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D 4.5 MIDIH Open CPS/IOT Integrated Platform v1

WP4 – Open Platform architecture, development, integration and testing

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Executive summary

The goal of Task WP4.5 is to integrate, test and prepare the MIDIH Open System for the MIDIH Industrial experiments. In this first iteration of WP4.5, D4.5 summarizes the activities carried out by the WP4-WP5 joint teams to adopt and integrate the MIDIH Open Platform, having as final objective to perform the assessment of the solution in terms of functional and non-functional properties.

5 new MIDIH foreground technological assets developed and reported in D4.3 have been now integrated and are reported in this deliverable:

- The T4.2 MIDIH Open Edge Node based on FogFlow, to allow the MIDIH Open system to provide a distributed cloud architecture (such as Fog Computing, Local Clouds or generically Edge-oriented).
- The T4.3 MIDIH Open Interoperability Solutions based on an OPC UA Agent, a MASAI MindSphere interface and a FIWARE IDS Connector, respectively to allow brownfield integration and interoperability with proprietary solutions and standards, implementing gateways between MIDIH platform and proprietary but open commercial solutions in the field of IOT.
- The T4.4 MIDIH Open Industrial IoT and Analytics solution to allow the MIDIH Open System to have mechanisms for analytics based on FIWARE and on worldwide known Open Source projects and Foundations, such as APACHE.

These 5 foreground assets have been integrated with **34** background open source assets, coming from MIDIH beneficiaries and from external Open Source communities such as FIWARE and/or APACHE enablers (e.g. Apache Hadoop, Apache Zeppelin, Grafana, Kafka, Orion Context Broker, PSYMBIOSYS Platform, etc..), in order to provide developers with ready-to-adopt reference implementations for the Smart Factory, Smart Product and Smart Supply Chain scenarios.

This ecosystem of 39 technological assets represents the MIDIH open CPS/IOT integrated platform, made available for further experimentations also outside of the MIDIH project, to other I4MS and FOF projects and to the Open Calls winners.

Moreover, legacy systems available in the experimental facilities have been considered and integrated as well, in order to meet our objectives.

Three integrated platforms for MIDIH industrial experiments are here described, as well as the setup of the Milano Didactic Factory (DF) integrated platform:

- CRF Cross-Border Experimentation in Automotive Sector, integrating a total of 11 MIDIH Open Source components.
- NECO Cross- Border Experimentation in Cutting Tools Sector, integrating a total of 16 MIDIH Open Source components.
- IDSA Cross-Border Experimentation in Additive Manufacturing, integrating a total of 4 MIDIH Open Source components.
- POLIMI Energy Management application developed in its didactic factory, integrating a total of 10 MIDIH Open Source components.

Task T4.5 has been focused in achieving the initial phase of integration of the MIDIH Open platform in the experiments. Therefore, the result of this task is the implementation of several customised instances of the MIDIH Open Platform for the Industrial experiments, which is fully explained along the different chapters of this deliverable *D4.5 MIDIH Open CPS/IOT Integrated Platform v1*.

Accordingly, the purpose of this deliverable is to support the prototype implementation and to facilitate its understanding and adoption. With this regard, it is totally aligned with WP5, installing and adapting one specific MIDIH Open platform instance for each of the experimenters based on their requirements.

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1 Introduction

1.1 Scope of the deliverable

The main objective of WP4 is the design, development, integration, deployment and testing of the functional and modular MIDIH Reference Architecture which will support all the cross-border experiments in the CPS/IOT domain.

The goal of T4.5 is to provide several customised instances of the MIDIH Open platform to the experimenters, covering for each of them the required functionalities and the concrete implementation based on the components selected, either the FIWARE or the APACHE line. In addition will offer support to concrete implementations of the MIDIH Open Platform to the 20+ industrial experimentations coming from the Open Call.

In order to accomplish with the objective of the WP4.5, the document has been structured in order to reflect the following information for each experiment:

It is briefly described the Business scenario; the business processes and it is drawn the required architecture (functionalities) for the different BPs. Finally, is defined the workflow diagram for each BPs covered in each Business scenario integrating all the components, including the specific additional components complementary to the MIDIH Open platform.

The deliverable is structured as follow:

- In **Chapter 2**, an overview of the background (BG) and Foreground (FG) components/developments carried out in T4.2, T4.3 and T4.4 is presented, and how these developments have been integrated in the MIDIH Open Source System.
- In **Chapter 3**, two integrated architectures based on open source software blocks are presented, the former for Smart Factory and Smart Products scenarios, and the latter for Smart Supply Chains scenarios.
- In **Chapters 4-5-6-7**, an overview of the customised MIDIH Open platform at M12 for the three industrial experiments and the Milano Didactic Factory is reported.
- Finally, in **Chapter 8** lessons learned and recommendations for second iteration of developments are sketched.

In the composition of this deliverable, the three experimenters and their technological partners (CCs and DIHs) have participated actively. It is important to remark that the work done is aligned with WP5, which is responsible for the Cross-Border Industrial Experiments.

1.2 Overview of the Content

This deliverable includes relevant information about how the MIDIH Open Platform has been adopted and customized in each Industrial experiment (see Figure 1), detailing which functionalities and components has been selected to cover their requirements. After that, a specific customised instance of the MIDIH Open Platform has been deployed, as well as dedicated activities for their setup and configuration took place, for finally assess and validate the overall solution realized.

Figure 1 – Phases for adopting and validate the MIDIH Open Platform

Therefore, the different industrial Scenarios of the experiments overview have included:

- Brief description of scenario
- Description of the Business Process/es
    - An overall picture of the Architecture for the scenario based on the functionalities contemplated in the MIDIH Reference architecture identifying required developments made in Tasks WP4.2 (Edge), WP4.3 (Interoperability) and WP4.4 (Analytics)
    - A justification regarding the selected functionalities/components
    - The workflow of the final solution together with a description of the usage
- Data available
- Scenario Architecture, identifying (when needed) additional components complementary to the MIDIH Open Platform for the specific scenario

2 MIDIH Integrated Reference Implementations

2.1 The MIDIH Open Edge Node (T4.2)

This section describes how the work carried out in T4.2 (named Open Edge Node) has been integrated with other solutions to made up the Open MIDIH edge computing platform to be adopted and customized by the experiments.

In particular, this integration activity explores the opportunity via IoT Brokers to integrate data and make bridges with other solutions such other protocols/open firmware (4DIAC), other platforms (OpenMTC) and legacies (e.g. ModBus)

2.1.1 FIWARE Integration in FogFlow[1]: the MIDIH Open Edge module

2.1.1.1 Architecture and components

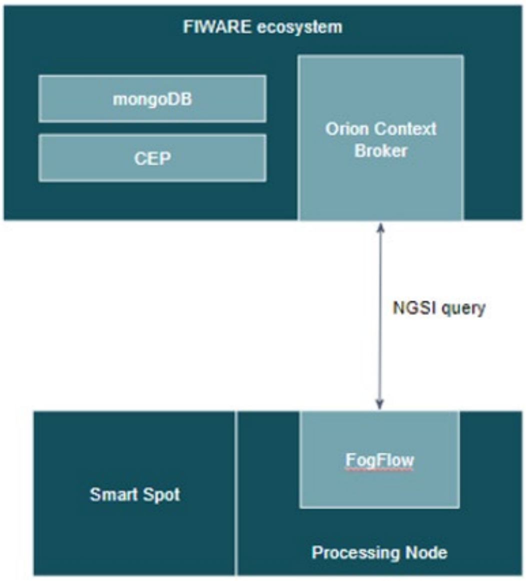

Figure 2 – Fogflow and FIWARE Communications

During the collaboration with the owner of FogFlow (NEC[2]) to work with fog computing capabilities to the project, an incompatibility protocol problem has arisen: the NGSI used by FogFlow is slightly different from the used by the FIWARE platform.

This issue introduces small complications such as the capability to directly connect already developed IoTAgents (FIWARE protocol integrators) to the FogFlow IoT Broker. To solve this issue T4.2 developed an adapter between protocols to allow connect both components.

2.1.1.2 Foreground and innovations

In T4.2 we have designed and developed an extensible IoT device, which offers great functionality for any environment, and that will allow us to achieve great improvements in terms of industry 4.0.
Thanks to the extensibility of our product we can add software/hardware to add more functionality, as shown in the following sections to add the necessary functions for FogFlow and MIDIH.

Processing Node:
We added an extra component based on external hardware called Minnowboard to provide us an excellent performance that, together with FogFlow's capabilities, reduces latencies and the time needed to perform tasks, as well as protecting context-sensitive information.

Next, we show the services that we are currently developing of Minnowboard:

- **Modbus Edge Agent**

[1] https://fogflow.readthedocs.io/en/latest/
[2] https://www.nec.com/

We currently have it working in conjunction with FIWARE architecture, in charge of collecting the data generated by the intelligent device and transmitting them. Soon we expect to have it too for MIDIH.

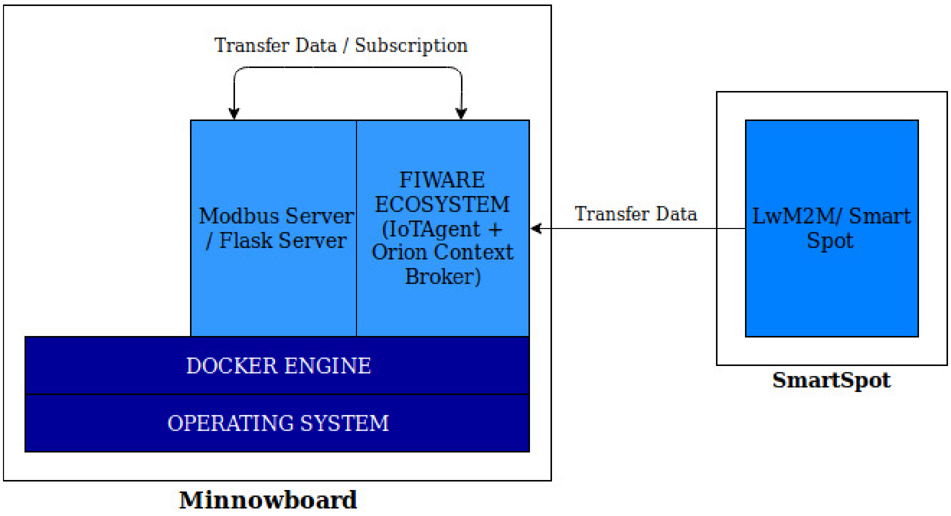

Figure 3 – Diagram of architecture

- **Development to integrate FogFlow in the same version of NGSI communications as FIWARE**

We currently have a working adapter, but it only allows communications between IoTAgent and FogFlow for data loading, but we are working with NEC to make the communication between FogFlow and native IoTAgent. This and the changes in FIWARE's API v2 communication with IoTAgent are causing small delays in the estimated time for the integration of both systems.

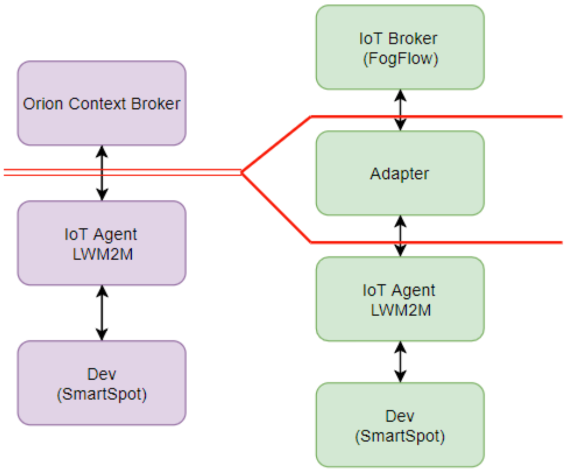

Figure 4 – Fogflow NGSI Integration

Currently, T4.2 is preparing a document to send to NEC about what is needed for the IoTAgent communications (see Figure 5).

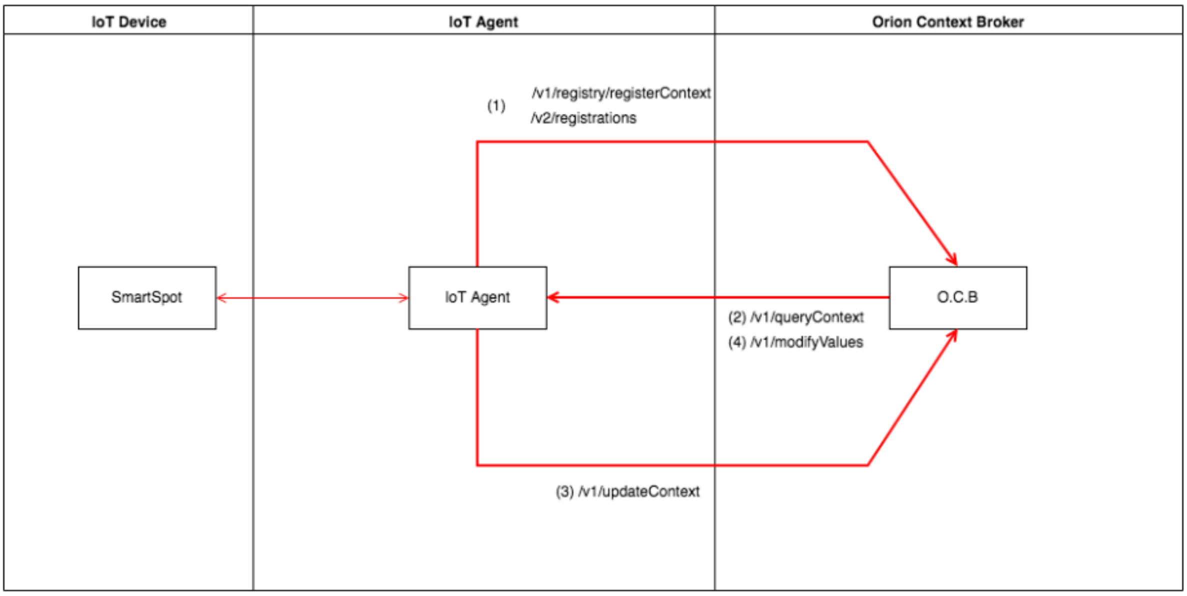

Figure 5 – Fogflow IoTAgent Communication Requirements

2.2 The MIDIH Open Interoperability Solutions (T4.3)

This section shows how the Background components and the Foreground developments carried out in T4.3, have been integrated to make up a part of the Open MIDIH System in order to be adopted and customized by the experiments.

