine



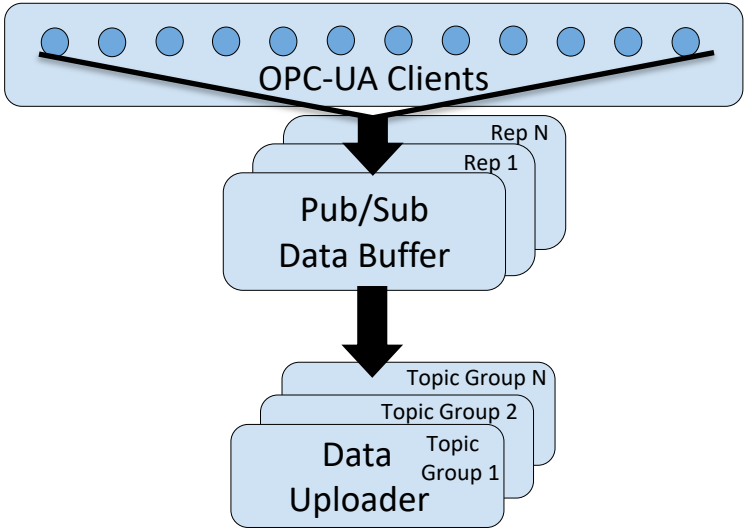
Publish/Subscribe Data Buffer

- A *publish/subscribe broker*
- *Large data streams* handling
  - partitioned in different *topics*
- Multiple instances to guarantee
  - *fault tolerance*
  - *high performance*
- Improves architecture extensibility
  - extra producers/consumers can be *added easily*



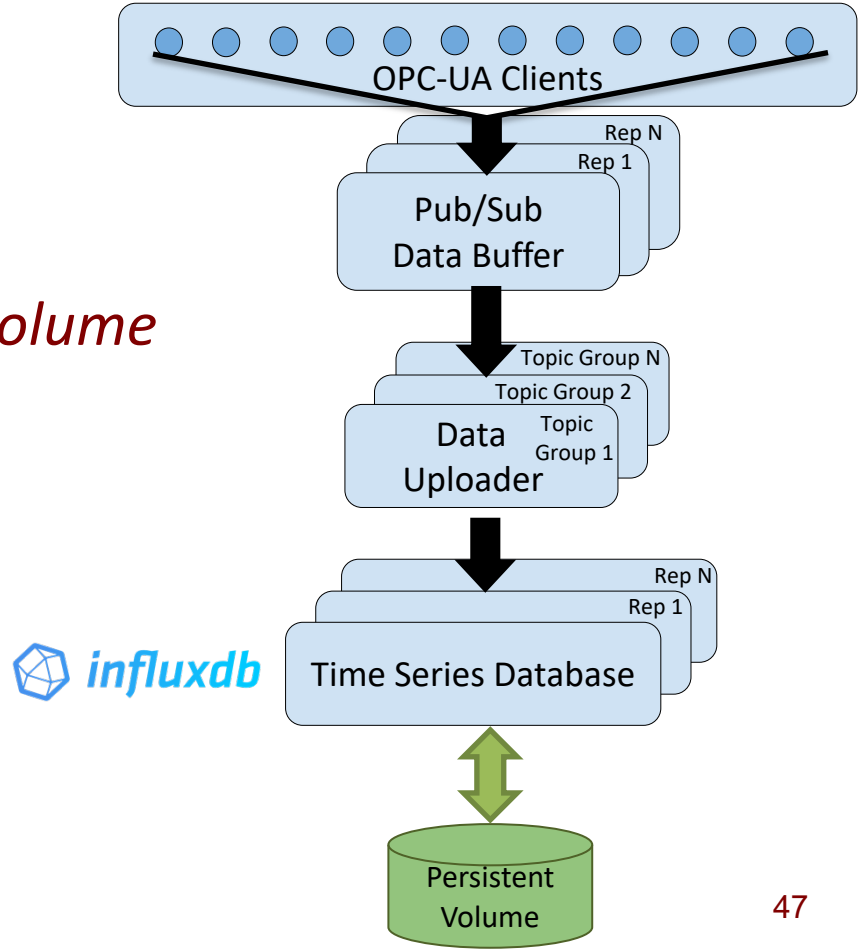
From Buffer to Database

- *Data Uploader nodes*
- Each node has its *topic-group*
  - *scalable solution*
- Each node sends *chunks* of data



