16

The EFPF Approach to Manufacturing Applications Across Edge-cloud Architectures

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Abstract

Manufacturing as a Service (MaaS) refers to a set of tools and processes that can assist the shared use of networked production facilities. In the core of this paradigm is a vision where manufacturing environments shall profit from an online set of tools and services that can be tailored to the requirements coming from the different manufacturers, thus reaching a higher degree of flexibility and an increase in production efficiency.

In the context of MaaS, the **Horizon 2020 European Connected Factory Platform for Agile Manufacturing (EFPF)** provides an operational instantiation of a large-scale MaaS across Europe, integrating a diverse set of services such as data analytics, factory connectors, and an interoperable Data Spine to proportionate a high level of automation across different shop-floors.

This chapter explains the EFPF MaaS concept, going over its architectural design, and giving insight into how developers and SMEs can profit from the EFPF open-source SDK to generate new products, and how these products can be integrated into the EFPF broad marketplace. The chapter gives insight also to the different pilots developed in the project, explaining challenges faced, and proposed solutions.

Keywords: MaaS, machine learning, IIoT, federated platform, SDK.

16.1 Introduction

In Europe, manufacturing is one of the key pillars of economical and societal development. While usually perceived to be solely limited to production, manufacturing businesses cross different areas and sectors, from agriculture, automotive, and construction, currently directly providing support for 32 million jobs in Europe[1]. While it shows a tremendous growth potential, manufacturing in Europe has seen a series of challenges, ranging from a shift in demand from goods to services; an increasing competition of emerging markets; lack of skills in different sectors, to comply with a technology-driven approach to manufacturing, required to make it grow to a sustainable level.

A key aspect to allow manufacturing to grow is to provide **Small and Medium Enterprises (SMEs)** with innovative tooling, to foment the development of innovative assets and services with a short time-to-market and to assist SMEs with broad dissemination coverage for the services developed. This aspect can be further developed, if SMEs can cooperate with research institutions, as this can assist in better understanding the novel directions to take.

Manufacturing as a Service (MaaS) therefore plays a key role in the future of manufacturing in Europe, in particular considering the development of SMEs. While there are multiple approaches to MaaS platforms, the key shared aspects relate with the capability to easily allow for new products to be

[1] https://www.iwkoeln.de/fileadmin/user_upload/Studien/IW-Studien/PDF/Studien_Manufacturing-in-Europe.pdf

generated and applied; to reach a high capability of customization to customer requests; and to ensure an adequate adaptation and integration of different tooling that can better support process and product efficiency. Backed up by edge- and cloud-based services, MaaS is currently reaching a mature stage, allowing for a true distributed manufacturing value-chain based on different sets of tools.

In this context, the current trends point to a combination of novel approaches, such as edge−cloud architectures [1], [2]; **Artificial Intelligence (AI)/Machine Learning (ML)**; semantic technologies; and **Industrial IoT (IIoT)** to sustain a MaaS distributed edge−cloud vision.

This chapter addresses the MaaS paradigm based on the **European connected factory platform for agile manufacturing (EFPF)**[2] concept and learnings, which integrate over 30 partners across the whole manufacturing value-chain (users, technology providers, consultants, and research institutes) from 11 European countries.

The key contributions of this chapter are:

- A presentation of an active MaaS concept, the EFPF architecture based on the implementation of advanced interoperability concept (Data Spine [3]) through innovative technologies.
- An overview of the EFPF SDK, which can be used by SMEs to compose and develop innovative applications that profit from the EFPF services and from the highly interoperable EFPF Data Spine.
- An overview of EFPF pilots deployed across Europe, describing challenges and solutions thereof.

16.2 Related Work

The European vision on Industry 4.0, the fourth industrial revolution, addresses the need to integrate a high degree of smart automation, where not just technology processes but also societal patterns are to be supported. Several related work has therefore been focusing on addressing the interoperability challenge in flexible, smart manufacturing. For instance, Datta et al. propose a secure and interoperable platform for lot-size-one manufacturing [4]. This platform is based on the EFPF collaboration tool, showing benefits in terms of interconnection of entities focusing on lot-size-one production.

