The IoT Solutions Space: Edge-Computing IoT architecture, the FAR EDGE Project

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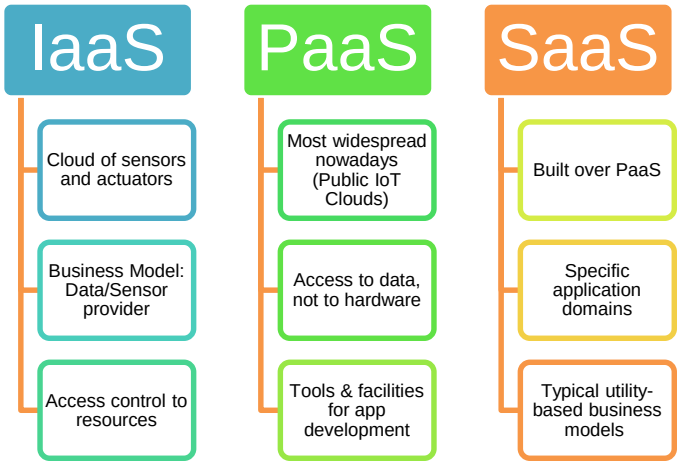
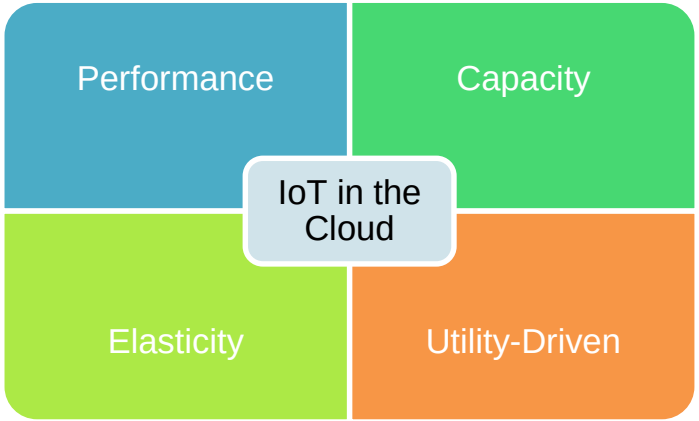
Industrial IoT Applications in the Cloud

- Industrial IoT (IIoT) Applications are in the Cloud:
  - Based conventional Cloud Models (IaaS, PaaS, SaaS)
  - But also IIoT specific cloud models (e.g., Sensing as a Service, Maintenance-as-a-Service)





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Industrial IoT Solutions in the Cloud: The State-of-the-Art

General purpose public IoT cloud services, offered by IT vendors

- E.g., Microsoft's Azure IoT Suite
- IBM's Watson IoT platform
- SAP's HANA Cloud platform with IoT support and extensions
- Amazon AWS IoT LogmeIN's Xively platform
- Not tailored to specific verticals
- Scalable and cost-effective cloud infrastructures for IoT

IIoT services offered by leaders in industrial solutions

- E.g.., SIEMENS, Bosch, ABB etc.
- Partnerships between IIoT vendors and providers of IT (IoT/cloud) infrastructure services e.g., ABB & Microsoft partnership, Bosch's IoT services run over various digital plumbing platforms such as Amazon's
- Distinction of business roles

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Limitations of IIoT in the Cloud

Waste of bandwidth	Network latency	Inefficient use of storage	Limited flexibility to address privacy and data protection	Data “away” from users
• Not all IoT data need to be stored in Cloud • Waste of bandwidth especially in large scale applications	• Interactions with the Cloud are not network efficient • Can be a problem for real-time application	• Information with limited (or even zero) business value is stored • Typical example: Sensor data that does not change frequently (such as temperature information)	• All data stored to the Cloud • No easy way to “isolate” private/personal data	• Not ideal for applications involving mobility and large scale deployment • Higher latency and cost

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When Cloud is not enough: Edge Computing to your rescue

Edge Computing

- Move IoT data processing and actuation to the edge of the network
- Introduce a layer of gateways (Edge Nodes) between the Cloud and the IoT devices

Edge Node Types

- Depend on the scale and the nature of the deployment
- Embedded controllers or IoT devices with processing capability
- Computers
- Clusters or small-scale data centers

Benefits

- Reduced latency for real-time applications
- Efficient use of bandwidth and storage resources
- Improved scalability
- Reduction in costs and energy consumption
- Better privacy control

