“Digital Models for Data Analytics and Digital Twins in Industrial Automation Applications

Introduction of a Common Interoperability Registry for linking diverse functional domains”

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UBICOMM 2019 / IFDA

FAREDGE DIGITAL MODEL & CIR

ATHENS INFORMATION TECHNOLOGY

Digital Twin for Industry 4.0

1. Digital representations of physical world objects and processes as a means of executing automation and control operations
2. Digital modelling of the physical world
3. Objectives of Digital Models
    1. Semantic interoperability +uniform representation of CPS & Sensors
    2. Information Exchange
    3. Digital Operations (configure and update models to reflect the physical world. Synchronization is challenging)

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A new Digital Model introduced

- Our needs dictated the design of a new model focused on data collection, routing and analytics i.e., typical data-intensive applications
- In the complex landscape of various standards for digital modelling in Industry 4.0, there exists no "one size fits all“solution that will prevail, until the present day
- Standards are tailored to different applications, e.g., automation, simulation, digital twins, Big Data analytics, supply chain management, etc.

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Address Data Intensive IIoT Challenges

Edge Computing & Blockchains for Industrial Automation

Predictive Maintenance for IIoT - Manufacturing

Security for Industrial IoT and Smart Objects

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Blockchain for DDA: Rationale

1. Collection and processing of data from multiple different sources of the shopfloor.
2. Only a fraction of industrial/enterprise data are actually used in digital solutions (~1% of organizational data used - ~80% of Data Unprotected)
3. DDA employs blockchain (Distributed Ledger) technologies in order to synchronize data analytics operations in a highly distributed environment
4. Analytics transparency – Guarantee the Quality of the Data
5. Prevent Data Leaks and Hacks
6. Emerging of decentralized platforms for analytics based on distributed ledger technology (e.g., Path (https://path.net/))