Traditionally, the fastest step toward complete and integrated interoperable digitization is to rely on a cloud-based approach, as it provides more

[2] https://www.efpf.org/

flexibility in terms of product development, scaling, and product dissemination [5]. Cost-wise, cloud-based services become cheaper than investing on dedicated hardware. The use of cloud-based services is usually done based on an integrative perspective, where it is feasible to consider marketplace platforms to test and to try new suppliers, or eventually new customers based on a low-cost approach. This implies the development of highly interoperable and secure platforms, which on its turn require a vast support of different connectors, at different layers of the OSI stack [6].

The MaaS approach goes beyond cloud manufacturing platforms, in the sense that it addresses a collaborative, decentralized perspective integrating IIoT to boost new levels of process efficiency and productivity; sharing or community-oriented business models; and open-source software [7], [8]. Furthermore, a stronger involvement of all stakeholders, including the customer, in the overall manufacturing wholesale value-chain, is supported in the MaaS vision, by aiming at a higher degree of customization that is customer-driven [9]. This requires, as explained before, to integrate intelligence across the whole value-chain of manufacturing (across edge-cloud) and providing a distributed abstraction approach that can sustain the integration of the different manufacturing stakeholders, since the creation of materials, until the delivery of customized products on the market.

In this context, the work described in this chapter focuses on the initial steps that have been taken in the context of the European H2020 project EFPF, to provide an operational instantiation of a MaaS approach.

16.3 The EFPF Architecture

EFPF is a federated smart factory ecosystem that enables the federation of digital manufacturing platforms and interlinks different stakeholders of the digital manufacturing domain. The EFPF ecosystem enables users to utilize advanced interoperability solutions, implement innovative technologies, experiment with disruptive approaches, and develop custom solutions to maximize connectivity, interoperability, and efficiency across the supply chains.

16.3.1 The EFPF ecosystem as a federation of digital manufacturing platforms

The key components underpinning the EFPF federated platform ecosystem is illustrated in Figure 16.1. The EFPF ecosystem is formed by connecting a number of digital manufacturing platforms that provide ready to use

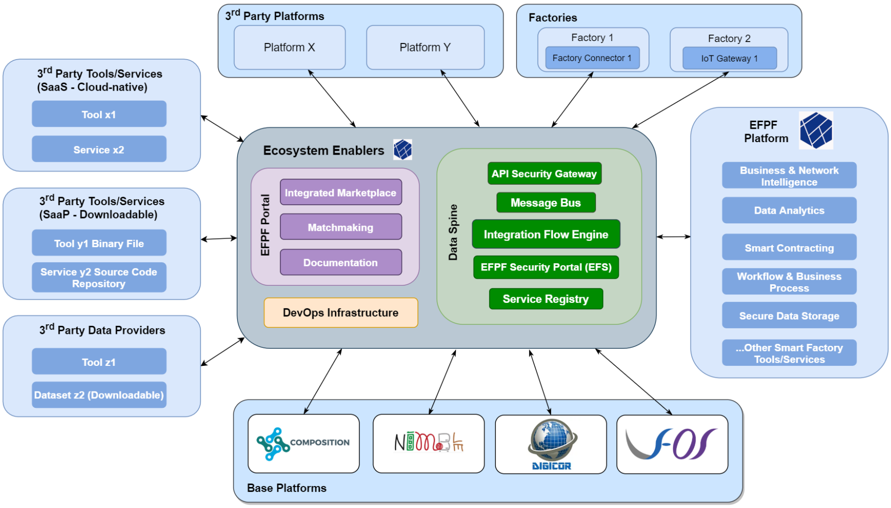

Figure 16.1 High-level architecture of the EFPF ecosystem.

and reusable functionalities. A set of central components called "ecosystem enablers" provide the core functionality that is needed to federate these platforms and enable interoperation among them. This ensures seamless access to the platforms' resources such as tools, services, and data, thereby enabling reusability and sustainability. The ecosystem enablers together with the tools and services of the connected platforms provide the necessary techniques and technologies to support the adoption and development of advanced manufacturing applications.