Focused on the southbound of the reference architecture, T4.3 provides interoperability mechanisms to the MIDIH System, allowing to integrate data coming from the shopfloor into proprietary and commercial IoT solutions, initially with the Siemens MindSphere IoT platform. Moreover, brownfield integration with legacy systems that can communicate through various protocols and standards (OPC UA, MQTT, etc.) is also covered. Once the data has been captured and placed in the FIWARE environment, this data can be distributed through the FIWARE Orion Context Broker (OCB), as well as be injected into the IoT MindSphere platform.

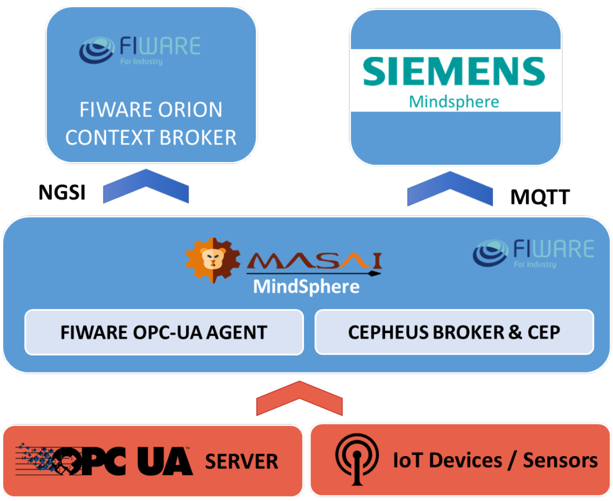

Figure 6 – Brownfield Integration Diagram

2.3 The MIDIH Industrial IoT and Data Analytics solutions (T4.4)

The T4.4 Platform covers an advanced set of functionalities in order to support the challenging manufacturing scenarios the project is targeting. On the application and data processing levels, the Platform will offer a rich feature set for cloud enablement and generic data treatment, which can be used to rapidly assemble end-to-end IoT applications for industrial systems automation, predictive maintenance, and remote monitoring.

2.3.1 Background

D2Lab (https://d2lab.nissatech.com/) is the proprietary framework by NISSATECH for developing big data analytics solutions. It can be treated as a personalized diagnostic laboratory for industrial cases. The framework has been applied for the development of several efficient and scalable systems for data-driven quality control.
The main innovation is related to the data-driven management of usual/unusual behaviour that enables us to treat unusualness as first-class citizens and consequently to provide support for the whole life cycle of the usual/unusual (anomalous) behaviour.

2.3.2 Foreground component

The main outcome of T4.4 is the MIDIH d^{2}A: data driven Analytics Platform (cf. Figure 7) which represents **new generation of data analytics platforms which are oriented towards understanding the behaviour of the subjected industrial system/process** (applying exploratory analytics on past data for getting so called process understanding) in order to enable **continuous process improvement**. We argue that “traditional” data analytics approaches are primarily focusing on “data understanding”, i.e. extracting the value from data for resolving a particular problem (e.g. predictive maintenance)

Therefore, MIDIH d^{2}A Platform enables creation of data-driven behavioural models of industrial systems, derived from past data using advanced data analytics. Such a model can be used for monitoring the real-time operation of the system and supporting quality control (like anomaly detection) and process improvement tasks.

Here we will briefly describe each of the components’ roles and their interactions within the system:

- **Adapters** These components are responsible for retrieving and parsing raw input files from clients and storing the resulting instance in the Storage.
- **Storage** As a storage we use Cassandra that is a distributed scalable non-relational database for managing large amounts of loosely-structured data.
- **Data Analytics** Different analytics tasks can be performed whereas clustering is most suitable for the learning of the behavioural models. As the result of the clustering procedure models (which contain cluster information) are generated. Clusters can be used to analyze existing patterns in the data, while the model can be used in real-time, for real-time anomaly detection. The clustering procedure is performed periodically, and new models are generated, and the newest model is used for anomaly detection.
- **Real-time Monitoring** This module classifies new instances based on previously generated (newest) model. The goal is to understand real time behaviour of the system, i.e. the system is working as expected or its id exhibit some anomalous behaviour.

- **Visualization** Clients can use the Web Portal to perform a more visual inspection of the system behaviour, e.g. they can view uploaded instances and see information about the detected anomalies. Clients will mainly utilize this when their manufactured product malfunctions, in order to try identifying the reason.

In the rest we provide a system walkthrough. Provided visualizations can be applied on an arbitrary use case. This part can be adapted to the requirements of a use case.

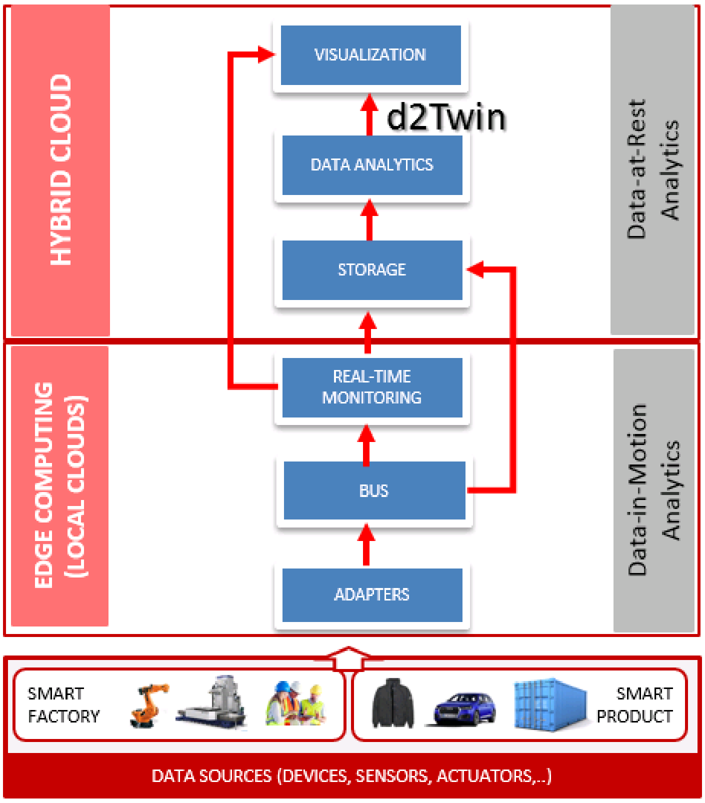

Figure 7 – MIDIH d2A modules (mapped on MIDIH data-driven RA Implementation)

3 MIDIH Integrated Architectures for Smart Factory, Product and Supply Chain scenarios

3.1 MIDIH Background/Foreground Asset Matrix

The following table shows the usage of the MIDIH background and foreground components and their use in each of the integrated platforms (Smart Factory, Smart Product and Smart Supply Chain).

	COMPONENT	TASKS	LANE	REPOSITORY	Smart Factory	Smart Product	Smart Supply Chain
BACKGROUNDS	**Cepheus**	**T4.3**	FIWARE	https://github.com/Orange-OpenSource/fiware-cepheus	X	X	
	IDAS	**T4.2, T4.3, T4.4**	FIWARE	https://github.com/Fiware/catalogue/tree/master/iot-agents	X	X	
	Orion Context Broker (OCB)	**T4.2, T4.3, T4.4**	FIWARE	https://github.com/telefonicaid/fiware-orion	X	X	X
	Perseo	**T4.4**	FIWARE	https://github.com/telefonicaid/perseo-core	X	X	
	Cygnus	**T4.4**	FIWARE	https://github.com/telefonicaid/fiware-cygnus	X	X	
	Quantum-Leap	**T4.4**	FIWARE	https://smartsdk.github.io/ngsi-timeseries-api/#quantumleap	X	X	
	Knowage	**T4.4**	FIWARE	https://github.com/KnowageLabs/Knowage-Server	X	X	
	Draco	**T4.4**	FIWARE	https://github.com/ging/fiware-draco	X	X	
	Wirecloud	**T4.4**	FIWARE	https://github.com/Wirecloud/wirecloud	X	X	
	Cosmos	**T4.4**	FIWARE	https://github.com/telefonicaid/fiware-cosmos	X	X	
	Apache Flume	**T4.4**	APACHE	https://flume.apache.org	X	X	
	Apache Nifi	**T4.4**	APACHE	https://nifi.apache.org	X	X	
	Apache Kafka	**T4.4**	APACHE	https://kafka.apache.org/	X	X	X
	Apache Spark	**T4.4**	APACHE	https://spark.apache.org/	X	X	X
	Apache Flink	**T4.4**	APACHE	https://flink.apache.org/	X	X	

Apache Hadoop	**T4.4**	APACHE	https://hadoop.apache.org/	X	X	
Apache Zeppelin	**T4.4**	APACHE	https://zeppelin.apache.org/	X	X	
Apache Ozzie	**T4.4**	APACHE	http://oozie.apache.org/	X	X	
Apache HBase	**T4.4**	APACHE	https://hbase.apache.org/	X	X	
Cassandra	**T4.4**	APACHE	http://cassandra.apache.org/	X	X	X
MongoDB	**T4.2, T4.3, T4.4**	FIWARE	https://mongodb.com/	X	X	X
Grafana	**T4.3, T4.4**	FIWARE / APACHE	https://grafana.com/	X	X	X
DiM & DaR Analytics Pipelines	**T4.4**	APACHE	MIDIH - deliverable D4.3 Annex D. Factsheet for Industrial IoT and Analytics Platform – Apache line	X	X	
DiM & DaR Analytics Pipelines	**T4.4**	FIWARE	MIDIH - deliverable D4.3 Annex E. Factsheet for Industrial IoT and Analytics Platform – FIWARE line	X	X	
Druid	**T4.3**		http://druid.io/	X	X	
HIVE	**T4.4**	APACHE	https://hive.com/	X	X	
WSO2	**T4.3**		https://wso2.com/	X	X	
RubyOnRails	**T4.3**		https://rubyonrails.org/	X		
TensorFlow	**T4.3**		https://www.tensorflow.org/?hl=hi	X		
Nginx	**T4.3**		https://www.nginx.com/	X		
Logstash	**T4.3**		https://www.elastic.co/es/products/logstash	X		
CEP Siddhi	**T4.3**		https://github.com/wso2/siddhi	X		

LTU Arrowhead	**T4.2**		http://www.arrowhead.eu/		X	
PSYMBIOSYS Platform	**T4.3**		https://github.com/epu-ntua/PSYMBIOSYS-Influencial		X	

Table 1 - Main background components

	COMPONENT	TASKS	LANE	REPOSITORY	Smart Factory	Smart Product	Smart Supply Chain
FOREGROUNDS	**HOPU FogFlow**	T4.2	FIWARE	https://fogflow.readthedocs.io	X	X	
	FIWARE IDS Connector	**T4.3**	FIWARE	https://github.com/telefonicaid/fiware-orion			X
	MASAI MindSphere	**T4.3**	FIWARE	https://github.com/ARI-MR/MASAI	X	X	
	OPC UA Agent	**T4.3**	FIWARE	https://github.com/Engineering-Research-and-Development/iotagent-opcua	X	X	
	Dd2Lab	**T4.4**	APACHE	https://d2lab.nissatech.com/	X	X	

Table 2 - Main foreground components

3.2 Smart Factory and Smart Product Integrated Architecture

Smart Factories rely on the building blocks of Industry 4.0, namely the internet of things, edge computing, big data, analytics and cloud computing, which allow machines, sensors and people to connect and communicate with each other in real time, providing at the same time mechanisms to have a flexible production, preventive and predictive maintenance, remote monitoring and quality control. Then, Smart Manufacturing must deal with interoperability, virtualization, real-time capability, service orientation, modularity, connected systems and open standards, with the final objective of optimize the production processes, in terms of production costs reduction, efficient energy usage, improvement in production reliability, production machines usage, etc., via the monitoring and management of the production process and of its components.

Therefore, the integrated platform for Smart Factory and Smart Product will allow experimenters to have mechanisms for a seamless integration of disparate systems and data sources, advanced analytics and algorithms on large data sets (e.g., for analyses and forecasting on productivity, throughput, downtime), as well as standardized interfaces for data exchange.

With this objective, the integrated architecture for Smart Factory and Smart Products, provides capabilities for collecting data from different data sources such as intelligent devices and systems, and also, mechanisms to aggregate and analyze this data to have intelligent decision making facilitating the data-driven manufacturing, giving support to workers and plant managers in their daily operations and decisions

In parallel, for Smart Products, the integrated platform must provide a consolidated and integrated access to product life-cycle information managed by the various systems, tools and sources available in the factory. In addition, will allow manufacturers and users to generate a new revenue models, create some forward-looking services, preventive maintenance and Intelligent cross and up-selling.

Having taken into account all characteristics and functionalities described before, for Smart Factory and Smart Products, the MIDIH Open Platform integrated architecture must deal with:

1. collection and transfer of all types of data (Data Ingestion);
2. real-time analytics, processing huge amount of streaming data in order to predict and detect events based on underlying patterns and correlations (processing Data in Motion), applying edge computing techniques, and;
3. storage layer for persisting all type of data, like past data, meta-data, models (Data Persistence);
4. data-analytics services on multidimensional and complex data, including exploratory analysis, multivariate analysis, predictive analytics and deep learning (processing Data at Rest);
5. visualization services to enable users to contextualize, understand and apply results for better decision making.