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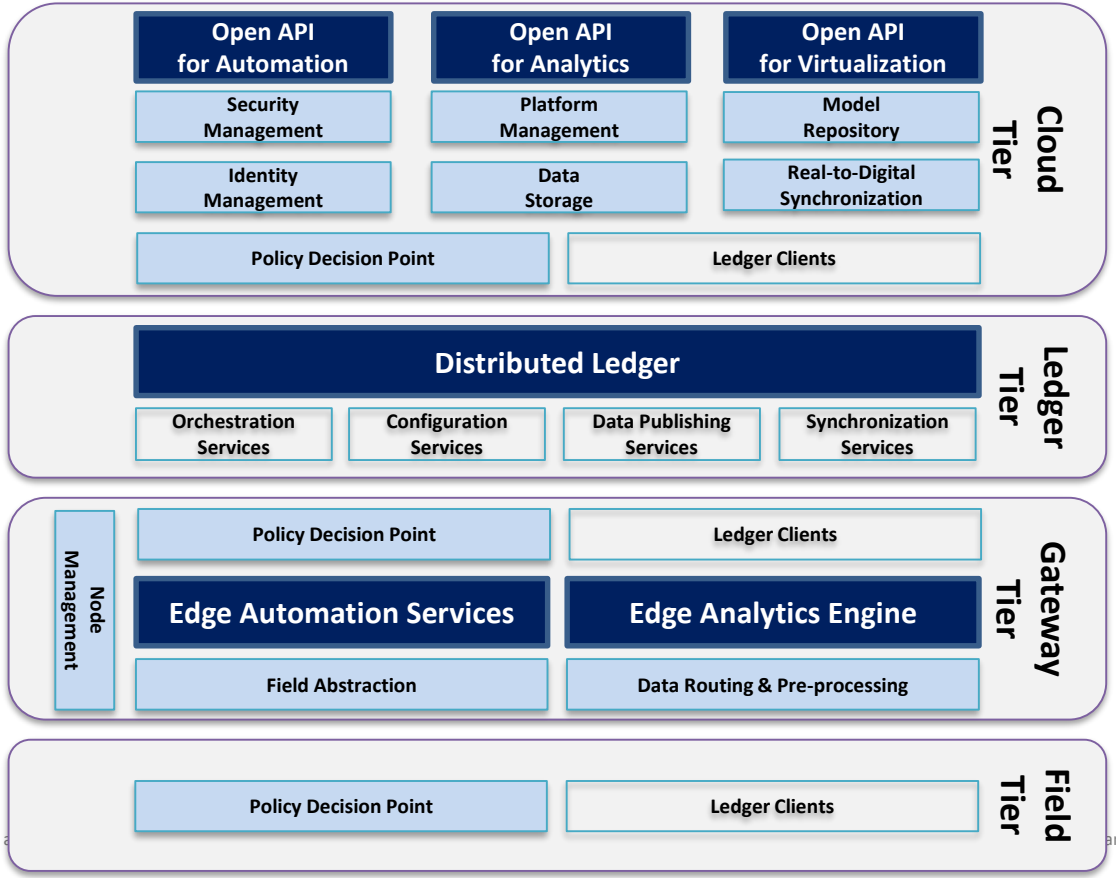
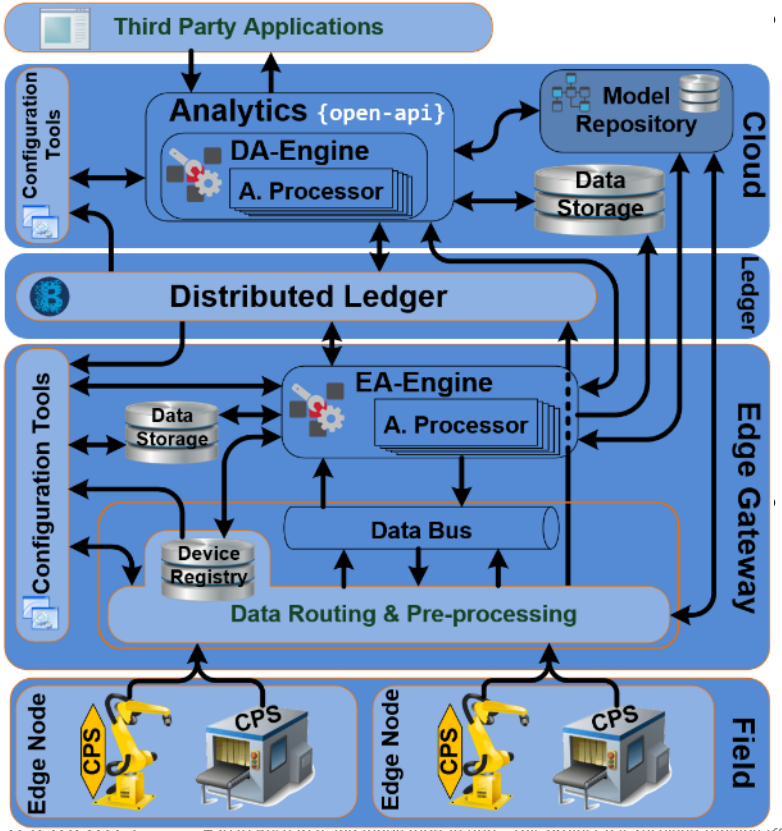
FAR-EDGE Reference Architecture



Functional Architecture for DDA



Distributed Data Analytics system integrated with:

- Data Routing & Pre-processing,
- Data Bus,
- Device Registry,
- Data Storage (cloud and local) and
- Model Repository

Benefits:

- Configurable
- Extensible
- Dynamic
- Stream Handling

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Scope of DDA in FAR-EDGE

Local Level Analytics ("Edge Scoped")

- Close to the Field
- E.g., Level of a Station in the Factory
- Supported by Edge Analytics ("Edge Analytics Engine")

Global Analytics ("Ledger Supported")

- Factory-wide (or even across factories)
- E.g., spanning multiple stations & instances of local level analytics
- Supported by Open API for Analytics

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Role & Scope of Digital Models in FAR-EDGE

- Data Information Persistence
  - Digital Twins & Simulation
  - Data Analytics
- Configuration of the FAR-EDGE System
  - Hold the Logical Configuration of FAR-EDGE Components (e.g., Edge Gateways, Data Sources, Devices)
  - Enable the configuration of FAR-EDGE components (e.g., definition of new data sources, association of data sources to edge gateways) using IT APIs and tools
- FAR-EDGE has reviewed standards and specified its own digital models tailored to Edge Computing

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Standards-Based Digital Models (1/3)

- ***IEC 62264 B2MML*** *modelling interactions across entities within MES and ERP systems and their involvement in automation operations.*
- ***IEC 61512 BatchML*** *XML based implementation of the ANSI/ISA-88 Batch Control family of standards*
- ***IEC 62769 (FDI)*** *represents automation systems' topologies, suitable for modelling information on the field layer of the factory (devices, networks)*
- ***ISO 15926 Xmplant*** *structure, the geometry and 3D models about a plant based on the ISO 15926 specification*
- ***IEC 62453 (FDT)*** *Field Device Tool (FDT) by fdtgroup.org, is an open standard for industrial automation integration of networks and devices*