Some of the key components in the EFPF federated platform ecosystem include:

- **Data Spine [3]:** Corresponds to the core of the EFPF ecosystem that enables interconnection and interoperability. The Data Spine provides services such as single sign on; service registration and discovery; message brokering; and dataflow management and service composition. Being the interoperability backbone of the EFPF platform, one of the Data Spine's focuses is to bridge the interoperability gaps at the levels of identity providers, data models, protocols, and processes between the tools that it interconnects. The Data Spine supports both synchronous request-response as well as **asynchronous publish/subscribe (Pub/Sub)** communication patterns. The Data Spine's architecture and capabilities are explained further in the next section.

- **EFPF Portal**[3] [4]**:** Acts as the single point of entry for the EFPF ecosystem. It allows the users to access connected tools, services, platforms, and marketplaces through a unified **graphical user interface (GUI)**. The GUIs of many tools and services in the EFPF ecosystem are integrated with the EFPF portal and can be accessed directly through the portal.
- **Integrated marketplace** [4]**:** Provides an extensible framework to integrate multiple marketplaces, allowing users to access distributed offerings (from multiple marketplaces) through a unified interface. Moreover, the integrated marketplace framework consists of a component called "accountancy service" that tracks the user journeys from EFPF ecosystem to the interlinked marketplace(s), while supporting the sales-commission-based business models.
- **Matchmaking service:** Provides a federated search functionality that facilitates EFPF users to find the best suited suppliers from across different platforms and enables them to transact with them efficiently and effectively. Once a match of suitable partners is found, the matchmaking service enables users to form teams or consortia, to be able to jointly address specific business opportunities, and transact with them efficiently and effectively.
- **Factory connectors and IoT gateways**: Correspond to communication connectors deployed at the edge (e.g., MQTT Sparkplug connector) that collect data from the sensors and make it available to the cloud-native services such as the Data Spine. Some of the IoT gateways also consist of a middleware that provides some form of data processing functionalities, e.g., matchmaking between IoT data sources and services.
- **EFPF platform**: Provides unified access and interfaces to distributed smart factory tools and services. Examples of such tools and services include data analytics, predictive maintenance, track and trace, process design and execution, etc.
- **Base platforms**: Correspond to the four digital manufacturing platforms from the European Factories-of-Future (FoF-11-2016) cluster focused on supply chains and logistics, namely, COMPOSITION[4], DIGICOR[5], NIMBLE[6], and vf-OS[7]. The EFPF ecosystem is created by initially

[3] https://www.efpf.org/
[4] https://www.composition-project.eu/
[5] https://www.digicor-project.eu/
[6] https://www.nimble-project.org/
[7] https://www.vf-os.eu/

interlinking these base platforms. These platforms provide functionality that is complementary to each other with minimum overlap, and, hence, by interlinking them, the EFPF ecosystem is able to offer a comprehensive set of business functions.

- **Third-party platforms**: Correspond to the digital manufacturing platforms interlinked with the EFPF ecosystem that are provided by independent third parties. Each platform offers a range of tools and services that can be used by the users in the federation.
- **Third-party tools, services, and data:** Correspond to the individual tools, services, data APIs, etc., provided by independent third parties that do not belong to an existing platform.**Interoperable Data Spine:**

Figure 16.2 illustrates the EFPF Data Spine [3] as the central entity that enables the creation of the EFPF ecosystem by interlinking various platforms and enabling communication among them. The Data Spine follows a federation approach to interoperability, where the interoperability between a pair of services is established "on-demand," i.e., when required by a use case. There is no common data model or API imposed at the ecosystem level. This enables the creation of a modular, flexible, scalable, and extensible ecosystem.