The following picture (Figure 8) shows the Integrated Architecture of the MIDIH Open Platform for Smart Factory and Smart Product:

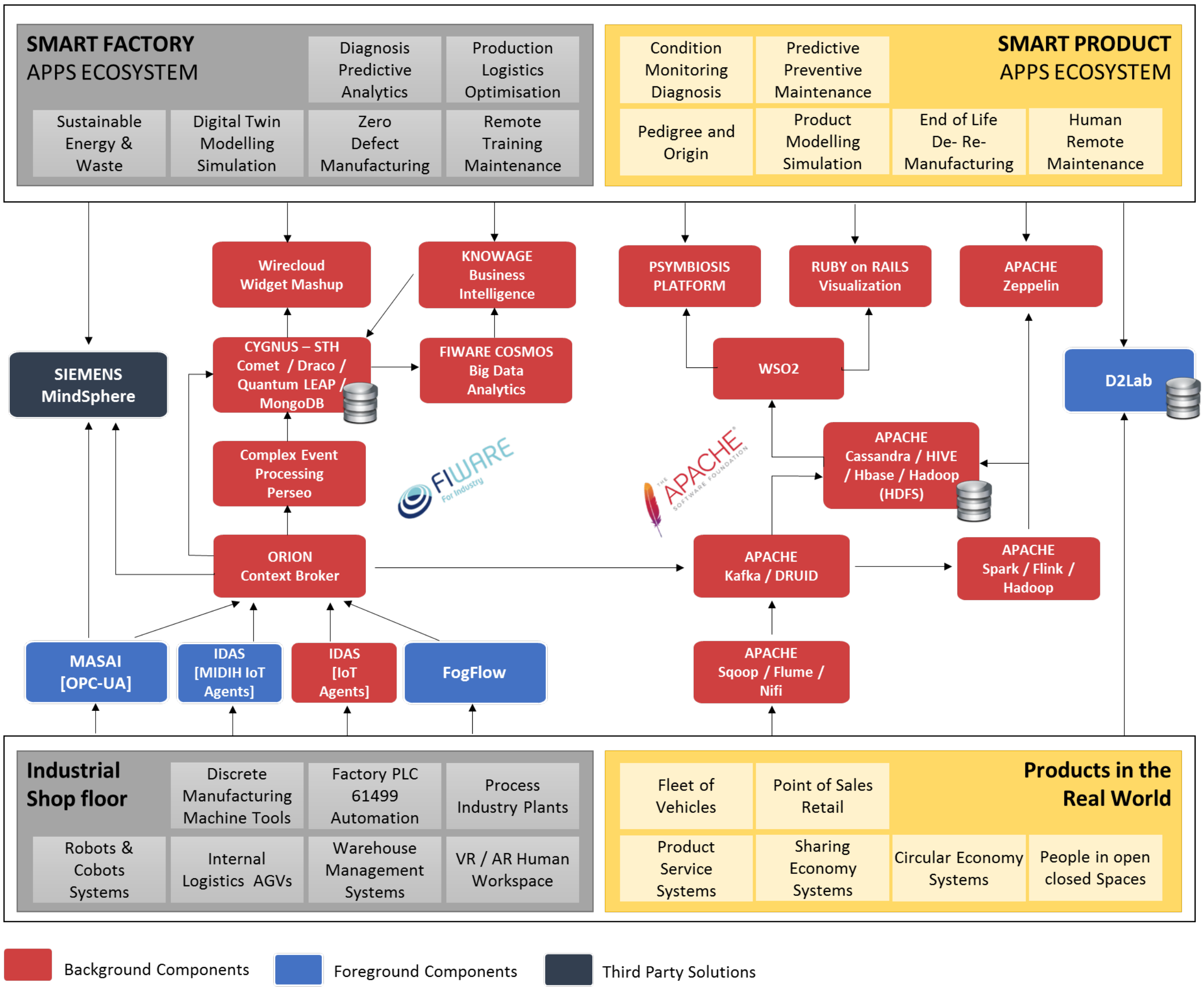

Figure 8 – Smart Factory and Smart Product Integrated Architecture

3.3 Smart Supply Chain Integrated Architecture

The integrated architecture of the MIDIH Open Platform for the Smart Supply Chain focuses on providing the mechanisms for managing collaborative supply networks, based mainly on:

- Collaboration between OEMs and subcontracts through standardized interfaces;
- Global real-time visibility regarding production, inventory, and materials;
- Supply chain decision-making through advanced analytics and next generation optimization software, allowing a quick response in supply chain planning's;
- Provide mechanisms for secure data sharing based on digital identity, sharing policy, sharing agreement and data certification.

For this, the integrated architecture of the MIDIH Open Platform must support the development and management of inter-company value chains and networks through horizontal integration, digital end-to-end engineering across the entire value chain of both the product and the associated manufacturing system, and the vertical integration of flexible and reconfigurable manufacturing systems within businesses.

The following picture (Figure 9) shows the Integrated Architecture of the MIDIH Open Platform for the Smart Supply Chain:

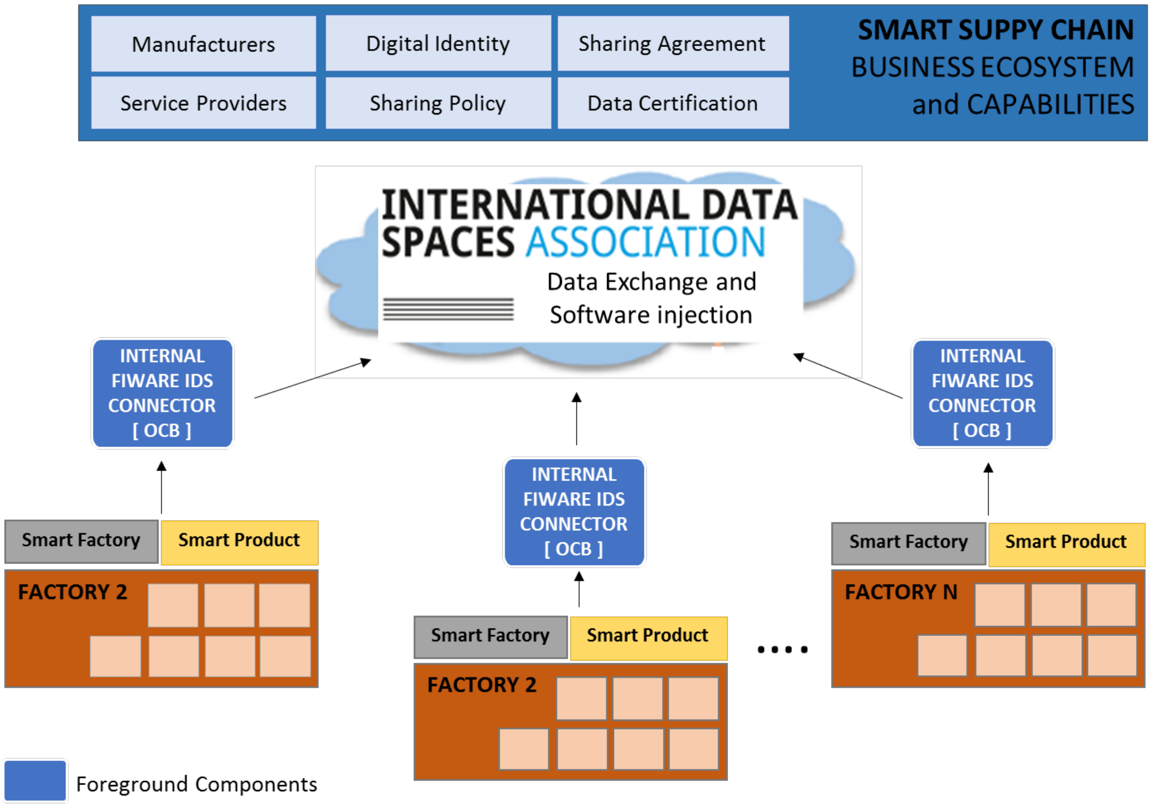

Figure 9 – Smart Supply Chain Integrated Architecture

4 Cross-Border Experimentation in Automotive Sector

For the CRF Use Case, two different Business Scenarios are considered, one regarding the **Smart Factory** and one the **Smart Supply Chain**. Both of them have been deeply described in D5.1, therefore we will report here few highlights intended to ease the reader on catching the main business motivations, existing background systems and components integrated, and the value added by the MIDIH foregrounds.

4.1 Smart Factory Scenario in FCA

4.1.1 Scenario description

For the Smart Factory scenario, the aim is the creation of innovative industrial processes, where parameters are measured, and their trend is analysed in order to allow a continuous monitoring and a predictive maintenance. The test bench focuses on the exploration of the application of Machine Learning techniques and algorithmic approaches using innovative technologies. This includes data acquisition systems, mainly relying on the FIWARE lane, as well as complex data analysis and processing, for predictive maintenance and increased energy efficiency.

Smart Factory scenario background consists of a FIWARE lane with several components:

- **Data ingestion**: IDAS GE to enable physical level to FIWARE (i.e. OPC UA, MQTT, etc.). Factory devices can be connected to FIWARE-based ecosystem using an IDAS agent or creating custom connectors.
- **Data bus**: Orion Context Broker to manage context information. Factory data can be managed as context data, using NGSI data model.
- **Data processing**: Perseo GE to create complex events, elaborating raw data coming from devices producing information useful for process improvement.
- **Data persistence**: Cygnus and QuantumLeap to store context data both on relational database like Postgres and time series database like Crate.
- **Data visualization**: Knowage, WireCloud and Grafana to view context data with custom dashboards.

The background and foreground components in this scenario are shown in the following Table 3.

COMPONENT	TASKS	LANE	STATUS	CLASSIFICATION
IDAS	**T4.2, T4.3, T4.4**	FIWARE	DONE	BACKGROUND
Orion Context Broker (OCB)	**T4.2, T4.3, T4.4**	FIWARE	DONE	
Cygnus	**T4.4**	FIWARE	DONE	
QuantumLeap	**T4.4**	FIWARE	DONE	
Knowage	**T4.4**	FIWARE	DONE	
Wirecloud	**T4.4**	FIWARE	DONE	
MongoDB	**T4.2, T4.3, T4.4**	FIWARE	DONE	
Grafana	**T4.3, T4.4**	FIWARE / APACHE	DONE	

Table 3 - MIDIH components adopted in the CRF Smart Factory scenario

4.1.2 Business Process/es

The first scenario is about the Smart Factory applications developed in CRF, based on an innovative welding cell integrated with sensoring system, where the IT infrastructure is integrated with SCADA and other OT systems. A second scenario has been identified in order to cope with new equipment and solutions (e.g. new AGVs and collaborative workstations).
For further details on business scenario please refer to D5.1.

The functionalities expected by the use of MIDIH Digital Platform are:

- Monitoring and identifying incoming events (i.e. machine breakdown or quality issues);
- Visualizing and enabling decision making (i.e. update maintenance plan);
- Trend analysis and abnormal behaviour early identification.

4.1.3 Data available

Process parameters and energy consumption are monitored by the platform, named "Smart Observer", able to allow communication with smart sensors, analysis and visualization of data, management of maintenance etc. Other data sources were already available at OT level.

The integration of the different data sources with the MIDIH Digital Platform allows a complete analysis that enables the continuous monitoring and predictive maintenance of the welding cell.

Data captured by CRF systems are saved as *.csv* files in a server in the shop floor, from which they are periodically (once per hour) sent to the MIDIH Digital Platform.

The final aim of the scenario is to identify possible correlation between incorrect functioning of the robots in the welding cell and the vehicle variants, and so it is necessary to crosscheck the data from the sensors with the data about the different vehicle variants that are worked in the cell. To this end, information about the variant is taken from a file in the PLC that registers the status of the conveyor, the product identification number of the vehicle and the timestamp. These data are collected also as *.csv* files and, in the same way as the sensor data, are sent periodically (once per hour) to the MIDIH Digital Platform. A trigger activates the saving of the data on the file and this happens only when the conveyor starts moving.

4.1.4 Architecture

The CRF Smart Factory Scenario is based on the monitoring of a welding station, consisting of several parts such as engine, connecting rod, coolant, bearings, etc., each equipped with numerous sensors to detect certain quantities of interest (such as velocity, acceleration, flow, temperature, etc).

All sensing devices are connected to an internal SCADA system called "Smart Observer" that collects all production data in order to monitors and controls the plant area.

The MIDIH Digital Platform has been tailored to the specific CRF business requirements, as shown in Figure 10: involved components are highlighted in green.

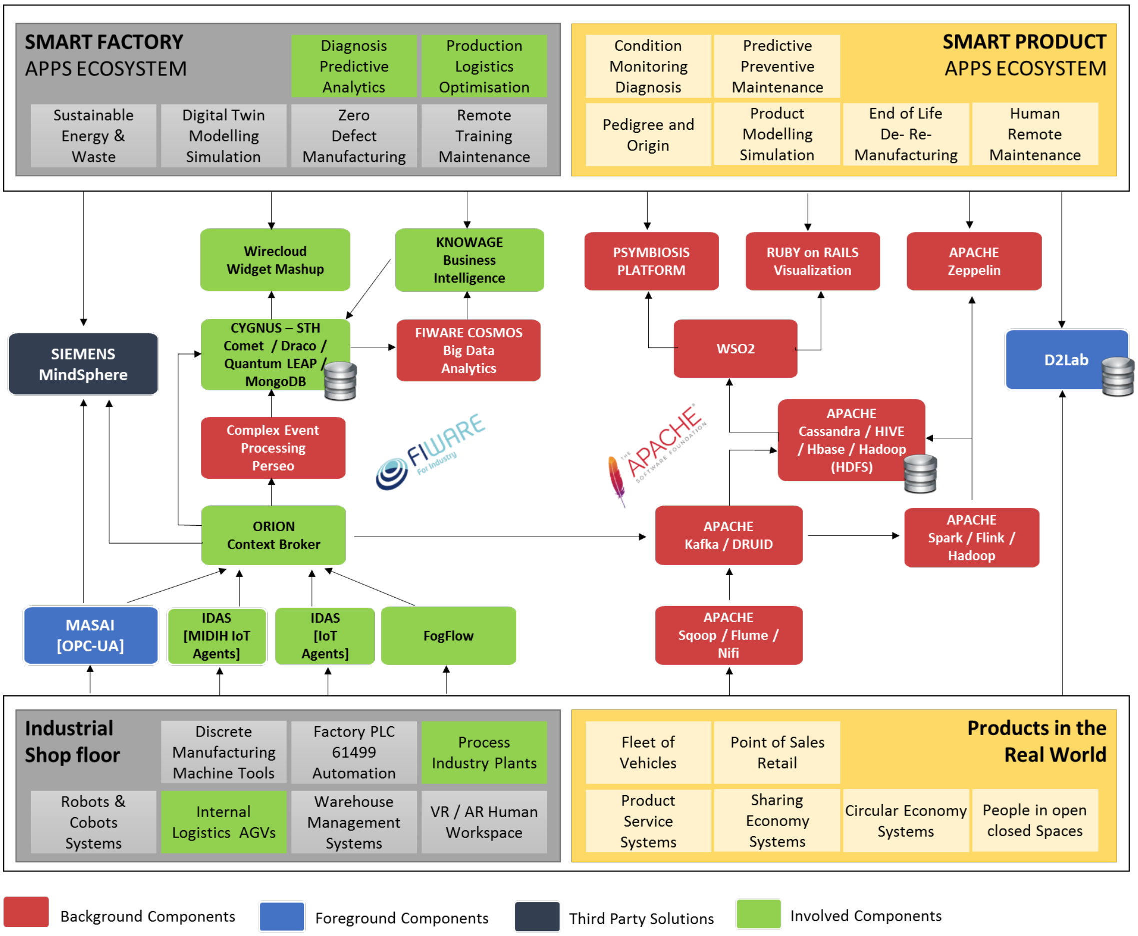

Figure 10 – CRF Smart Factory Scenario Architecture

4.1.5 Experiment session

The elaboration of the data in the MIDIH Digital Platform gives first of all a visualization of different graphs from which a general trend can be easily deducted. This is a first basis on which to create big data algorithms for more complete analysis.