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Standards-Based Digital Models (2/3)

- ***IEC 61512 (Batch Control)*** *referenced by RAMI 4.0. It models batch production records, including information about production of batches or elements of batch production.*
- ***IEC 61424 (CAEX)*** *Hierarchical. XML-based representation of plant information, including all components in a hierarchical structure, and adopts an object-oriented philosophy*
- ***IEC 62714 AutomationML*** *commonly used to facilitate consistent exchange and editing of plant layout data across heterogeneous engineering tools. relies on 3 other standards, : CAEX (IEC 62424) for topological information, COLLADA (ISO/PAS 17506) to model and implement geometry concepts, 3D information, and Kinematics (i.e., the geometry of motion), and PLCopen XML (IEC61131) for sequences of actions, internal behavior of objects and I/O connections*

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Standards-Based Digital Models (3/3)

- ***MTConnect*** *XML-based format for exchanging data between the shop-floor and IT applications, including data about devices, topologies and component characteristics.*
- ***PERFoRMML*** *from H2020 PERFORM for a plug-n'-produce infrastructure. Based on Automation ML. Makes provisions for Machinery and Control Systems and also Data Backbone entities*

A. All used as an architecture basis.
B. All reviewed as being world-renowned
C. Insufficient for **data-intensive applications**

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FAR-EDGE Digital Models: Main Entities

- **Factory Data Description**
  - **DSD**: Data Source Definition
  - **DI**: Data Interface specification
  - **DK**: Data Kind
  - **DSM**: Data Source Manifest
  - **DCM**: Data Consumer Manifest
  - **DCD**: Data Channel Descriptor
- **Factory Analytics Description**
  - **APD**: Analytics Processor Definition
  - **APM**: Analytics Processor Manifest
  - **AM**: Analytics orchestrator Manifest
- **Mapping Across Functional Domains**
  - **CIR**: Common Interoperability Registry

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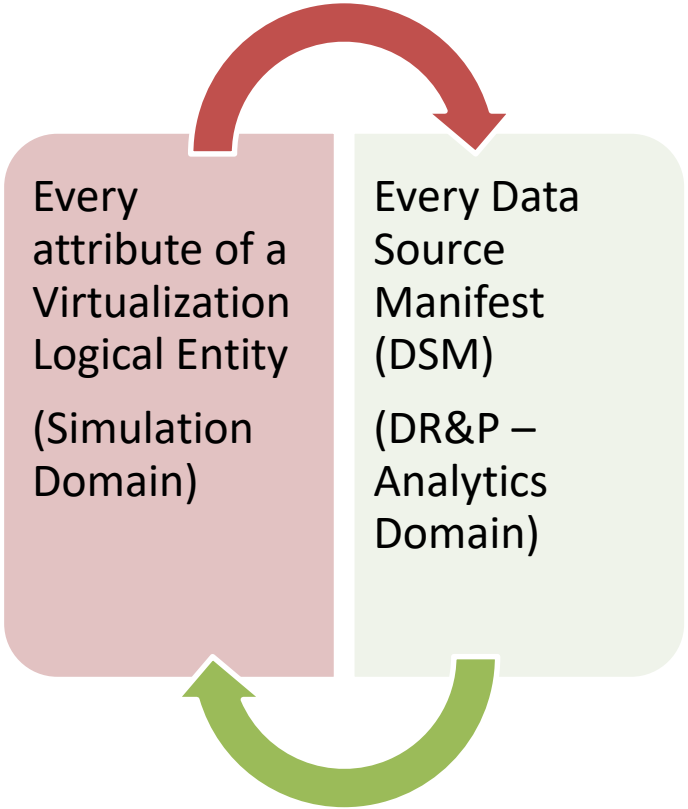
Cross-Domain Data Mapping in FAR-EDGE

One to one mapping among two entities of the Simulation and Virtualization Model



DSM is uniquely identified by an ID (UUID) which is generated from the first component that introduce it to the system.