The Data Spine consists of the following components that bridge the interoperability gaps among platform services at the levels of identity providers, data models, protocols, and processes and enables the creation of cross-platform applications in an easy and intuitive manner:

- **EFPF security portal (EFS)** federates the identity providers of the connected platforms and enables **single sign-on (SSO)** functionality in the ecosystem.
- **Integration flow engine (IFE)** provides a low-code development environment that can be used to create composite applications in the form of dataflows or "integration flows." The IFE provides a drag-and-drop style visual interface and built-in reusable components such as protocol connectors and data transformation processors that can be used to bridge the interoperability gaps among services.
- **EFPF message bus** enables asynchronous pub/sub-based communication in the EFPF ecosystem.
- **EFPF service registry** enables the lifecycle management and discovery of the service/API metadata that is needed for finding and consuming the services across the connected platforms.

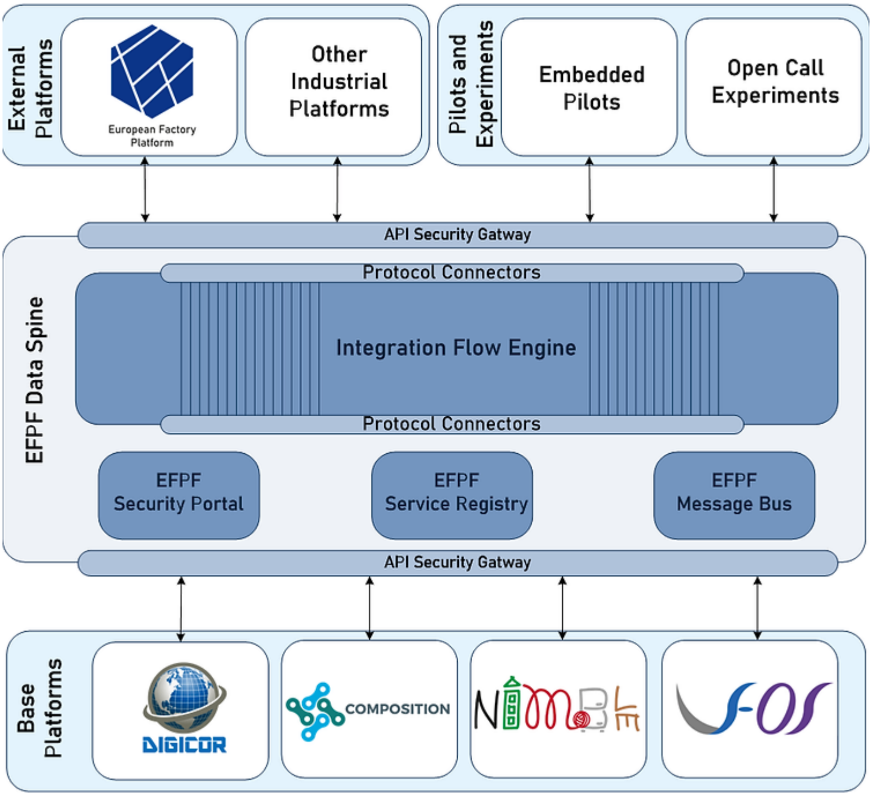

Figure 16.2 High-level architecture of the Data Spine [3].

- **API security gateway** acts as the policy enforcement point for the HTTP-based APIs exposed by the integration flows.

The Data Spine is realized through the implementation of several open-source components and the overall solution is made available as a permissive open-source solution for addressing interoperability challenges at diverse levels of the digital infrastructure. Overarching the interoperability features, holistic security, and privacy concepts are implemented to ensure transparent utilization of tools and services, as well as secure data exchange based on HTTP, MQTT, and AMQP protocols in the EFPF ecosystem.

The Data Spine was validated through the establishment of a platform federation that initially interlinked the tools, services, and user communities from the base platforms. Additional validations are carried out by adding external industrial platforms (from EFPF partners) in the federation.

Based on the interconnectivity and interoperability enabled by the Data Spine, the EFPF federation represents a vibrant digital ecosystem that brings together and interconnects the providers and consumers of smart factory tools, services, and interfaces. The tools and services in the EFPF ecosystem cover the complete lifecycle of production and logistic processes that take place in a modern industrial environment. Examples of the tools include, e.g., data gateways, distributed production planning and scheduling, distributed process design, production monitoring, real-time decision support, process optimization, risk management, and blockchain-based trust and message exchange.