4.1.5.1 Application for Plant Condition Monitoring

In the Plant Condition Monitoring scenario, the main objective is represented by capturing data from **welding cell**, located in the **Suzzara Plant**, in order to:

- Visualize **trends** for different parameters and KPIs.

- Identify **anomalous behavior** of production systems.
- **Understand** which parameters affect more the production quality.
- Find possible **correlation** between process parameters.

Welding data are extracted from the SCADA system and exposed so that they can be immediately exposed to the MIDIH Digital Platform as shown in Figure 11.

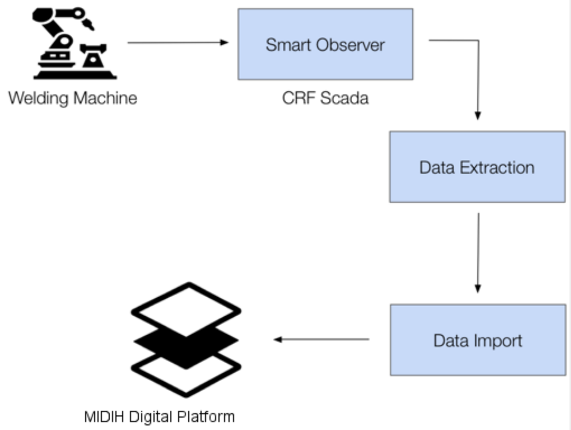

Figure 11 – CRF Welding Machine Data Flow

To this end, the MIDIH Digital platform receives data from the shopfloor, getting data from multiple data sources: sensing devices can be connected via the FIWARE IDAS Backend Device Management GE supporting several communication protocols such as MQTT, OPC UA, CoaP, etc. Furthermore, ENGINEERING has developed some specific system adapter to enable to acquire data from other custom sources.

The Orion Context Broker GE allows to manage the entire lifecycle of context information including updates, queries, registrations and subscriptions. Context information are persisted by the Cygnus GE component over a Postgres database.
At the top level, dashboards and cockpits permit to visualize relevant KPIs (e.g. by using the Knowage Suite).

4.1.5.2 Application for AGV Condition Monitoring

In **AGV** Condition Monitoring scenario located in **Melfi**, the main objective is represented by capturing data from AGV (see Figure 12) in order to:

- Visualize **trends** for velocity and acceleration parameters, relating to the 4 engines of the observed AGVs.
- Identify **anomalous behaviour** of AGVs.
- Compare different trends and infer **deviations** related to the item carried.
- **Improve** maintenance activities.

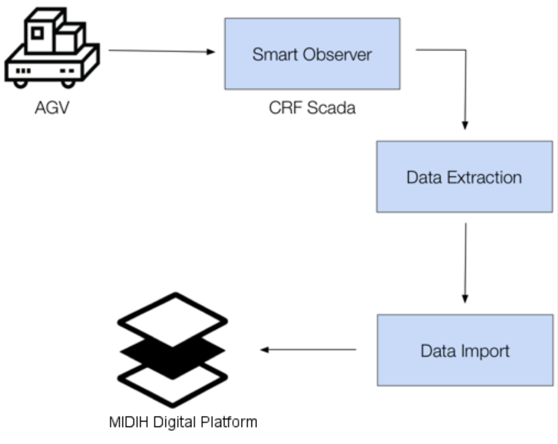

Figure 12 – CRF AGV Data Flow

AGV data are extracted from the SCADA system and exposed so that they can be immediately imported into the MIDIH Digital platform. In particular, data are extracted in real time in order to see updates at the top level instantly.

4.2 Smart Supply Chain Scenario in FCA

4.2.1 Scenario description

For the Smart Supply Chain, the main objective is the improvement of the efficiency of the transportation of components from the supplier plants to FCA production plants, monitoring parameters related to the conditions of the containers during the transportation, in order to be able to react to events than can happen during the travel, that can impact on the physical condition of the components or on the expected delivering date.

To reach this goal, travelling containers conditions will be monitored using an HW product prototype called "**Outdoor LOGistic TrackER**" (OLOGER from now), developed by Cefriel, that will be integrated with MIDIH platform. The first round of experiment (end by M18) will be focused on logistic data coming from these devices. The second round of Experiment (M27), will extend data sources, including other data sources like weather and traffic information, and will require to use other FIWARE lane components of the MIDIH platform.

In the first round, the data acquisition system, including transmission, management and storage of IoT industrial logistic data (DiM, Data in Motion), will rely on the **MindShpere/FIWARE lane**.

- **Data Ingestion**: the ingestion of raw data from the field to FIWARE /MindSphere will leverage on Data Collector modules. MIDIH foreground component **MASAI**.
- **Data Processing**: the analysis of logistic data (DaR, Data at Rest) in order to produce useful insight and information about the logistic process, will leverage on MindSphere components and ad-hoc logic.
- **Data Persistence:** Mongo DB to manage the storage and loading of data
- **Data Visualization**: visualization of output data will be done leveraging on a Production Logistic Optimization application developed within MIDIH by Cefriel (CC6).

[For more details concerning the Business Scenarios and Objectives, please refer to D5.1]

The background and foreground components in this scenario (first round) are shown in the following Table 4.

COMPONENT	TASKS	LANE	STATUS	CLASSIFICATION
MongoDB	**T4.2, T4.3, T4.4**	FIWARE	DONE	BACKGROUND
MASAI MindSphere	**T4.2**	FIWARE	DONE[3]	FOREGROUND

Table 4 - MIDIH components adopted in the CRF Smart Supply Chain scenario

4.2.2 Business Process/es

The object of this scenario is to control and monitor outdoor logistic shipments of components from supplier plant to FCA production plant. In particular, the first round of experiment will be focused on shipment of batteries from FCA supplier plant, in **Poland, to MIRAFIORI plant**, in Italy.

The stakeholders involved in this process are: FCA operators in Italy, responsible for the installation and retrieving of the OLOGER devices on the boxes, received from the supplier; FCA logistic and production responsible that will visualize logistic data coming from the MIDIH platform through the Logistic App.

The functionalities expected using the MIDIH platform are:

- Storage and management of raw data coming from the field to monitor logistic events
- Analysis and visualization of abnormal events
- Correlation of logistic events with other sources of data (like weather conditions or traffic information). This functionality will be part of the second round of experiment.

4.2.3 Data available

The first session of experiment leverages on logistic data produced by the OLOGER prototypes (Figure 13) that will be used to track containers. In this experiment there will be one physical OLOGER prototype for each specific container to track.

Figure 13 – OLOGER Prototype

[3] Foreground Masai Mindsphere ready and integrated at M12 (using MindConnct Lib v2), and updating it for the second iteration (using v3).

The type of information that will be generated and that will be monitored and managed by the MIDIH platform components are:

- GPS position
- Temperature: events over a threshold
- Humidity: events over a threshold
- Shocks: events over a threshold
- Vibrations: events over a threshold
- Diagnostics: battery level

Logistic data related to GPS position and about abnormal events captured on the field by the tracker can be configured to be sent to the MIDIH platform with a custom period (e.g. once a hour), depending on the length of the shipment and on the granularity of the information that is required by the stakeholders. Every time that an event or a position message will be processed by the MIDIH platform, the logistic application will send alert and show insights to the relevant stakeholders.

All the provided information can be recorded in an internal log file which developers can access through USB interface (direct physical connection). This feature is useful while troubleshooting issues or getting raw data without accessing the web application which the device relies on.

The advantage in using such a JSON format reflects on the number of messages needed to transfer a specific amount of data to the backend: grouping in the same frame more information units instead of using one dedicated new frame per each information unit to send, the overhead needed to complete the communication between device and backend is set to minimum load.

4.2.4 Architecture

Leveraging on data available and necessary for the experiment, the first session of the experiment will leverage on the following components of the MIDIH architecture (see Figure 14), highlighted in green.

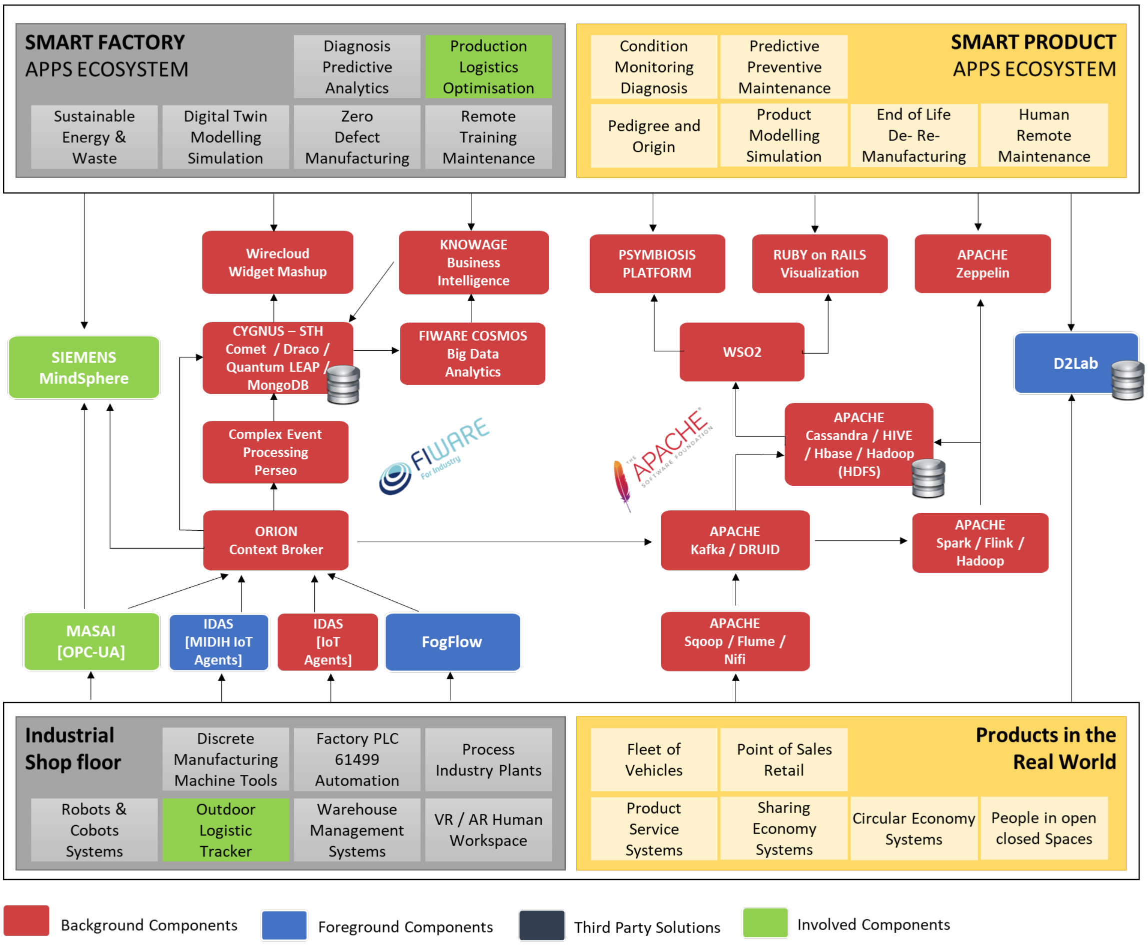

Figure 14 – CRF Smart Supply Chain Scenario Architecture

The architecture leverages on MIDIH components that will be designed, developed during task 4.3 and then tested and validated during the experiment:

- **MASAI**, designed and developed by Atos. This component will be responsible for receive data coming from OLOGERs devices, collect them and then manage them to send data to the MindSphere platform, leveraging on MindConnect Lib integrated into the component itself.
- **MONGO DB**, to store the raw data coming from the field and enable the analysis and visualization of data.
- **MindSphere:** the cloud platform will be used to manage and analyse time series data coming from devices through MASAI in the platform.
- **Production Logistic Optimization application**, designed and developed by Cefriel. This App will be responsible for retrieve data sent to the MindSphere platform and then provide all necessary information to the plant stakeholders.

4.2.5 Experiment session

The experiment will be organized into these activities with these milestones:

- Interviews with relevant stakeholders to acquire information about shipment and physical setup and definition of the process; start development of modules, and definition of integration mechanisms with MIDIH platform. End by M15.
- Start the First session of tests, to acquire data of shipments from the field, and use them to tune the prototype thresholds. Complete the development and integration with the MIDIH platform. End by M17.
- Start the second session of test the transmission of data during the shipment using the MIDIH platform SWs components, with visualization of data in the application.