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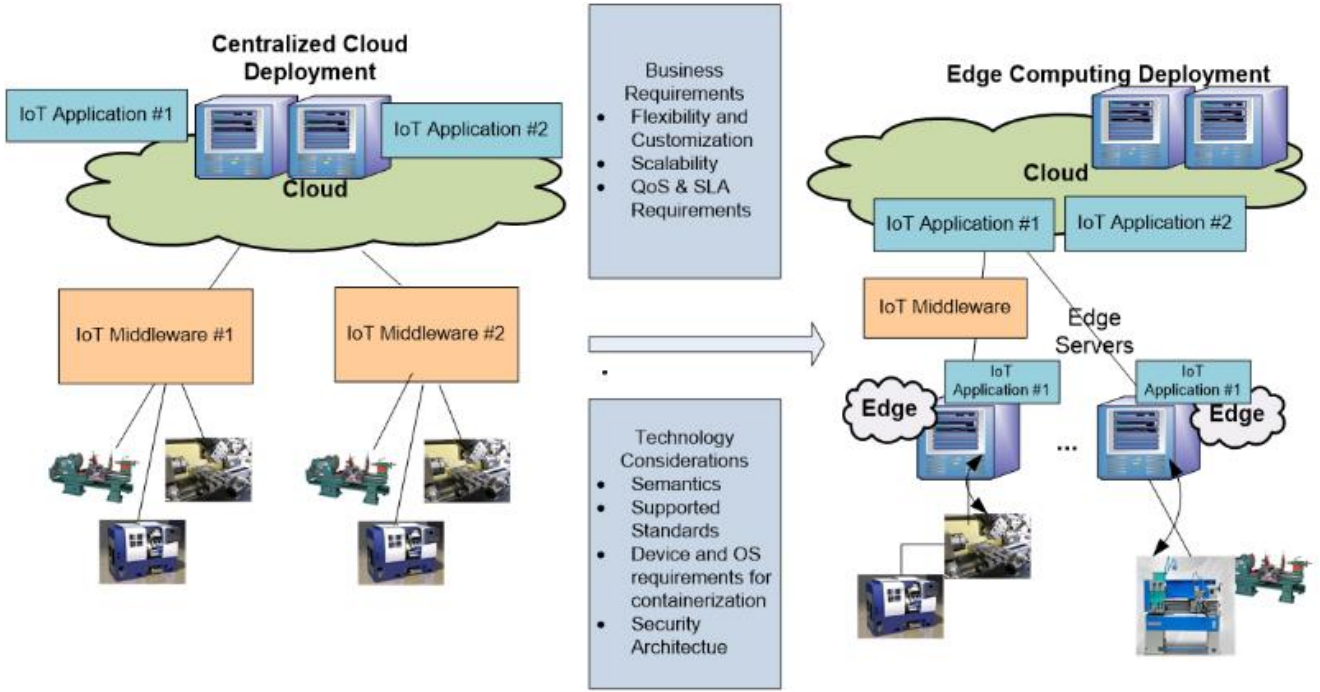
High Level Concept



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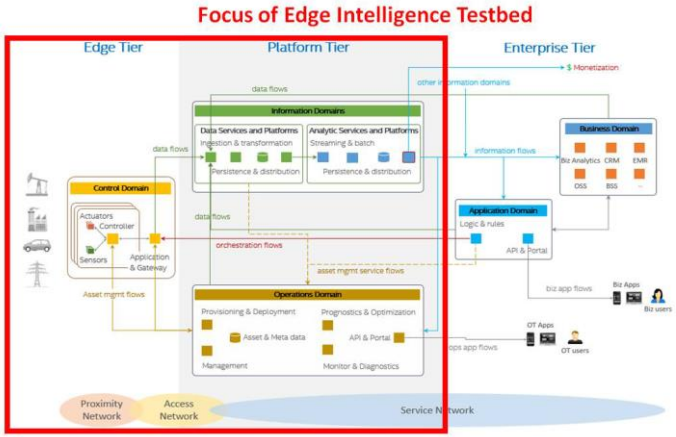
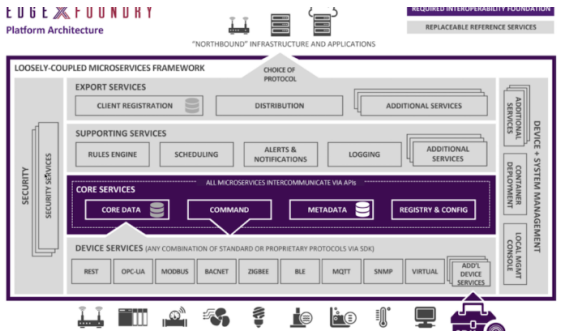
Edge Computing Standards & Reference Implementations for IIoT