16.4 EFPF SDK

The EFPF project aims to provide manufacturing businesses as an essential artifact, which is to have mechanisms to enable them to create their own applications, which can be best suited to the specific needs of the business, so that they do not require specialized companies (tied to EFPF) to make these applications. The objective is to enable the development of applications that can be done by small third parties or even developers from the manufacturing customer. This, on one hand, allows the customers to be less dependent on specialized companies for performing any development that involves EFPF, fostering an environment where the services of EFPF are made available in a centralized way so that they can be configured and applied to small high-value applications. On the other hand, this development environment also allows external third-party software development companies to use it for developing their own applications using the EFPF framework, where these developed applications can then be built and published in the EFPF marketplace, thus fostering a parallel business model that can bring them interesting revenue.

EFPF provides a range of tools included in its SDK[8] to help achieve the above goals. Several **Business Intelligence Applications (BI Apps)** were also developed to demonstrate its benefits to business as well as to highlight the SDK capabilities, which utilize different technologies provided by the EFPF SDK. Examples of these BI Apps are the **Shopfloor Intelligence BI App**, the **Lagrama Predictive Maintenance App**, and the **Spray Booth BI App**, which represent specific use cases that show users what they can achieve by using the SDK.

[8] https://www.efpf.org/sdk

The development environment is very rich, featuring best-of-breed solutions such as an SDK that centralizes the EFPF features and APIs so that they can be accessed, a full web-based IDE (based on Eclipse CHE, a project of the Eclipse foundation) to develop the applications, which is integrated with the SDK and with other EFPF-developed tools such as a Frontend Editor, which provides a simple way to produce the application's look and feel, the integration with WASP's Process Designer, which allows the users to define BPMN flows of the application behavior, and integrating the generating code back in the IDE. Other tools are also integrated such as the EFPF Engagement Hub, a portal that is aimed to promote the connection and interactivity between the developers, fostering open source and collaboration between them, as can be seen in Figure 16.3.

The EFPF SDK is a Javascript wrapper that comprises calls to the EFPF APIs, which then can be integrated in the IDE to make successful calls to the EFPF services as long as they are conformant with the corresponding protocols. The internal scripts have a flow that can be seen in Figure 16.4.

Moving along the SDK framework, the SDK Studio is a full-fledged integrated development environment (IDE), based on one of the most popular development platforms, Eclipse CHE, which allows having all the EFPF development environment in a Web-based platform, as can be seen in Figure 16.5.

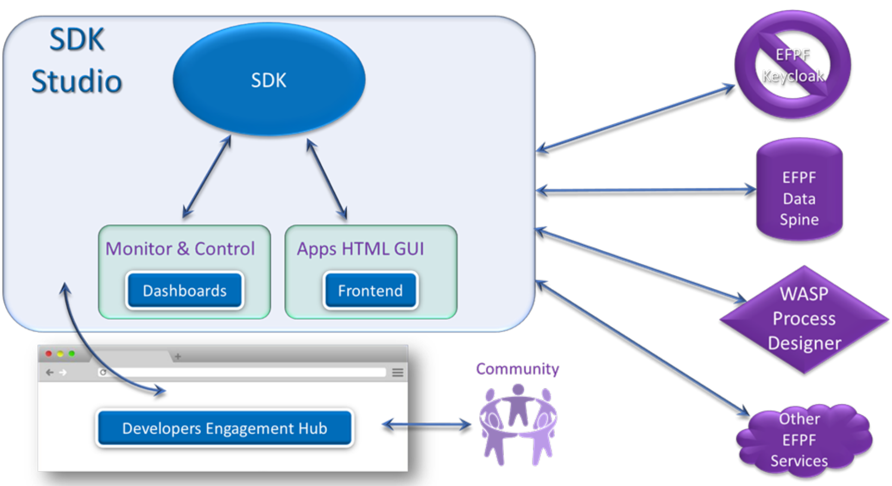

Figure 16.3 EFPF SDK architecture.