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Interoperability Registry (CIR)

- Concept used in Open O&M
- Provides the “Yellow-Pages” lookup for all systems to locate an identical object in another system
- Glue to tie systems together which have different Identifiers for the exact same object but never had to talk “on-line” before
- Provides a globally-unique CIR Identifier (CIR Id) to link “local” object IDs

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Function of CIR in FAREDGE

- **Mapping Across Functional Domains**
  - **FDEM**: Functional Domains and crosscutting functions Entity Mapping
    - **SDRM**: Simulation and Data Routing Mappings
    - **ADRM**: Automation and Data Routing Mappings

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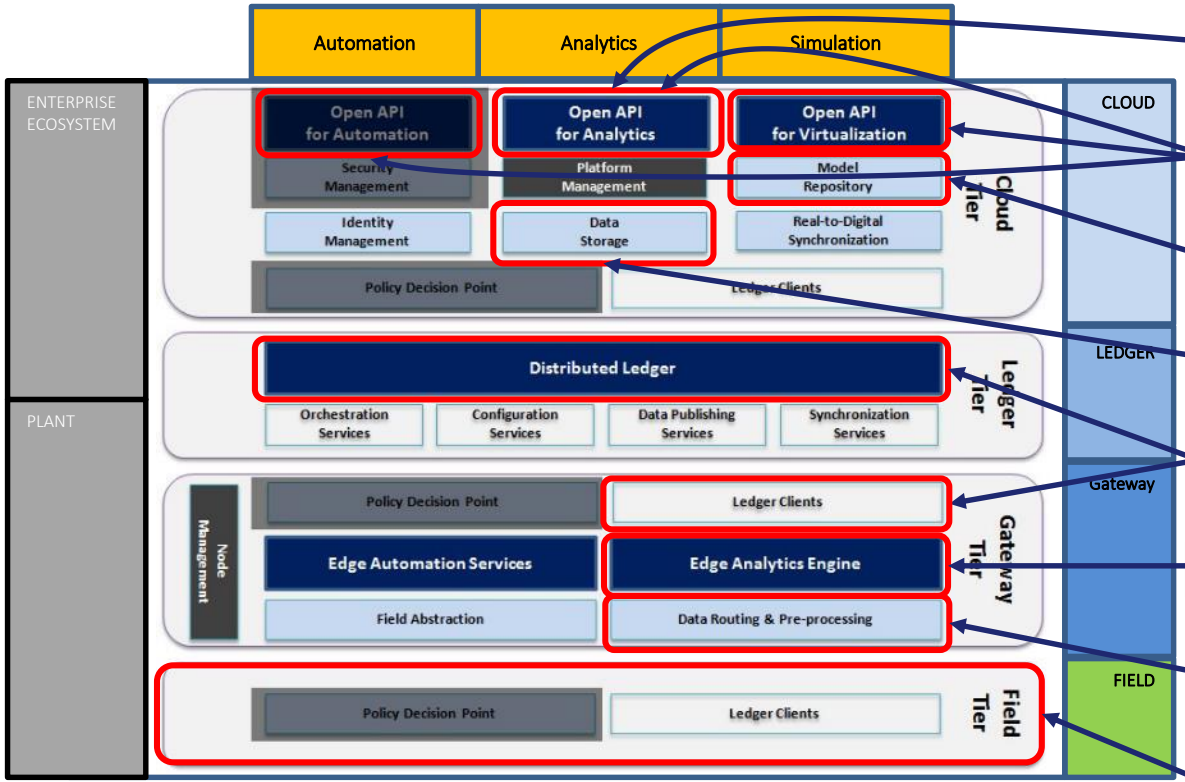
Data Models Use in the FAR-EDGE Architecture



Registration of **APM**/**AM** (-> DSM)
Generation of **Observations**

Common Interoperability Registry **CIR** for Each Functional Domain

Model Repository for **DSD** (**DI** & **DK**), **APD**,

Storage of **Observations**

Keeping record of **Edge Gateways**
Keep synchronized **DSM** and **AM**

Registration of **APM**/**AM** (-> DSM)
Generation of **Observations**

Registration of **DSM**
Generation of **Observations**

Logical Description (focusing on Data) of the Edge Node through the **DSM** (Referencing **DSD**)