4.2.5.1 Application for Inbound Logistics Tracking

The Smart Supply Chain scenario main objective is to implement Inbound Logistics container tracking in order to:

- **Track** containers path sector by sector
- Identify **anomalous delay** of containers during a trip
- Identify **anomalous logistic data**

5 Cross- Border Experimentation in Cutting- Tools Sector

The use case for NECO has two different scenarios: Smart Factory and Smart Product Scenarios.

To ensure the performance of the tool the actual state is that it depends on: the machine, the design constraints, the particular conditions, the operation and also the material to work. But NECO cannot control these parameters because they are external to their process.

But in the own process NECO can control the Product and the Factory parameters. The experiment consists into the incorporation of quality control, process control and also the visualization of the machine and tooling status. All the information will be automatized and also dumped into the platform to get the right performance and cost estimation.

Data about the quality control of the manufactured taps and also Data from the machines and tooling will be extracted. This kind of data will be considered Data in Motion as is only used for a quick control and for the generation of alarms in case that an abnormal event is detected.

Both kinds of data will be collected together as Process Data. So, the data that was considered in Motion is storage to be considered now at Rest as it needs to be processed in order to feed AI-based advanced applications. Then the data is automatized and integrated on the PSYMBIOSIS platform to get the right performance and cost estimation of the process.

5.1 Smart Factory Scenario in NECO

5.1.1 Scenario description

In the Smart Factory scenario, the proposed solution is the development of a system to control and analyse the quality control and process control data. The aim is to provide capabilities of visualization and predictive maintenance to the production line.

For this, MIDIH will develop a solution to provide the blue-collar workers and plant supervisors with the capability to visualize and prevent the factory production. In addition to this quality control, a machine and tooling status control module will be developed.

Smart Factory scenario background consists of a FIWARE and APACHE lanes with several components:

- **Data ingestion**: Data Collector to enable physical level to FIWARE (i.e. OPC UA, non OPC UA, etc.).
- **Data bus**: Orion Context Broker to manage context information or KAFKA to integrate data streams.
- **Data processing**: CEP Siddhi, Logstash and TensorFlow to analyse events and create complex events or to elaborate files with information when services are executed.
- **Data persistence**: Druid to manage which data must be loaded.
- **Data visualization**: Ruby on Rails and Nginx to present the data.

The background and foreground components in this scenario are shown in the following Table 5.

COMPONENT	TASKS	LANE	STATUS	CLASSIFICATION
Orion Context Broker (OCB)	**T4.2, T4.3, T4.4**	FIWARE	DONE	BACKGROUND
HADOOP	**T4.4**	APACHE	DONE	
HIVE	**T4.4**	APACHE	DONE	
IDAS	**T4.2, T4.3, T4.4**	FIWARE	DONE	
MIDIH Connectors	**T4.3**	FIWARE	DONE	FOREGROUND

Table 5 - MIDIH components adopted in the NECO Smart Factory scenario

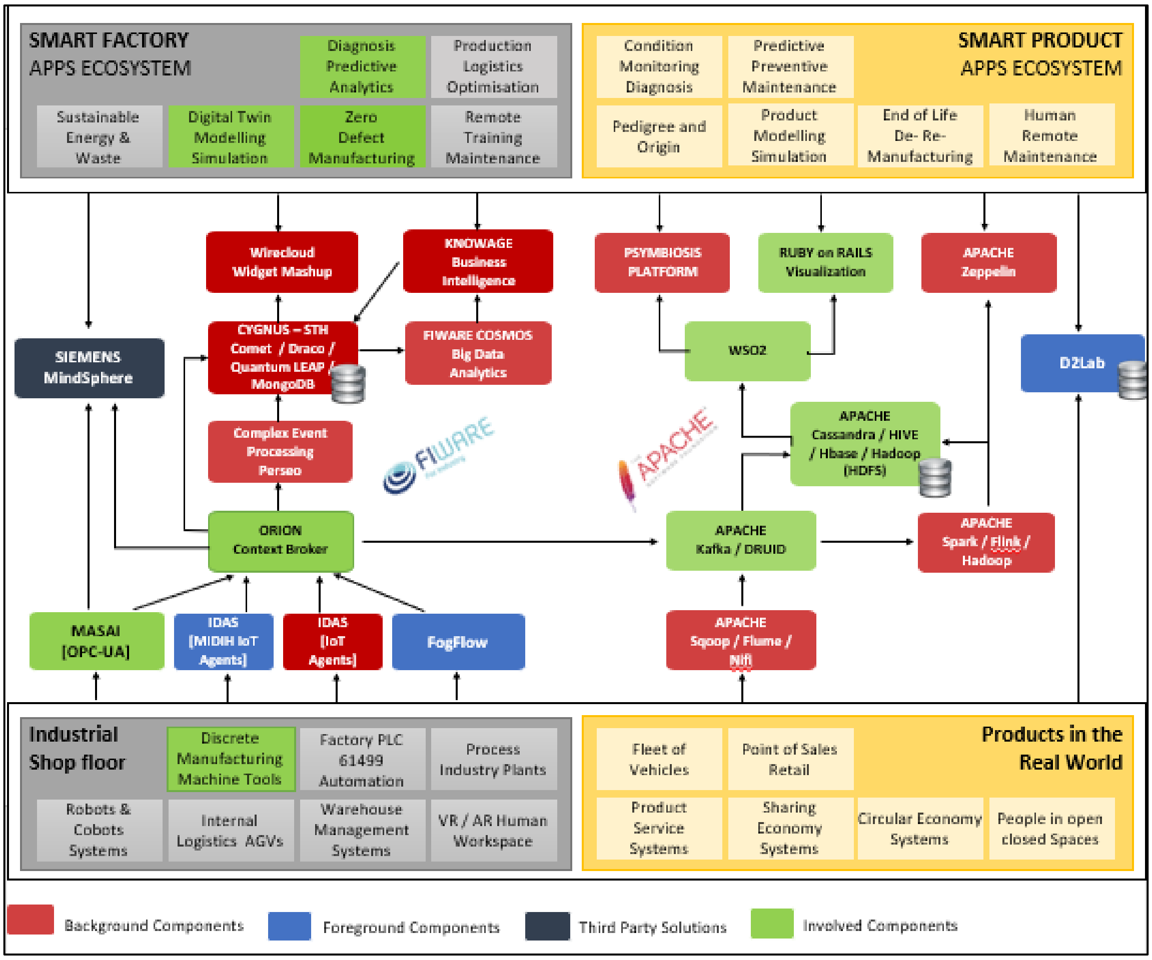

Figure 15 – Data flow for the Smart Factory Scenario (NECO Use Case)

5.1.2 Business Process/es

Inside the Smart Factory Scenario, three different business processes are approached, and they are presented below:

During the **Business Process 1. Manufacturing process digital twin** data from the taps will be extracted through the use of a CMM that will digitalise the taps. This data is considered data in motion as it is a simple way to show values of the taps and to make a quick quality control.

For that, components of visualization of the data and online processing are needed to show the measurement to the workers and to process the data generated.

During the **Business Process 2. Tools and fixtures digital twin** data from the process will be displayed to the workers through the use of a data gathering Platform. This data is considered data in motion as it is a simple way to show process parameters and to have a control and availability of the process.

Components of visualization of the data and online processing are required to show the parameters to the blue-collar workers and to process the data generated.

In the last **Business Process 3. PLC interoperability** data of the quality control and data from the process is analysed and visualized. For that, components of the IOT Middleware are required to transform the different machine languages into a common one. After that a Data Persistence Middleware is used to collect the data from these multiple sources, store it and to make it available to various applications such as for analytics, display, and reporting. The data that was considered in Motion is storage to be considered now at Rest as it needs to be processed in order to feed AI-based advanced applications. With the data semantic model this data is analyse and then with the information bus is presented to be used by the different applications.

After the analysis, the information is presented with the DaR Visualization compound and the DaR Processing component provided with deep-learning capacities.

The case chosen to apply MIDIH in NECO is in a **WALTER HELITRONIC Machine** in which the Flute Grinding process takes place. Actually, the experiment is focus on the acquisition of data for the Business Scenario 1 and 2.

In the first business scenario the parameters to be controlled are the cutting angle of the tap and also its flute form. In the second business scenario, the machine and tooling status will controlled two parameters: temperature and vibration. With MIDIH this step of the process will be controlled integrating sensoring systems and connecting the data with the platform.

The functionalities expected using MIDIH Digital Platform are:

- Monitoring and identifying incoming events (i.e. process control of the process: quality and machine and tooling status)
- Visualizing and enabling decision making
- Trend analysis and abnormal behaviour early identification

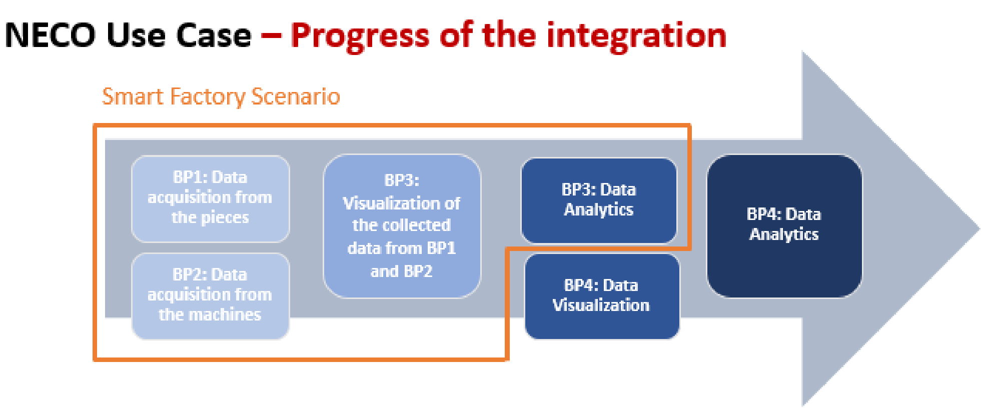

Figure 16 – Progress of the integration process for the NECO Smart Factory Scenario

5.1.3 Data available

In this experiment a **Coordinate Measurement Machine** (CMM) will be installed to obtain quality control data, able to provide quality measure in the form of cutting angle and flute form.

The digitalization machine will have data from the taps. The quality control data from the digitalization machine will be integrated in the MIDIH Platform. For this, it is necessary to know how to identify the data that it will be published in the Orion Context Broker so that it can be seen later and how these data that it is in format (DMO) in NGSI format must be transformed so that they can be published properly in the broker context.

For the second Business Scenario data from the machines and tooling will be extracted. The machine has a CNC control that allows recording certain production and environment parameters to be extracted later. For this second scenario some errors of the machine and tooling status are really important to keep under control. To control them some information from the machine has to be extracted.

To have a better machine control, it is necessary to visualize the critical production parameters, showing the data obtained from the machine and tooling status. The errors produced during the flute grinding have been identified and have to be controlled. The most important ones are the following: the diamond roll has the profile worn or it doesn´t cut, Z-Axis clearance, wrong grinding feed, wrong number of passes or depth quantity, wrong clamping pressure, Z-Axis vibration, A-Axis clearance, C-Axis clearance and insufficient or irregular flow or pressure of oil or nozzles in poor condition or incorrectly oriented. Some of these errors can be measured with actuators or extracting the parameters from the CNC control. For others paper with data, table distance rule, pressure gauge or flowmeter are required. Two types of sensors need to be installed such as the temperature and vibration sensor to be able to control the tap temperature and the Z-Axis vibration respectively.

So, with these two business scenarios the critical parameters will be checked. From one side, the dimensional control of the tap with the control of the tap. On the other side the numerical control of the machine and other sensors will offer the parameters to control the status and availability of the actual machines and tooling.

To sum up the following Table 6 contains all errors to be checked in the machine and also the critical ones with its correspondent measurement:

Errors	Measurement	Way
Diamond roll: profile worn or not cut	Diamond milling engine consumption	Actuators o CNC
	Dressing Time	CNC
	Wheel weight	CNC program
Wrong grinding feed	Process data	Paper with data
	Difference of initial and final position and elapsed time	Table distance rule
Wrong number of passes or depth quantity	Process data	Paper with data
	Grinding wheel motor consumption	Actuators o CNC
Wrong clamping pressure	Clamping air pressure	Pressure gauge

Insufficient or irregular flow or pressure of oil or nozzles in poor condition or incorrectly oriented	Oil flow	Flowmeter
	Oil pressure	Pressure gauge
	Tap temperature	TEMPERATURE SENSOR
Z - Axis vibration		VIBRATION SENSOR
A - Axis clearance	Preventive maintenance check	Preventive maintenance report
C - Axis clearance	Preventive maintenance check	Preventive maintenance report
Z - Axis clearance	Preventive maintenance check	Preventive maintenance report
Wheel spindle runout		
Wrong dressing feed		
Variable quality of the wheel		
Wheel with ferrules		
A - Axis vibration		
Inequality in the grooves of the grinding wheel		
Wrong dressing depth		
Unbalanced wheel		
Vibrations of the diamond roller spindle		
Diamond roll spindle runout		
Wheel spindle belt no ok		
Lack of alignment between center points		

Table 6 - Analysis of the data to be controlled

The third Scenario will be deployed after the recompilation of the data from the previous scenarios. Therefore, it will be developed after the execution of the first two scenarios.

Process parameters coming from the quality control data and the machine and tooling status control are monitored by a platform. The integration of the data allows the development of analysis that enables the monitoring and the predictive maintenance of the production line:

- Trend visualization and analysis of parameters
- Continuous monitoring
- Alarms or events management

5.1.4 Architecture

The NECO Smart Factory Scenario (see Figure 17) is based on the Taps digitalization to have the quality control and also the data gathering from the machines and tools. The digitalization of the taps will be done by a Coordinate Measurement Machine with an optical sensor to detect irregularities in the product.

The machines and toolings status control will be provided by the data extracted from the machines to visualize certain parameters of interest (such as Axis vibration, Temperature, etc).