- Standards:
  - OpenFog Consortium & OpenFog Reference Architecture
  - Industrial Internet Consortium (IIC) and Industrial Internet Consortium Architecture
- Implementations:
  - IIC's Edge Intelligence Testbed
  - EdgeX Foundry (Dell/EMC)





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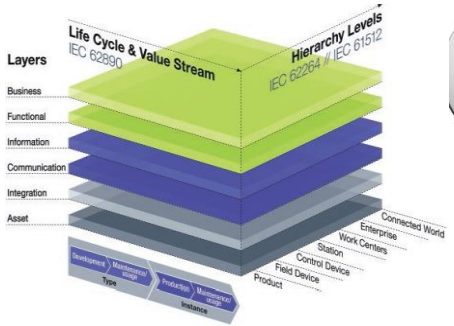
FAR-EDGE = Joint effort of global leaders in manufacturing and IoT towards adoption of *virtualized* Factory Automation

- Cloud and Edge Computing for Manufacturing
- Decentralization of control
- RAMI 4.0 & Industrial Internet standards

Expected Outcomes

- Reduced Time to deploy new automation concepts and technologies (e.g., 3D printers)
- Better Exploitation of Data
- Increase automation in factories
- Improve process agility
- Enable x-factory collaboration
- RAMI Compliant Implementation



FAR-EDGE Aligns to RAMI4.0: Common Language for I4.0 (work-in-progress)

Advisory Board Member

FAR-EDGE Vision and Unique Selling Proposition

Vision: The vision of FAR-EDGE is to research & provide a first-of-a-kind Industrie 4.0 compliant factory automation (FA) platform based on the edge computing paradigm, which will deliver the benefits of the decentralized automation and without compromising the production quality, time and cost offered by existing platforms.

USP: FAR-EDGE goes beyond existing edge computing efforts for FA (E.g., IIC Edge Intelligence Testbeds) based on the use of blockchain and “smart contracts” for flexibly orchestrating factory automation tasks across plants and factories