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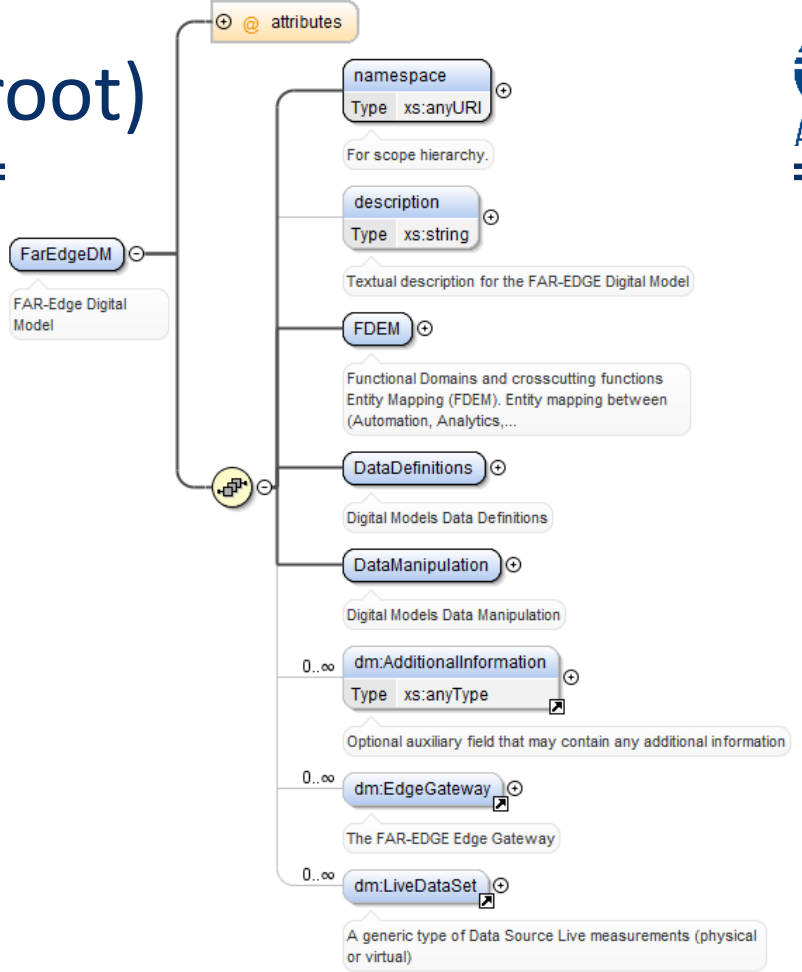
Digital Models Structure (root)

- FAR-EDGE Digital Models employ an hierarchical structure to define different configurations of the FAR-EDGE system
- Top Level Structure is depicted on the right



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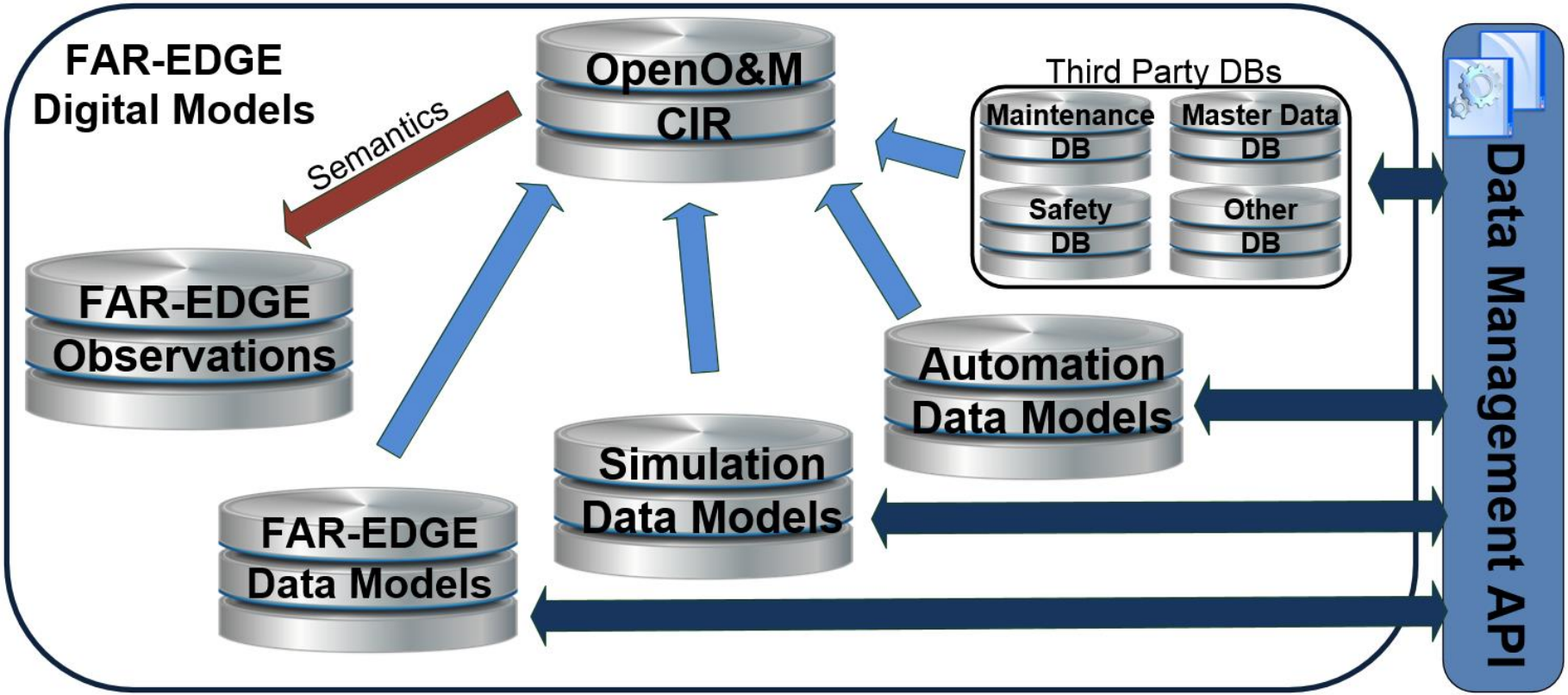
FAR-EDGE Digital Models Interaction