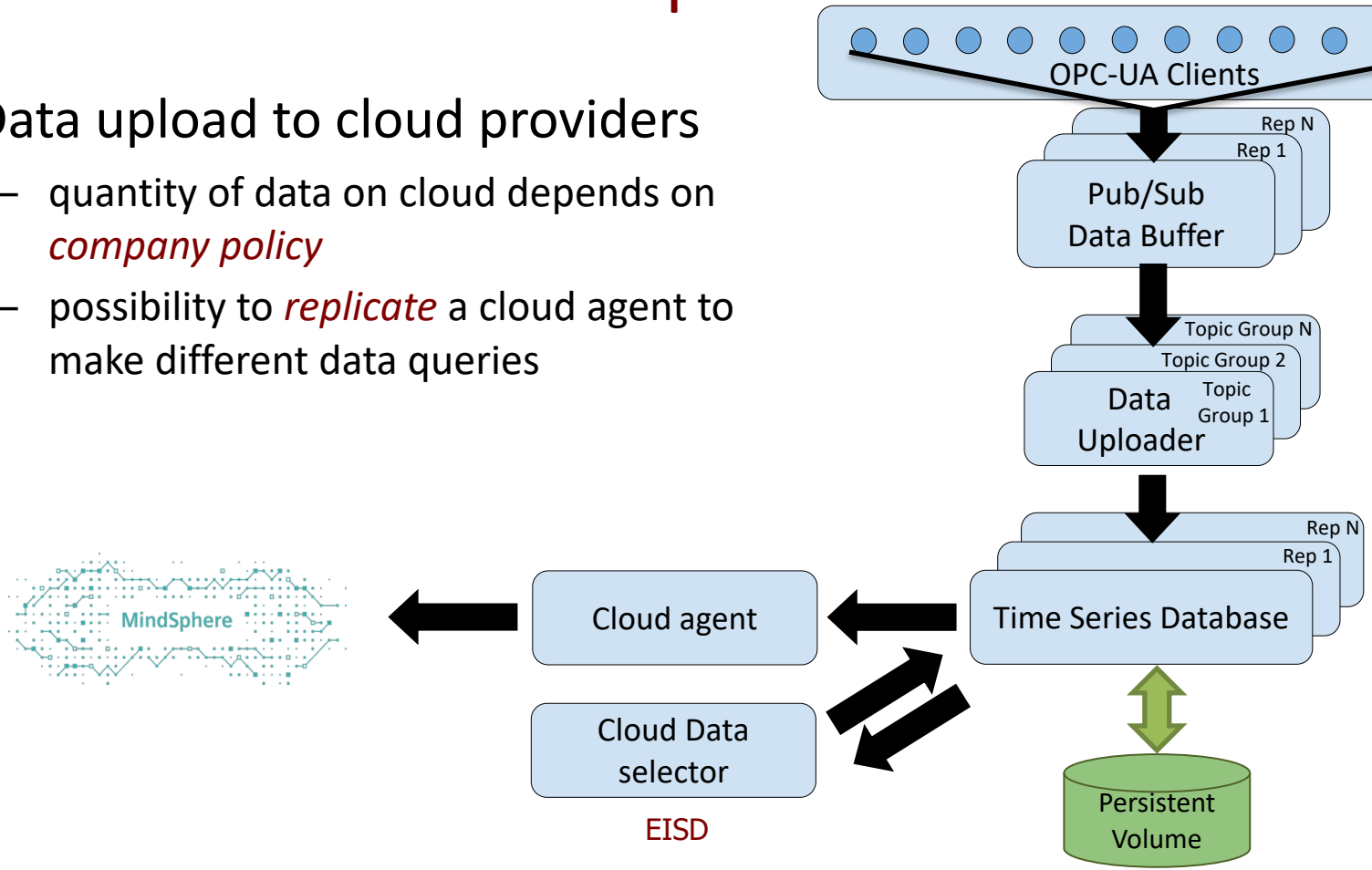
Time Series Database

- NoSQL Database
- Stores all data on a *persistent volume*
  - can optionally *filter incoming values*
  - can perform *data aggregation*
- Data organized in *buckets*



Cloud Uploaders

- Data upload to cloud providers
  - quantity of data on cloud depends on *company policy*
  - possibility to *replicate* a cloud agent to make different data queries



From Database to Mindsphere

No-SQL Database

influxdb

ICEData

CleanData

ToMindsphere