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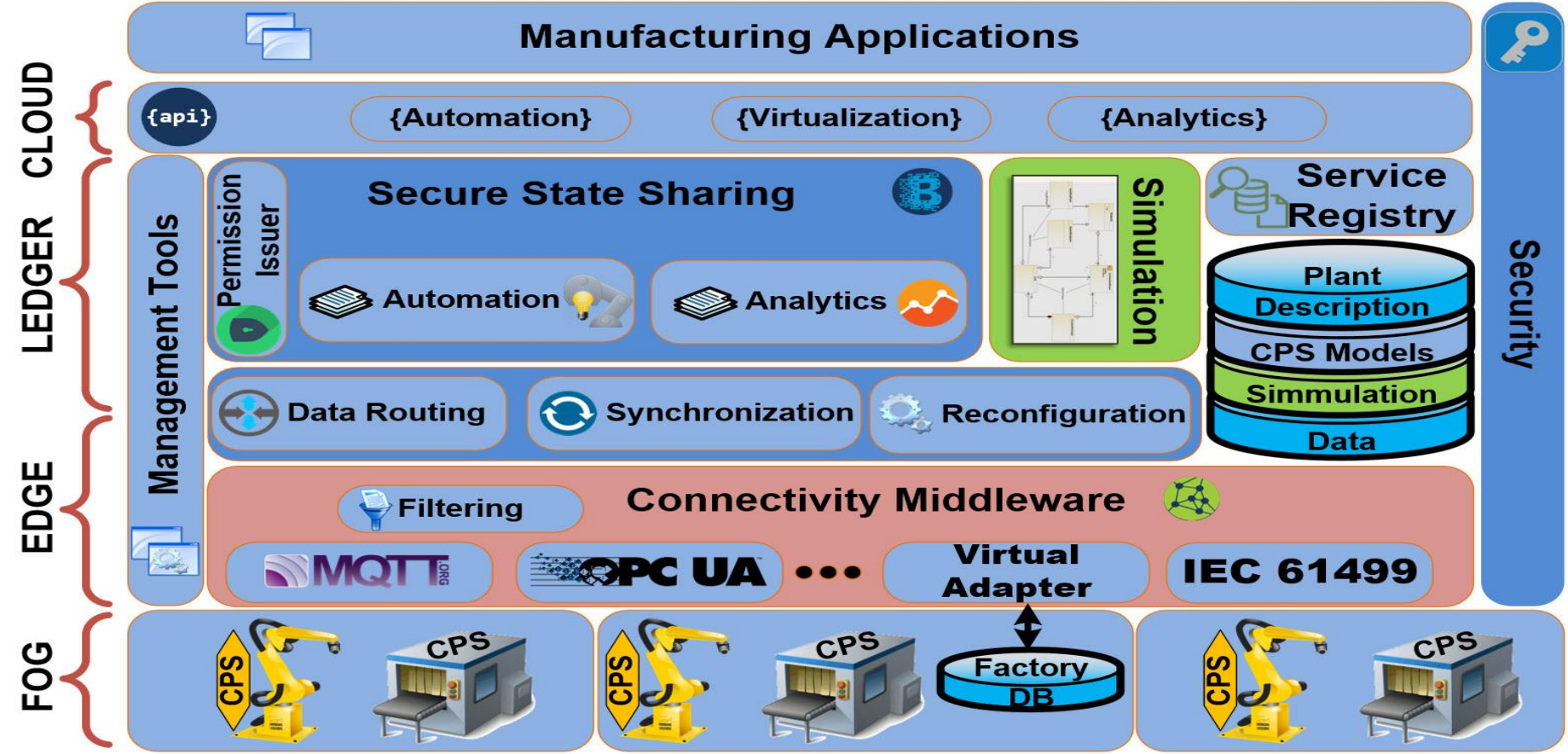
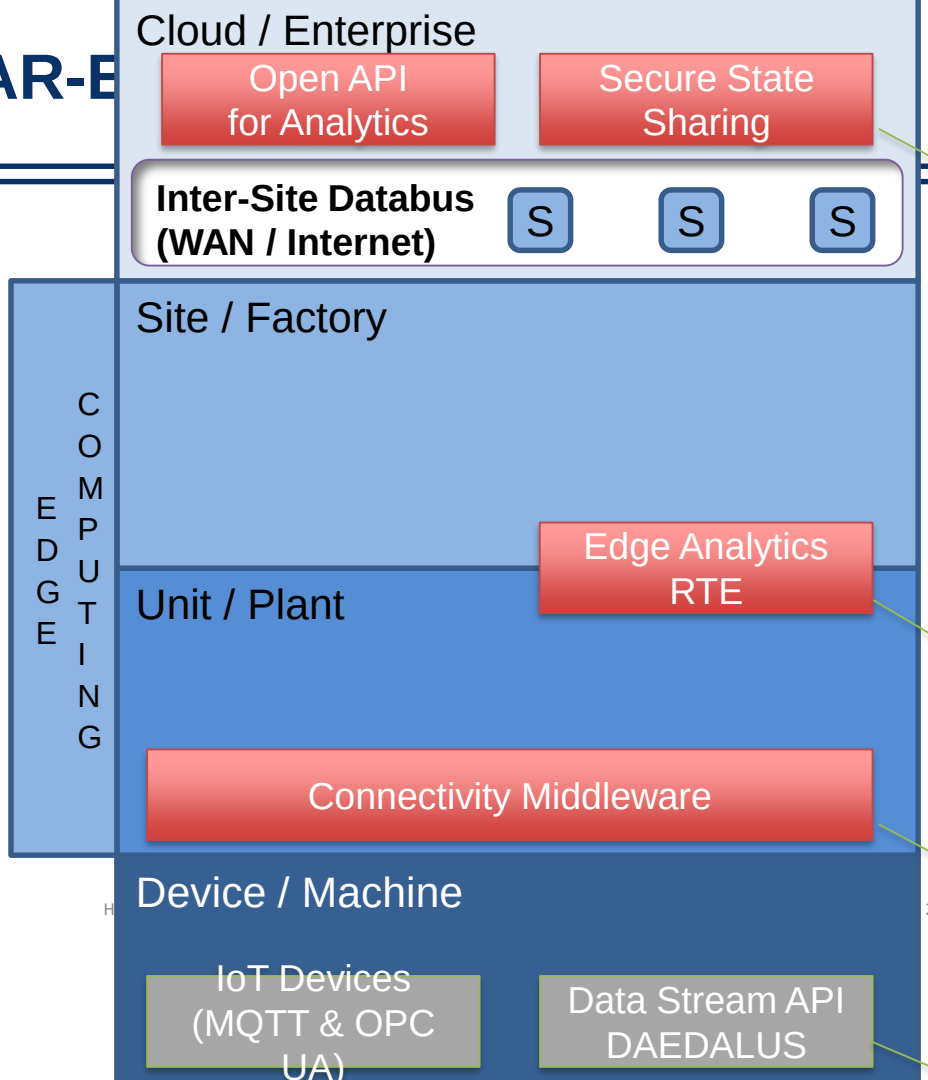
FAR-EDGE Architecture: High Level Logical View (Layered)





Blockchain *peer nodes* run on cloud hardware. Collection and **aggregation** of Site Analytics results from individual "trusted" Sites.