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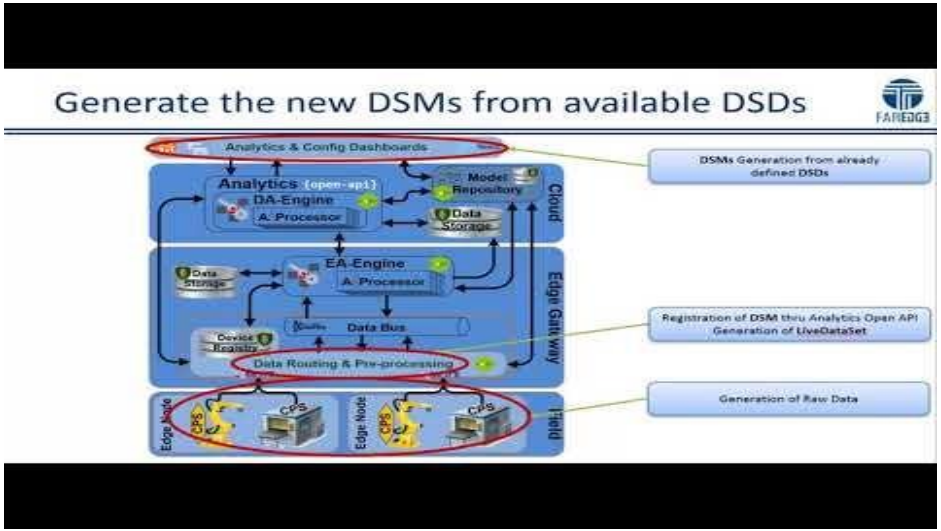
DDA GitHub & Video (www.edge4industry.eu)

- GitHub URL: https://github.com/far-edge/distributed-data-analytics
  - edge-analytics-engine:
    - containing the source code of the Edge Analytics Engine component.
  - open-api-for-analytics:
    - containing the Open API for Analytics component.
  - mqtt-random-data-publisher:
    - containing an application which simulates the functionality of Data Routing & Pre-processing component for demonstration purposes.