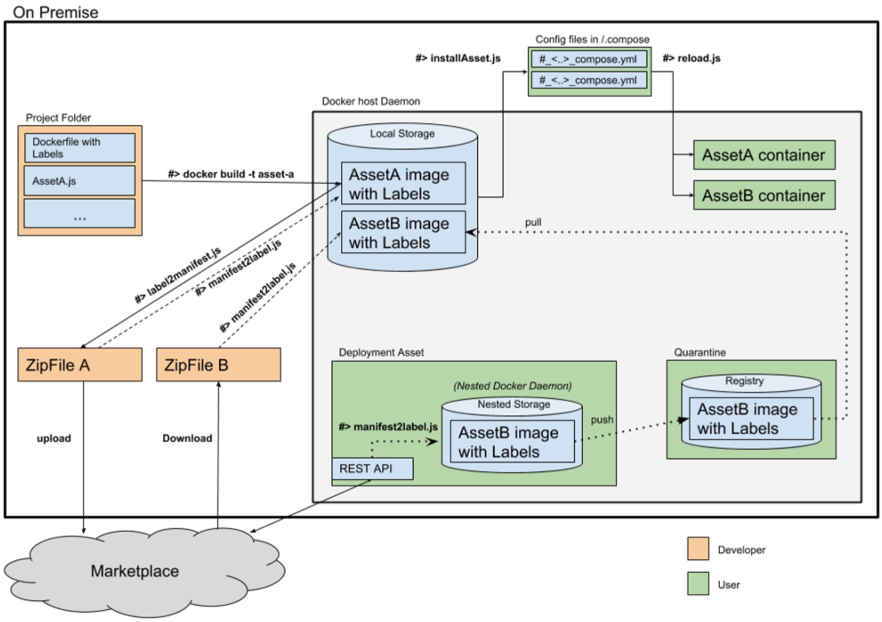

Figure 16.4 EFPF SDK flow.

The SDK Studio is able to develop applications in multiple languages and integrate with different technological stacks, and, of course, includes all the best features of the Eclipse IDE, such as the project development management, extensions, a complete editor with syntax highlighting, and many others. Despite the fact that the project uses Eclipse CHE, numerous customizations needed to be performed to integrate it with the EFPF environment, namely the SDK, the SDK Frontend, EFPF Keycloak, the WASP Process Designer, etc.

To enrich the look and feel of the developed applications, the EFPF SDK Frontend Editor is designed to support the development of custom applications initiated with the EFPF software development kit (SDK) based on the services provided by the EFPF platform. The Frontend's main functionality is to provide developers with a GUI editor for prototyping, to integrate and customize applications built with the SDK. Developers can combine all microservices based on implementations of the SDK integrated functionalities.

The frontend can be accessed by the SDK Studio interface using a plain browser. The solution is based on predefined templates that stand for