Host process runs on server-class hardware. Provides a runtime environment for Edge Analytics. Internally, the RTE provides services for subscribing to Machine-level Data Streams and for publishing local results to APi4Analytics and/or SSS.

One-to-one integration with IoT Devices and DAEDALUS-powered Machines (not a bus/aggregator), presents a unified Data Stream API.

Runs on PLC-class hardware.
Provides Data Stream Manifest Catalogue and

FAR-EDGE Layers & Elements (1)

Connectivity Middleware

- Interfaces to the Field through several standards-based protocols (OPC-UA, MQTT,…) and automation frameworks IEC 61499
- Homogenizes data according to FAR-EDGE Data Models
- Provides services to “upper” layers in a way that hides the connectivity protocol used
- Provides data “filtering” functionalities
- Note: According to IIC Connectivity is a Cross-Cutting Function

Data Routing

- Enables the combination, fusion and routing of multiple data streams from field devices
- It typically “consumes” data from the connectivity middleware
- Delivers combined streams to higher layer via a Message Bus infrastructure

Synchronization

- Keeps the Digital Representation of the Plant (Plant Description, CPS Models, Simulation Models) in synch with the physical world
- In FAR-EDGE it will most likely deal with a subset of the factory “mini-world” relevant to the use cases
- Runs independently of scenarios and other functionalities (as “framework service”)

Reconfiguration

- Leverages the synchronization capabilities in order to reconfigure the digital world based on changes to the physical world
- Handles complete processes (including batches of synchronization steps)
- Triggered from changes in the physical world (connectivity middleware layer) or the blockchain

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FAR-EDGE Layers & Elements (2)

FAR-EDGE Database / Datastore:

- Reflects a digital representation of the plant in terms of FAR-EDGE operations & applications
- Comprised of Metadata = FAR-EDGE CPS Models & Data = Reflecting the actual status of the plant

Service Registry

- Provides dynamic information about the status of the plant, along with dynamic bindings & handles to FAR-EDGE services (Service Oriented Approach)

Automation

- Implements automation workflows leveraging secure state sharing services
- In the scope of an automation workflow it can change and validate the status of objects and processes

Analytics

- Implements analytics workflows & pipelines based on rules configured in the blockchain
- Keeps track, configures and evolves the state of analytics rules in order to implement data analytics logic over shopfloor data

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FAR-EDGE Layers & Elements (3)

Secure State Sharing SSS

- Powered by blockchain – distributed ledger
- Provides the means for distributed configuration and validation of automation and analytics rules
- Provides the means for tracking and evolving the state of objects and processes involved in the automation
- Empowers analytics and automation
- Should be also used for the reconfiguration (even though reconfiguration box is outside SSS)

Simulation

- Leverages data from the connectivity middleware via data routing
- Exploits persistence services over the CPS models & Plant Description models (data & metadata)
- Implemented based on simulation engines from SIEMENS & SUPSI