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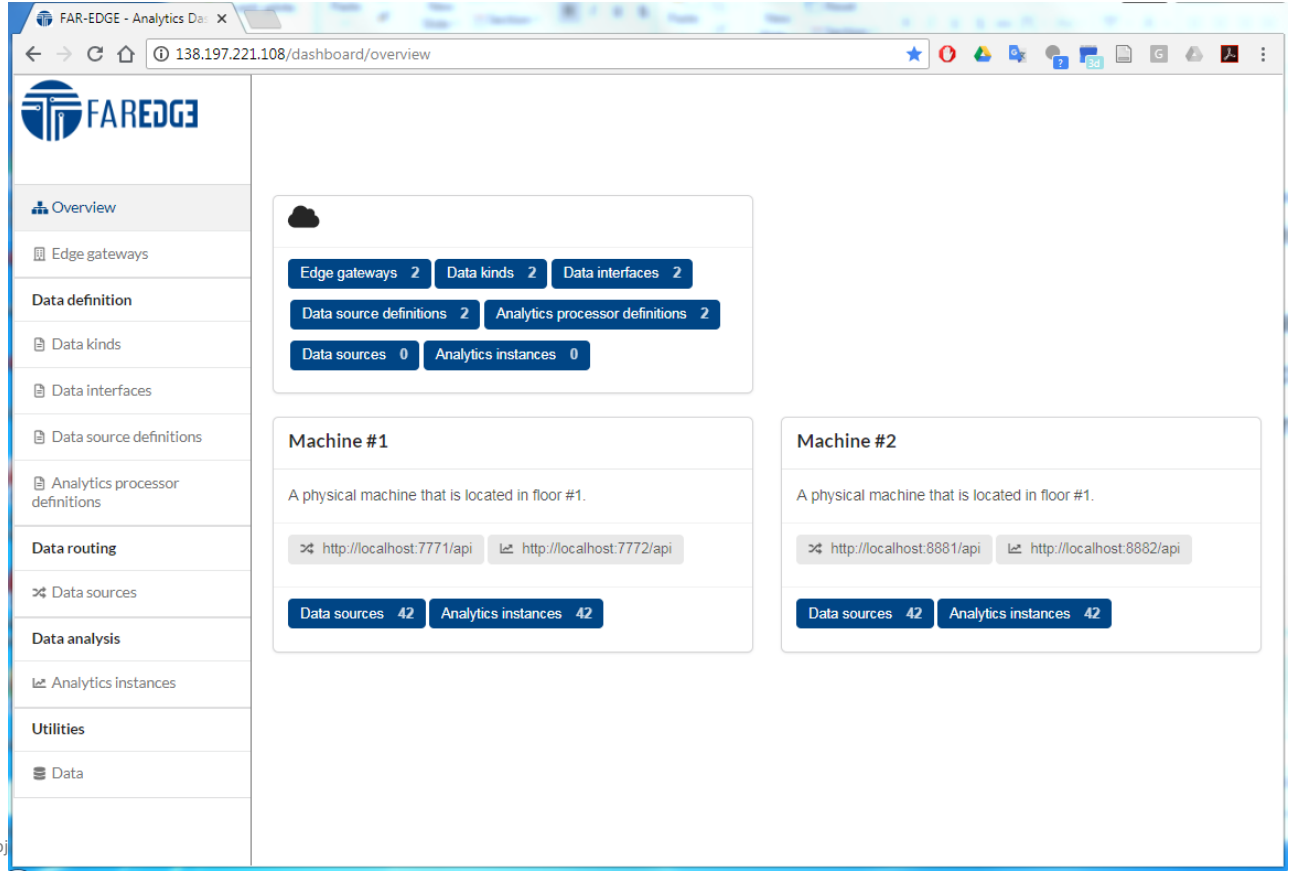
Analytics Dashboard

Provides configuration functionalities through **Open API for Analytics**:

- Distributed Analytics Engine
- Edge Analytics Engine
- Model Repository
- Data Routing & Pre-Procession



Digital Models GitHub Availability

- Digital Models GitHub URL: https://github.com/far-edge/digital-models
  - docs:
    - html: you can open “FarEdgeDM.html” to find the schema generated documentation in html format (after downloading the folder)
    - pdf: you can find the generated schema documentation in pdf format
  - libraries:
    - far-edge.dm.commons: you can find a Maven project which provides the Digital Models Java classes (JAXB annotated)
  - Schemata
    - far-edge.dm.schemata: you can find the xsd schemata of the Digital Models

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Implementation Model Repository GitHub

- Model Repository GitHub URL: https://github.com/far-edge/cloud-infrastructure
  - model-repository: the FAR-EDGE component that provides the mechanisms to manage:
    - Data Kinds (DK)
    - Data Interfaces (DI)
    - Data Source Definitions (DSD)
    - Analytics Processor Definitions (APD)

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Challenges / Future

- The future vision of a "Fully Digital Shopfloor" (i.e., for all production processes) will require the concurrent use of different models & standards. Hence, there is a need for more mechanisms to link those standards (like the proposed CIR), to digitally reflect the shopfloor consistently
- Digital modelling in Industry 4.0: there exists no "one size fits all" solution that will prevail.

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