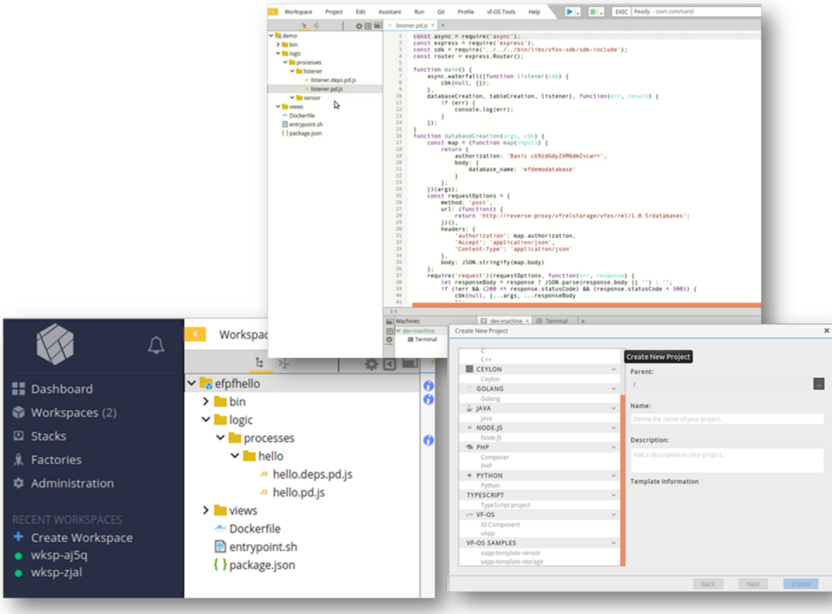

Figure 16.5 EFPF SDK Studio.

themselves (e.g., customized GUI elements) and can bind data sources from EFPF that are orchestrated by Application Development Studio. Application developers have a high degree of flexibility and power by combining the predefined templates and visual elements that can be used inline or nested. This approach results in a multitude of application designs.

The Frontend UI offers additional guidance and allows developers to speed up the process of rapid prototyping. Any design strategy is supported, and a broad range of applications can result from mixing single-page, multi-page, and progressive web application designs. The workflows are highly configurable translating business process models of the use-case scenarios into functional maintainable applications, as illustrated in Figure 16.6.

The main purpose of this web-based frontend is to get information from data-sources (e.g., databases, live sensor data, etc.) and display it in different components (e.g., tables, charts, etc.) in order to provide a better understanding of data, by using various visualizations elements. Each component presents specific data for each requested scenario. The Frontend Editor comprises numerous categories of components, such as horizontal/vertical tabs,

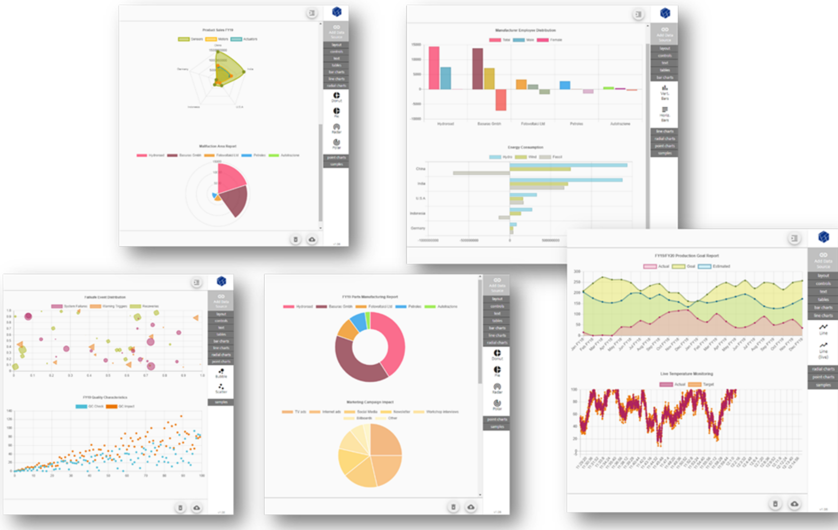

Figure 16.6 Frontend Editor architecture.

headers and footers, images, text labels and boxes, tables, and a variety of charts to display the proposed data.

To complement the set of tools available in the SDK framework, the EFPF Developer Engagement Hub has the purpose to define and develop a suite of tools that fit together and consist of a platform to support developer collaboration between developers, customers, and communities. It is a framework available from one single web-based platform, which not only supports the development of tools, but it also involves the development community, fosters their active contributions in the shape of tests, comments, suggestions, and new requests in the form of change requests in existing applications, e.g., to support other platforms, trends, needs, or extensions. It allows the community to download/reuse/fork the existing code from the Studio (if published) and actually use/test it on new conditions or scenarios. The outcomes of these tests will always come in the form of issues, reports, comments, or suggestions. It also promotes the usage and creation of standards, methodologies, and best practices. This framework includes mechanisms such as wikis, issue trackers, forums, and blogs. Other tools such as configuration management, business continuity, and business process design and management are initially conceived out of scope of this component and relevant to other components such as the SDK Studio.