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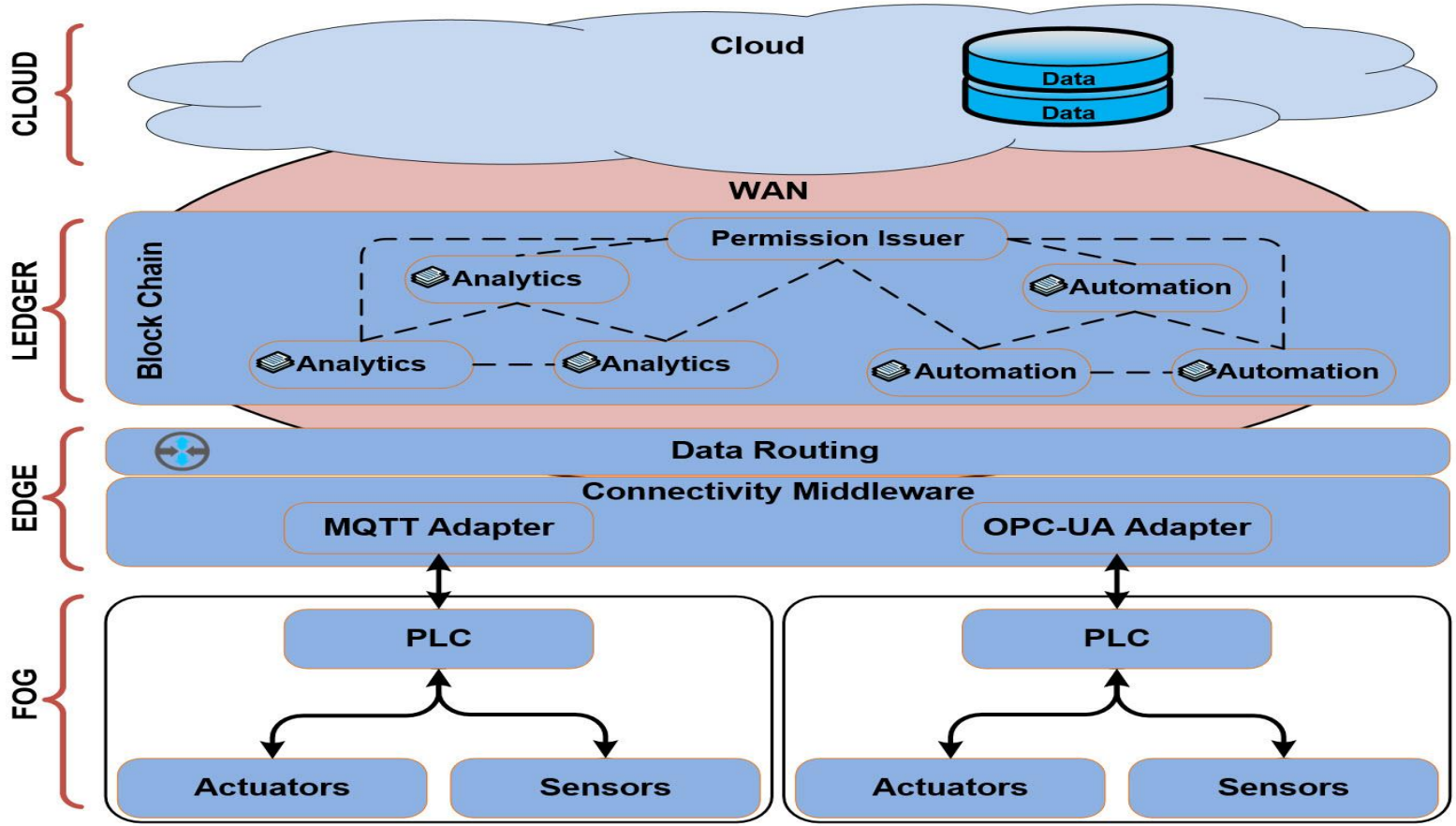
Example Physical View



FAR-EDGE Implementation Technologies (1)

Component	Implementation Technology
Connectivity Middleware	• Arrowhead or Open Source frameworks for MQTT, OPC UA • Custom Drivers to Factory Databases in WHR / VTC • FAR-EDGE DAEDALUS interface for IEC 61499
Data Routing	• Apache Edgent for supporting CPU constrained devices • Apache Kafka or Alternative Distributed Streaming Technology
FAR-EDGE Database & Service Registry	• Data Schemas AutomationML (Custom/MAYA), SenseML (Arrowhead), B2MML (Custom) • Service Registry (Arrowhead) • Data Management (Custom, Arrowhead Historian, BigData Framework e.g. Spark)

FAR-EDGE Implementation Technologies (2)

Component	Implementation Technology
Secure State Sharing	• Hyperledger Fabric
Automation & Analytics	• Configuration Protocols and Rules over the Fabric
Simulation	• Timeseries models (SUPSI) • Simulation Engine (SIEMENS)
Synchronization	• Custom implementation possibly extending Arrowhead mechanisms
Security	• NGAC on Policy Enforcement Points (PEP)
Reconfiguration	• Configuration Protocols and Rules over the Fabric

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Conclusions

- Edge Computing provides compelling advantages for several IIOT use cases
    - Especially when edge analytics and interactions “close” to the field are essential
    - Evident also in standards
- The industry is seeking for reference implementations and “best practices”
    - FAR-EDGE contributes in this direction
    - It is a reference implementation of an edge computing architecture
    - It also “researches” blockchain-empowered automation & analytics

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