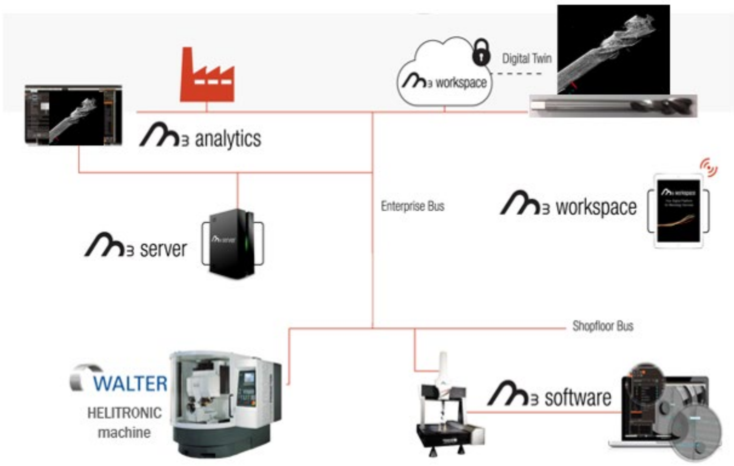

Figure 17 – NECO Smart Factory Scenario Architecture

5.1.5 Experiment session

The first business process is able to provide the quality control information from the parts with their digitalization.

The second business process shows the data that can be extracted from the machine and tooling after carrying out the analysis of the most relevant parameters for the process.

One these two business processes is completed during the third business process; the Platform will provide to NECO the availability to visualize some parameters and also graphs from which a correlation between quality control data and machine and tooling data can be done.

This is the first step to create Big Data Analytics that will be able to:

- Continuous control of the production line
- A predictive maintenance since the deviations of the products or the process parameters can be previously detected.

5.1.5.1 Application for Manufacturing process digital twin

In the first business process the main objective is to visualize the information of the quality control. With this, the blue-collar workers will be able to quickly see if the product is being manufactured properly.

The MIDIH Platform will receive information from the optical sensor installed in the CMM. The Orion Context Broker will manage the data compilation. The visualization and alarms and event management will be performed by Open APIs.

5.1.5.2 Application for Tools and fixtures digital twin

In the second business process the main objective is to visualize the information of the machine and tooling status control. With this, the blue-collar workers will be able to quickly see if the manufacturing parameters are within established values or if anomalies have been detected.

The MIDIH Platform will receive information of certain parameters from the Walter Helitronic Machine. The Orion Context Broker will manage the data compilation. The visualization and alarms and event management will be performed by Open APIs.

5.1.5.3 Application for Smart Production Analysis

Once that Quality Control data and Machines and toolings data are collected, both kinds of data are visualized and analysed in order to:

- Visualize **trends** for taps and production parameters;
- Identify **anomalous behaviour**;
- **Understand** which parameters affect more the production quality
- Find possible **correlation** between process and quality parameters

The MIDIH Solution will need a Middleware to collect the data and storage it to later make it available. With HIVE three functions will be achieved: data summarization, query and analysis. The information Bus will send the data to the TensorFlow which will develop some Deep Learning Algorithms.

5.2 Smart Product Scenario in NECO

5.2.1 Scenario description

Inside the Smart Product Scenario just one Business Process is considered.

Once that all the previous information (data from quality control and data from the manufacturing process) is compiled, in the **Business Process 4. Product Service System Platform for ZDM** it is automatized and integrated on the PSYMBIOSIS platform to get the right performance and cost estimation of the process.

For that, components of the IOT Middleware are required to transform the different data into a common one. After that a Data Persistence Middleware is used to collect the data from these multiple sources, store it and to make it available to the PSYMBIOSIS platform. With the data semantic model this data is analysed and then with the information bus is presented to be used by the PSYMBIOSIS platform.

The DaR Processing component provided with deep-learning capacities will process the data and also visualizes it and presents the information in the DaR Visualization.

This Scenario will be developed after the progress of the first two scenarios. Therefore, as the third scenario, it will be part of the second iteration.

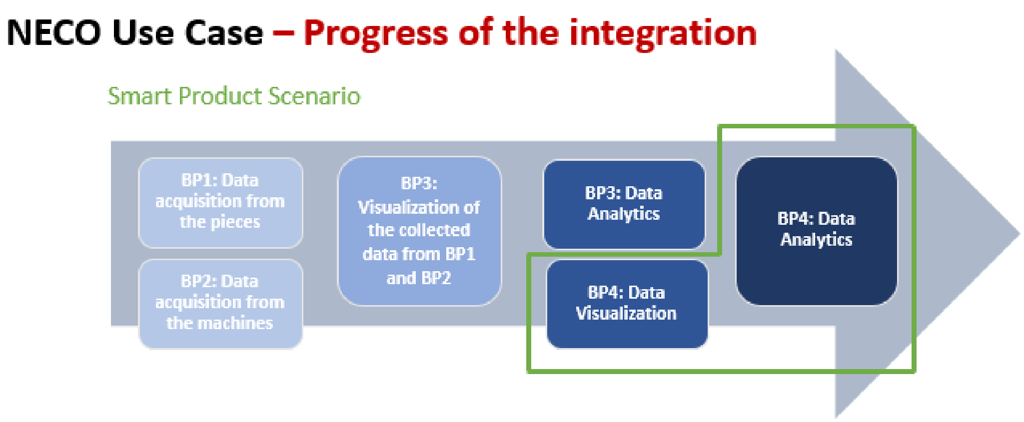

Figure 18 –Progress of the integration process for the NECO Smart Product Scenario

The Smart Product scenario background consists of an APACHE lane with several components:

- **Data information bus**: WSO2 to enable a common communication bus between diverse applications.
- **Data processing**: TensorFlow for numerical computation.
- **Data persistence**: Druid to manage which data must be loaded.
- **Data visualization**: Ruby on Rails to present the data.
- **Data semantic bus:** Hadoop or HIVE to provide grouping, query and data analysis.

The background and foreground components in this scenario are shown in following Table 7.

COMPONENT	TASKS	LANE	STATUS	CLASSIFICATION
Orion Context Broker (OCB)	**T4.2, T4.3, T4.4**	FIWARE	DONE	BACKGROUND
HADOOP	**T4.4**	APACHE	DONE	BACKGROUND
HIVE	**T4.4**	APACHE	DONE	BACKGROUND
IDAS	**T4.2, T4.3, T4.4**	FIWARE	DONE	BACKGROUND
MIDIH Connectors	**T4.3**	FIWARE	DONE	FOREGROUND

Table 7 - MIDIH components adopted in the NECO Smart Product Scenario

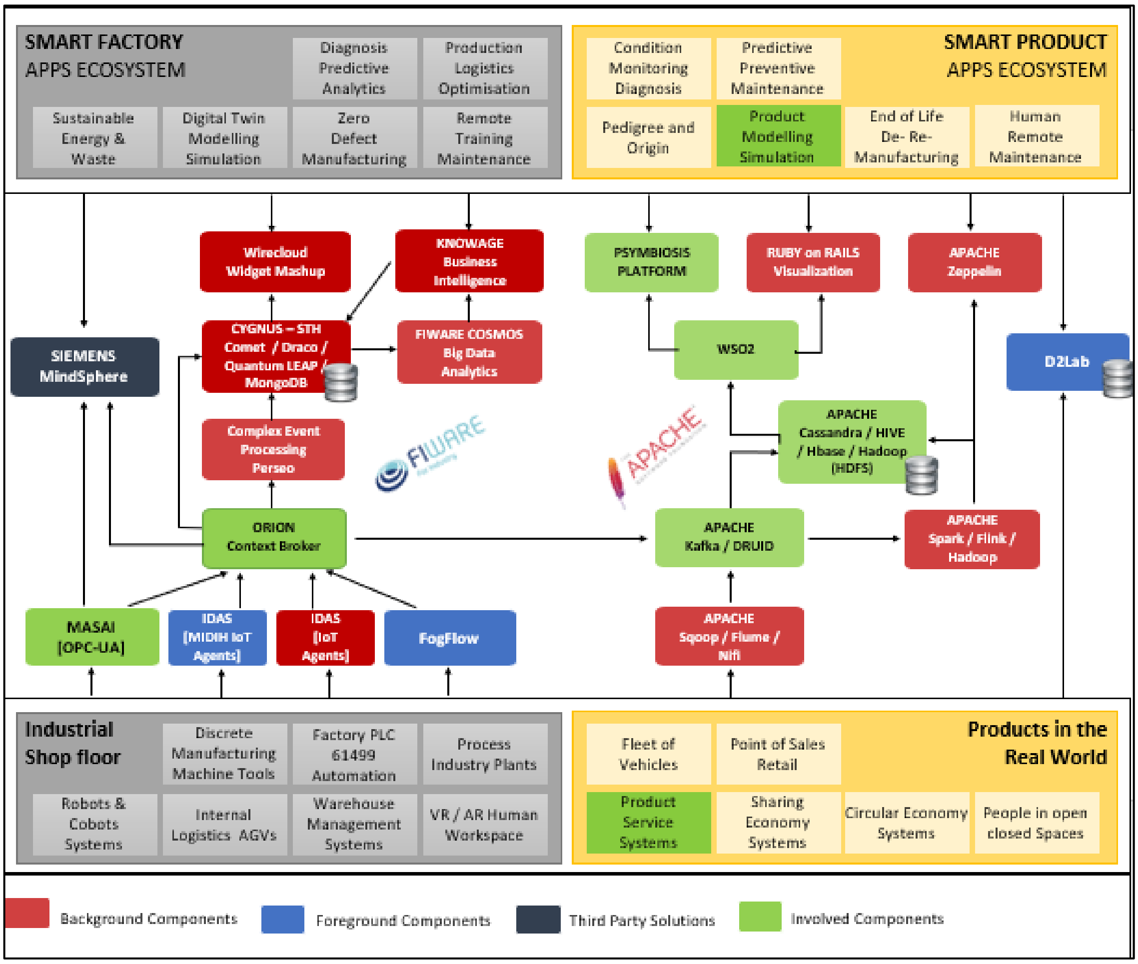

Figure 19 – Data flow for the Smart Product Scenario (NECO Use Case)

5.2.2 Business Process/es

The object of this last business process is to automatize and digitalize the product design process. For this, the requirements are:

- Data about the quality control
- Data from the process
- PSYMBIOSIS Platform that will visualize the data coming from the both previous steps

5.2.3 Data available

As it is said before, this process will be fed by the information of the Smart Factory Scenario. The required data comes from the quality control and the machine and tooling status control.

Also, more information about the following parameters will be needed:

- Price of the raw material
- Availability of raw material
- Duration of the manufacturing process
- Delays in the manufacturing process

5.2.4 Architecture

The architecture of this business process is similar to the one of the third business process in the previous scenario but now with the inclusion of the personalized platform.

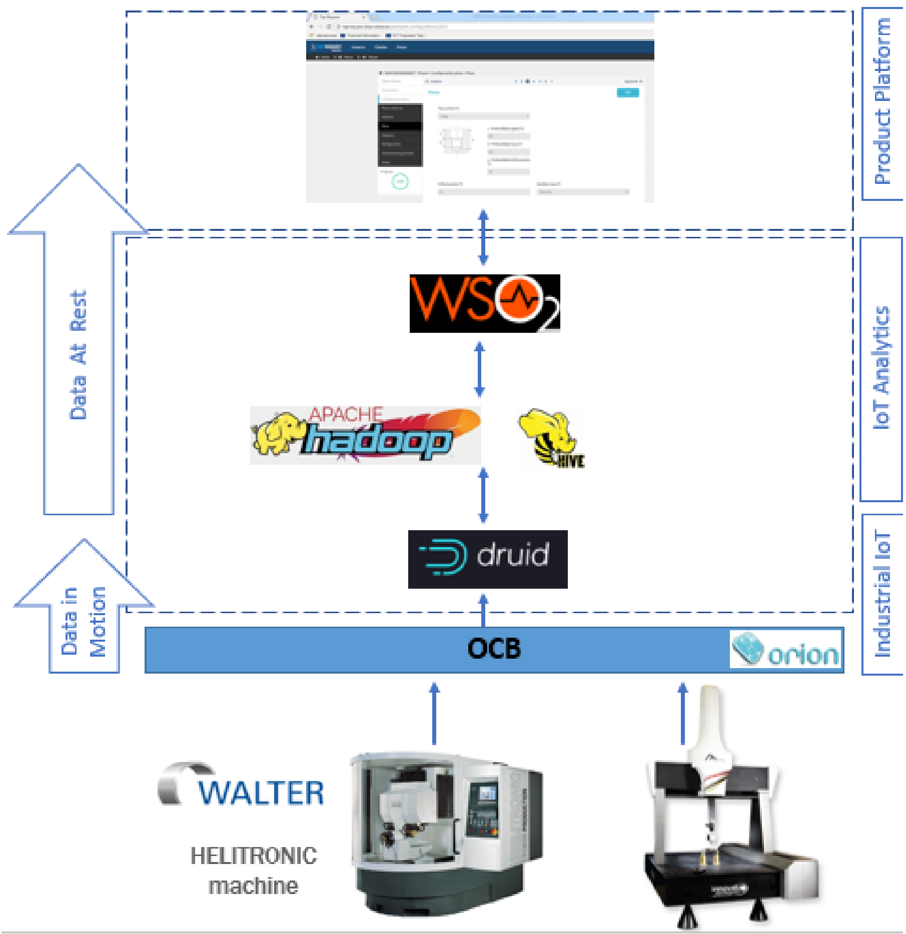

Figure 20 – NECO Smart Product Scenario Architecture

The architecture leverages on MIDIH components that will be designed, developed during task 4.3 and then tested and validated during the experiment:

- **Orion Context Broker**, developed by FIWARE. This component will be responsible for receive data coming from the sensors and the machines, collect it and then make it available to the MIDIH platform.
- **PSYMBIOSIS Platform**, the data automation of the platform will be also designed and developed by INNOVALIA, with the scope to analyse and visualize data in the requested format addressing stakeholder needs.

5.2.5 Experiment session

The experiment will be carried out in the following steps:

- First, acquire data from quality control and data from machine and tooling status. In this step, information from different relevant aspects of the manufacturing process (such as, delays, availability and price of raw material, etc.) has to be compiled. With all the data start the integration with the MIDIH platform and visualize the data.
- In the second development the data will be transferred to the customised platform.

5.2.5.1 Application for the Product Service System Platform for ZDM

The Smart Product scenario main objective is to automatize and digitalize the product design process with the last data available in order to:

- Take into account delays in the manufacturing process
- Identify duration of the process
- Know the availability of the raw material
- Keep updated the price of the raw material

6 Cross-Border Experimentation in Additive Manufacturing

6.1 Smart Supply Chain Scenario in THYSSENKRUPP

6.1.1 Scenario description

The technical approach consists of the creation of a data space as defined in the IDS Reference Architecture Model[4]. The software architecture represents the reference architecture of the Industrial Data Space. The elements Connector and Broker from the Industrial Data Space are used as well as the IDS Identity Provider (mandatory and not described in detail as this is a standard component in the Reference Architecture Model[5]). For the customer, the distribution network organizes itself via apps in the Industrial Data Space. Within MIDIH, a distribution planning app is installed in the manufacturer's IDS connector. The Service Application transferring data through the Supply Chain partners, in this case between the manufacturer and the logistics service provider resp. the transport service provider. The scenario is described in detail in D.5.1

COMPONENT	TASKS	LANE	STATUS	CLASSIFICATION
KAFKA	**T4.4**	APACHE	DONE	BACKGROUND
SPARK	**T4.4**	APACHE	DONE	

Table 8 - MIDIH components adopted in the Cross-border experimentation in Steel sector

6.1.2 Business Process/es

The experiment focuses on different scenarios. The first scenario covers distributed optimization of the smart supply chain in **distributed 3D printing**. The second scenario covers the creation of a smart product supported by a digital twin.

Scenario 1

This scenario covers the smart supply chain in 3D printing. The goal of this Business Process is the optimization of the supply chain for the customer, in the means of cost efficiency and/ or estimated time of arrival. The process covers the following steps (it is worth to notice that not every step is already available at M12):

1. Customer places order at materials company (thyssenkrupp material service - tkMX) for engineering support.
2. Materials company engineers part, creates a digital representation of the part and identifies possible production sites for 3D printing and post processing.
3. Materials company queries possible production sites for offers for production.
4. Materials company queries Logistics Service provider for offers for transport between the production steps and the delivery to the customer
    a. Logistics service provider queries carriers for transport offerings.

[4] https://www.internationaldataspaces.org/publications/ids-ram2-0/
[5] https://www.internationaldataspaces.org/publications/ids-ram2-0/

5. Distributed algorithm optimizes supply chain and identifies best offers regarding the optimization goals of the customer.
6. Customer selects offering, without knowledge of the partners involved.
7. Materials Company places orders in the network, depending on the choice of the customer.

Figure 21 shows the workflow to form a supply chain. Frequent iterations of this procedure, depending on new demand or abrupt changes creating dynamically changing business ecosystems.

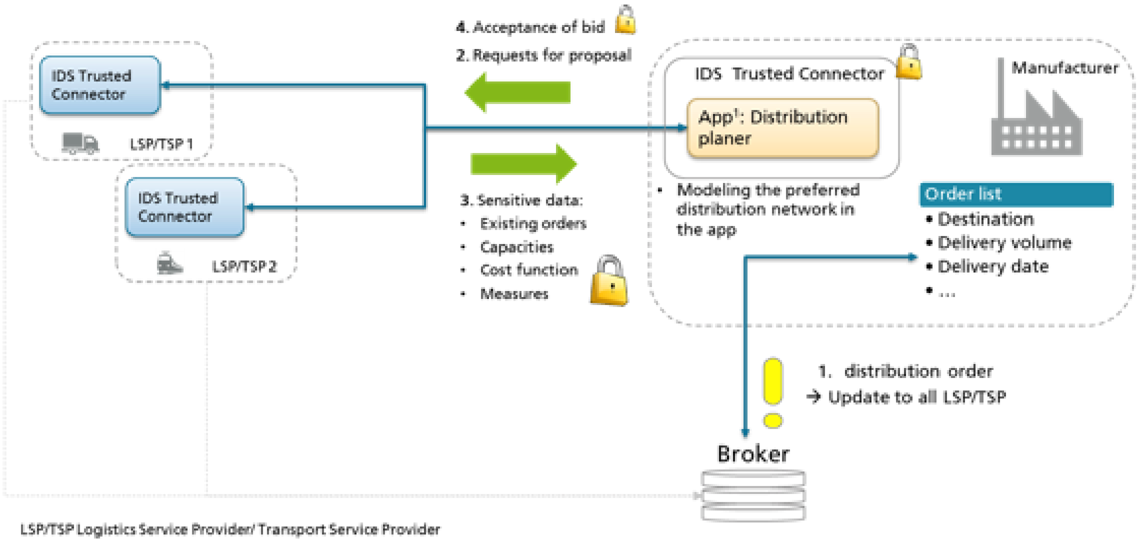

Figure 21 – Distribution management using the Industrial Data Space

This workflow fits to the needs as described in the Smart Supply Chain architecture (chapter 3.3) with the named requirements:

1. **Collaboration between OEMs and subcontracts through standardized interfaces** The IDS Reference Architecture Model provides a standardized component with its information model for technical interfaces (technical contracts) and the negotiation of legal contracts between participants to enable collaboration.
2. **Global real-time visibility regarding production, inventory, and materials** The ecosystem approach of these experiments as described in D5.1 enables the data exchange between participants in the ecosystem to support the data exchange. The IDS Reference Architecture Model does not require a predefined protocol, as this is heavily dependent on the use case. A use case describing the data exchange between ERP systems of different participants may be on a daily basis. The status of truck can be transferred and analysed in near-real time by the use of components the MIDIH Architecture, e.g. Apache Kafka (T4.4) and Apache Spark(T4.4).
3. **Supply chain decision-making through advanced analytics and next generation optimization software, allowing a quick response in supply chain planning's.** The experiment relies on distributed analytics and next generation optimization software to be run inside an IDS Connector. This IDS Connector can make use of the IDS Reference Implementation or FIWARE Context Broker (T4.2, T4.3, T4.4) or may be

implemented on another technical basis. The IDS Reference Implementation for Logistics is used in this scenario in conjunction with FIWAE based connectors. As described the availability of global data enables a global near-real-time planning for all participants instead of a local planning for every participant.

Scenario 2

The industrial experiment is originated from the supply chain scenario 1. In this scenario the use of **additive manufacturing** leads to distributed manufacturing in different facilities in different locations by different organizations. This leads to a distributed data model as the producer of the good will typically not share detailed data to prevent the disclosure of relevant data. With additive manufacturing a detailed digital model of the product is available and in conjunction with detailed sensor data from the manufacturing process (the sensors inside a 3D printer and in addition, but not part of this experiment, data from non-destructive testing) the simulation of the resilience of the part can be executed with a better accuracy. This simulation will be even more accurate by extending it with environment data of the intend use of the part. This is typically described as the digital twin. The creation of a digital twin follows this workflow:

1. Identify part: the part needs a unique identifier that creates the link between the physical and the virtual part.
2. Generate data: data generation by tools, e.g. CAD or sensor data, e.g. (I)IoT.
3. Generate metadata: Extend the data with metadata, e.g. data quality, data provider and link it to other relevant data, e.g. information on tool or machine.
4. Usage Policies: Attach Usage Policies to the data.
5. Transfer data: Transfer data to remote processing by using near-real-time systems, e.g. Apache Kafka.
6. Data storage: if necessary, store raw data (e.g. Apache Cassandra).
7. Process data: Generate insights by advanced analytics (e.g. Apache Spark) and store insights in database (e.g. Apache Cassandra).
8. Make data available: attach Usage Policies to generated data and make it available to the ecosystem.
9. Share data: Negotiate technical and legal contracts and exchange data.

The steps 4, 8 and 9 are described in detail in the IDS Reference Architecture Model[6].

6.1.3 Data available

For the execution of the experiment the following data will be used.

For the involved **facility**

- Name: Name of the partner
- Address: Address of the partner for transportation
- Geolocation: geolocation of the partner in addition to the address for transport optimization
- Processing services: types of processing service offered by the partner
  - Quality: quality measure of this service (e.g. resolution of the 3D Printer)

[6] https://www.internationaldataspaces.org/publications/ids-ram2-0/

- Material: materials supported
- Complexity supported: Supported complexity of service (details in 3D printing vocabulary, not part of this experiment)

For the **customer**:

- Name: Name of the partner
- Address: Address of the partner for transportation
- Geolocation: geolocation of the partner in addition to the address for transport optimization

For the **Carrier:**

- Name: Name of the partner

For the **Order**

- Customer: reference to customer
- Transports: reference to transports ordered
- Production steps: reference to production steps ordered
- Part: reference to part ordered
- Order placed: indicates if this order is placed or in the state of an offering

For the **Transport:**

- Carrier: reference to carrier executing this transport
- Pick up address: starting address
- Delivery address: Delivery address
- Part to be delivered: reference to part to be delivered
- Pick up datetime: Start time
- Delivery datetime: delivery time

For the **Production Step:**

- Part: reference to the part
- Facility: reference to the facility
- Cost: Cost of this production step
- Production start: start of the production
- Production finished: Time part is ready for transport

For the **Part:**

- Dimensions: dimensions of the part
- Weight: weight of the part
- Material: material of the part
- Quality: required quality regarding the processing steps
- Complexity: measures for the complexity of the part
- Transportation requirements: additional transport requirements

6.1.4 Architecture

The architecture follows the idea of creating a **data space for a smart supply chain in 3D printing**. The participants of the scenario are connected with IDS connectors (different technology base). The orchestration of the services is done with apps injected to the connectors. Interoperability is given by the use of **IDS vocabularies** (see Figure 22).

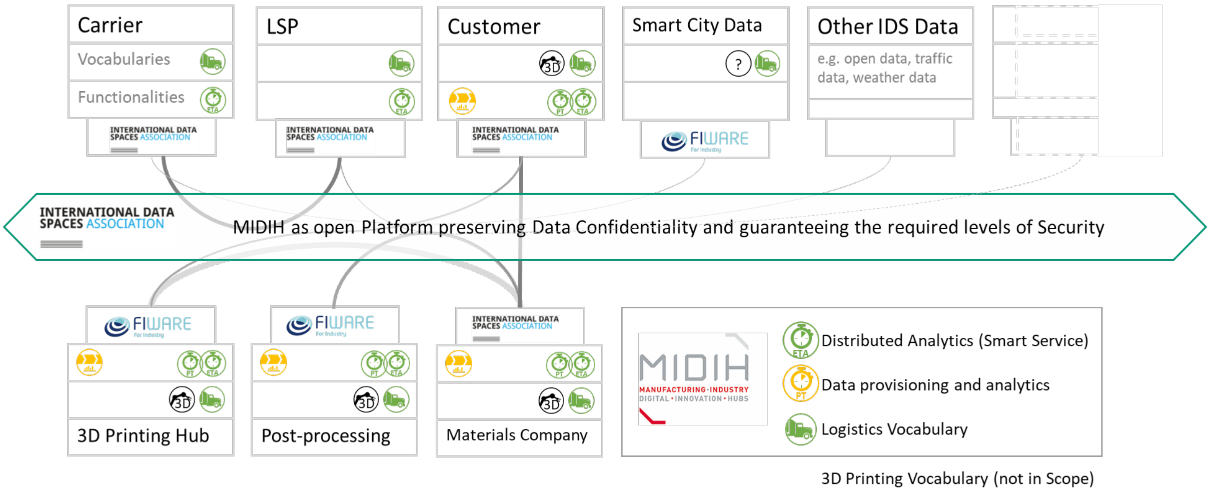

Figure 22 – Business Architecture of experiment

Therefore, the experiment makes use of the IDS Connectors as main foreground components. The connectors enable the exchange of data and support the injection of software components. The connectors involved are based on FIWARE components, on the IDS Reference Implementation (based on the Open Source branch of IDS Connector Reference Implementation as Base Connector or Trusted Connector) or other technologies. The IDS broker and the IDS Identity Provider are involved as well.

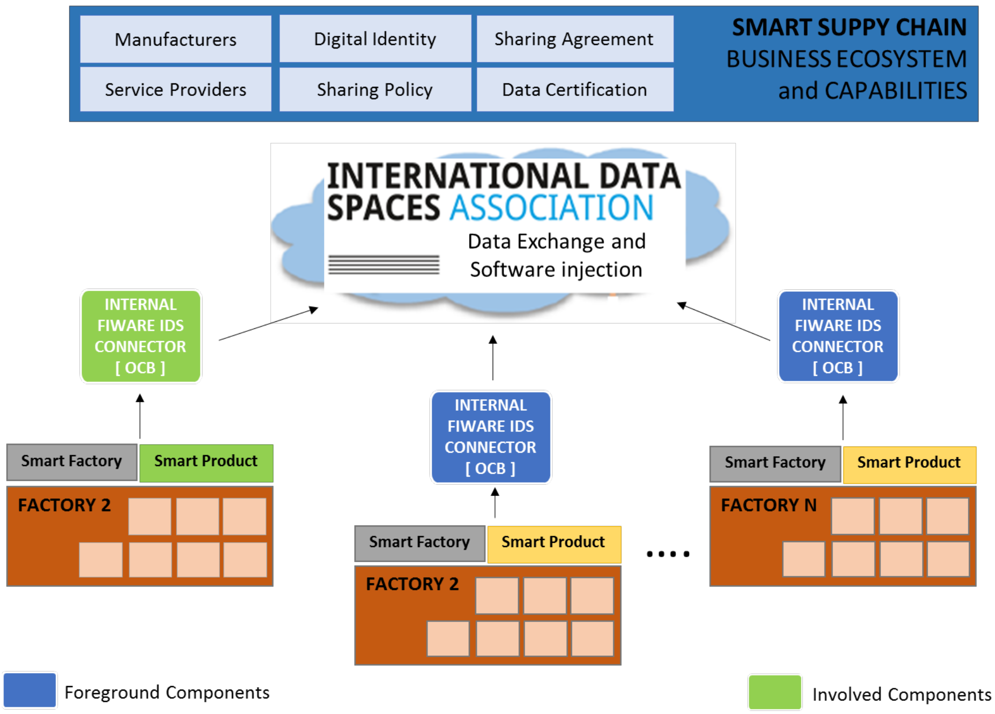

Figure 23 – Deployment of the components in the system

6.1.5 Experiment session

The experiment will be carried out by using the network of **thyssenkrupp materials service as materials company in this experiment and DB Schenker as logistics service provider in this experiment**. As the technical and economic properties of the part in scope are not relevant for this experiment, it is up to tkMX to choose suitable part. The experiment will make use of different parts to make use of different variants, depending on the complexity of the part and the material used (metal or plastics). The engineering part is not in the focus of the experiment. The experiment starts with a description of the part by a customer from the network of tkMX and given optimization goals (estimated time of arrival, price, both with minimal and/or maximal values given). The required data will be gathered in the network of tkMX and DB Schenker, depending on the results of the engineering phase in the means of complexity, material, and quality. The customer chooses a supply chain and tkMX places the subsequent orders.

For the second iteration of the experiment additional data from the process described before and the experiment of the first iteration. Additional data from the engineering phase as well as data from the printing and post-processing will be linked and attributed with Usage Policies.

7 Experimentation in the Didactic Factory (POLIMI)

7.1 Scenario description

The use case for POLIMI describes a Smart Factory Scenario implemented in POLIMI I4.0 lab. The main objective of this experiment is to develop a Production Monitoring application able to provide a full tracking of the production line, in order to enable managing the power status of the stations efficiently while reducing the idle time of machine in favour of stand-by states (i.e. control the line and turn on stand-by mode of a station while the previous station is completing their job).

The didactic factory powered by FESTO includes **14 OPC UA servers**, installed on 7 working stations and capturing both energy and MES data. The experiment consists into the processing of Manufacturing execution systems (MES) data in order to examine the progress of production along the conveyor. Furthermore, energy consumption data are elaborated to get information about main energy behavior of the stations.

POLIMI I4.0 lab is based on an internal network connecting all stations OPC UA servers to the two MES and Energy PC stations. The I4.0 lab network can connect to different networks:

- DIG departmental network (connection only ethernet, with internet access)
- I4.0 lab network (connection via ethernet and WIFI, no internet access)

The MES and PC stations are UBUNTU partitioned, with Docker installed. The FIWARE software is installed into a single Virtual Machine, with Docker in order to have several benefits such as isolation from the operating system, easy maintenance, availability and convenient recovery, portability across different machines, etc.

Smart Factory scenario background consists of a FIWARE lane with several components:

- **Data bus**: Orion Context Broker to manage context information. Supply Chain data can be managed as context data, using NGSI data model.
- **Data processing**: Perseo GE to create complex events, elaborating raw data coming from devices producing information useful for process improvement.

Regarding foreground components:

- **Data ingestion**: OPC UA Agent to bring device data from OPC UA Server to FIWARE.
- **Data visualization**: Knowage custom dashboards developed to monitor the status of the FESTO Didactic factory testing environment.
- **Data processing and station control**: custom flows developed in Node-RED a flow-based development tool for visual programming developed originally by IBM.

The background and foreground components in this scenario are shown in the following Table 9:

COMPONENT	TASKS	LANE	STATUS	CLASSIFICATION
IDAS	**T4.2, T4.3, T4.4**	FIWARE	DONE	BACKGROUND

Orion Context Broker (OCB)	**T4.2, T4.3, T4.4**	FIWARE	DONE	
Cygnus	**T4.4**	FIWARE	DONE	
Knowage	**T4.4**	FIWARE	DONE	
MongoDB	**T4.2, T4.3, T4.4**	FIWARE	DONE	
Grafana	**T4.3, T4.4**	FIWARE / APACHE	DONE	
OPC UA Agent	**T4.3**	FIWARE	DONE	FOREGROUND

Table 9 - MIDIH components adopted in the POLIMI Smart Factory scenario

7.2 Business Process/es

POLIMI Didactic Factory implements an assembly line for item production composed by 7 workstations connected by a conveyor belt. Each workstation has two OPC UA server, energy and MES. The energy server allows to monitor power consumption and compressed air usage whereas MES server tracks production flow in order to infer operational status of the stations.

The functionalities expected by the use of MIDIH Digital Platform are:

- Monitoring of energy consumption for every workstation
- Tracking item position in real time
- Managing Plug and Control devices.
- Autonomous energy control for every workstation as a CPS

7.3 Data available

Each station is equipped with sensors able to get in real time the operational status and the production resource usage (electricity and compressed air) of each WorkStation: the relevant data are stored in variables belonging to the station OPC UA servers, together with corresponding context data (such as timestamp, measure unit, etc.). Each WorkStation OPC UA servers stores approximately one hundred variables of various types**. Figure 24 shows** available data from the line relevant for this scenario, which are stored in persistency databases fed by the FIWARE components mentioned above (see Table 9)

As an example, with reference to Figure 24, if a part has entered a WorkStation, the corresponding sensor labelled xBG5 is triggered and Boolean OPC UA variable ‘xBG5’ stored in the MES OPC UA server address space of the WorkStation is set to TRUE. By means of the FIWARE components chain (OPC UA agent, Orion Context Broker and Cygnus connector), in a persistency database a corresponding record ‘StationEntryxBG5’ is set to TRUE, identified by WorkStation number, timestamp, etc.

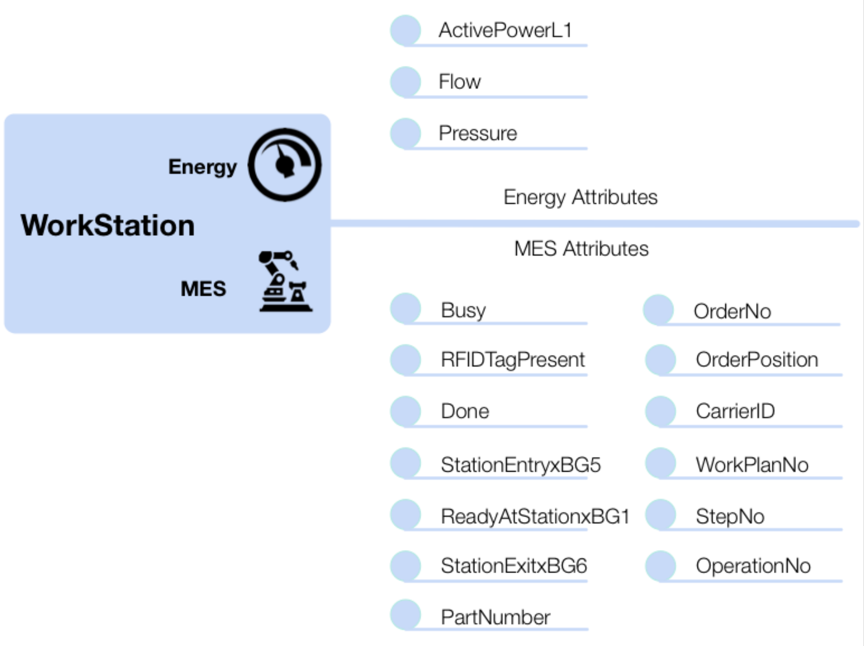

Figure 24 – POLIMI WorkStation Data

The same way, with reference to Figure 24 again, concerning the Energy OPC UA server data, record tables in the persistency database store context data about power consumption of WorkStations (ActivePowerL1, [W]), compressed air flow (Flow, [l/sec]) and compressed air pressure (Pressure, [atm]).

7.4 Architecture

MIDIH Architecture, see Figure 25, manages every server (both energy and MES) as a Device, allowing to add new servers on the fly, enabling new workstations to the FIWARE ecosystem in order to show data in the dashboard and enact autonomous energy control on the stations. On the southbound side, the FIWARE architecture based on OPC UA agent, acting as a context provider, feeds the ORION Context broker (OCB). OCB is able to manage context information: persists last observation about context data, handles subscriptions in order to notify context consumers about changes. Cygnus acts as a context consumer, getting notifications from OCB (previously subscribed) and, with a custom sink, writes context data on a Postgres database using custom tables. This way a persistency database is created, that will be the basis for both visualization and further processing with data mining, as an example in the northbound side, with node-red energy management application and Knowage visualization cockpit.

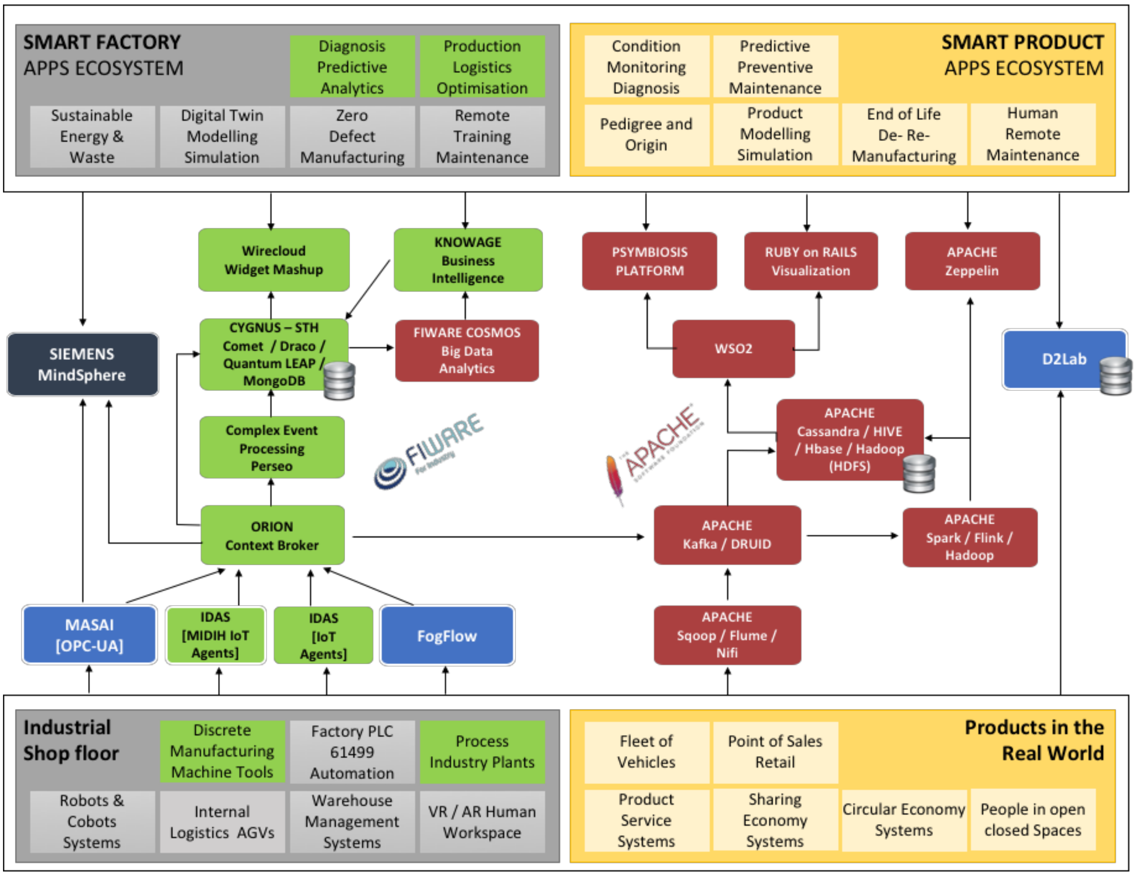

Figure 25 – POLIMI Smart Factory Scenario Architecture

8 Conclusions and future outlook to D4.6

Deliverable D4.5 provides complete information about the different steps carried out by the industrial experiments in order to deal with the adoption and integration process of the MIDIH Open platform. The process used has been characterized by an agile approach, starting from the identification of the functionalities to cover the main specific requirements, then instantiating a customised MIDIH Open Platform, and finally having the setup and configuration in order to complete the first integration process to allow the final solution adopted to operate with real data provided by the experiments. The process has been repeated several times in order to enrich the validation scenario, as well as the integrated components (mainly in terms of background assets integrated as part of the MIDIH Open Platform).

The foreground assets have been experimented by using it during their own development (and evolution cycles) as part of the activities carried on in T4.2, T4.3 and T4.4, and in close cooperation with the endeavour in WP5 (a close collaboration among leading partners in both WPs has been setup in order to drive the development and experimental activities).

For the next iteration (D4.6), further integration activities will be carried on in order to enrich the MIDIH Open Platform with the several foreground components, not yet mature enough to be part of the current deliverable, as well as integrating further BG/FG components adopted in all internal and external (e.g. via the Open Call mechanism) experiment. The knowledge and experience gathered by the Consortium on dealing with such a big set of BG/FG assets, often overlapping in terms of functionalities, will guarantee a successful second iteration with the objective focused more on the improvement of the overall solution and its enrichment with new functionalities provided by the more widely adoption of the MIDIH Open Platform in all the experiments architectures. Improvement, testing and validation cycles will provide a final sound solution for demonstrating the usefulness of the MIDIH solution in the different manufacturing sectors.

List of Acronyms and Abbreviations

ID	Comments
AGV	Automated Guided Vehicle
BG	Background
CEP	Complex Event Processing
CMM	Coordinate Measuring Machine
CNC	Computer Numerical Control
CPS	Cyber Physical System
CSV	Comma Separated Values
DaR	Data at Rest
DF	Didactic Factory
DiM	Data in Motion
FG	Foreground
GE	Generic Enabler
IT	Information Technology
IOT	Internet of Things
MES	Manufacturing Execution System
NGSI	Next generation Service Interface
OCB	Orion Context Broker
OEM	Original Equipment Manufacturer
OT	Operational Technology
PLC	Programmable Logic Controller
ZDM	Zero Defect Manufacturing