This tool was developed on top of best-of-breed portal GitLab community edition (CE). Besides having all the standard features of GitLab, numerous developments were added to the base platform, such as allowing multiple level projects (useful for maintaining large projects) with multiple-level issue trackers as well, and the inclusion of a chatting tool for better collaboration between the developers, integration with the SDK Studio and many other features.

The methodology to develop apps using the EFPF SDK is very flexible, which can be shown in the prototypes developed within the scope of the project, where some were developed by developing a backend application, defining the application flow in the EFPF tool WASP Process Designer, then exporting the results of the flow definition to the EFPF SDK, and then defining a frontend for the application; others were performed defining a data source using the EFPF Data Spine AMQP tool and then displaying the resulting information on charts defined.

16.5 EFPF Selected Pilots

EFPF has addressed multiple scenarios in the context of Aerospace manufacturing[9], and out of the developed pilots, this chapter describes three specific pilots for different manufacturing environments, to provide an explanation on the interactions of different components across edge−cloud and on the value-add provided to manufacturing stakeholders via the EFPF tools.

16.5.1 Aerospace manufacturing pilot: environmental monitoring

This pilot aimed at addressing the need for highly customized solutions provided by small but innovative high-tech companies to commercial aircraft vendors. Currently, customer demands for specific features (e.g., novel cabin features) imply a fast answer with OEMs, e.g., Airbus, and high-tech SMEs' close cooperation. For this, it is relevant to be able to provide diversity in terms of production and supply network, which is often done based on a cluster centered on the OEM. EFPF has addressed the design for such needs and proposed implementation aspects for distinctive features, ranging from material parameter monitoring to bidding. The full description of the pilot is available in EFPF Deliverable D9.1 [10]. In this sub-section, two specific

[9] https://www.efpf.org/_files/ugd/26f25a_b498d53f78174f94b3077eaca42d34d3.pdf

technical scenarios are described: automated environmental monitoring and continuous monitoring of production machines.

The main aim of this use case is related to developing an interconnectable service that could capture environmental material data on a traditional shop-floor controlled by a manufacturing entity that does not integrate IT skills.

This use case has been developed together with two aerospace SMEs. The first, **Walter Otto Müller (WOM)**[10], aimed at controlling environmental aspects such as temperature and humidity in their manufacturing area, to ensure consistent quality and environmental conditions required for component tolerances. Aeronautics manufacturing handles strict specifications provided by large OEMs (e.g., Airbus, Boeing, etc.), including fine-grained requirements for the monitoring of varied materials in a component, e.g., paint. The second, **Innovint Aircraft Interior GmbH (IAI)**[11], aimed at monitoring the vacuum in vacuum-forming machines. Key aspects in this use case are related with adequately modeling and interconnecting the sensors that should be selected to perform the monitoring; how these could be digitized to visualize them in the EFPF user interface, and also how to allow for an automated result to be provided based on data extracted from multiple sensors, and a customized service deployment via the EFPF Data Spine.

The overall concept is illustrated in Figure 16.7. Different environmental sensors have been deployed in the shop-floors of WOM and IAI (IoT sensor device). The sensors on the shop-floor communicate (via wireless or wired interconnections) to a local IoT gateway (TSMatch) [12], [13]. The fortiss TSMatch gateway[12] provides a way to automate the detection and selection of sensors on a shop-floor (in the case of this pilot, environmental sensors). The raw data is processed via MQTT; semantic abstractions of the sensors are kept in TSMatch. A TSMatch application provides the user with a monitoring and notification application. This is therefore performed at a local level, within the shop-floor.

TSMatch results are sent via MQTT to the EFPF Data Spine. Therefore, to allow visualization of the data analytics supported by EFPF, the Symphony Factory Connector is used, to provide results (stored in the Data Spine) to the end-user anywhere.

The Symphony platform has been adopted in addition to TSMatch to provide a consistent edge/cloud distributed IIoT management service. To

[10] https://www.wom.gmbh/
[11] https://www.innovint.de/
[12] https://git.fortiss.org/iiot_external/tsmatch

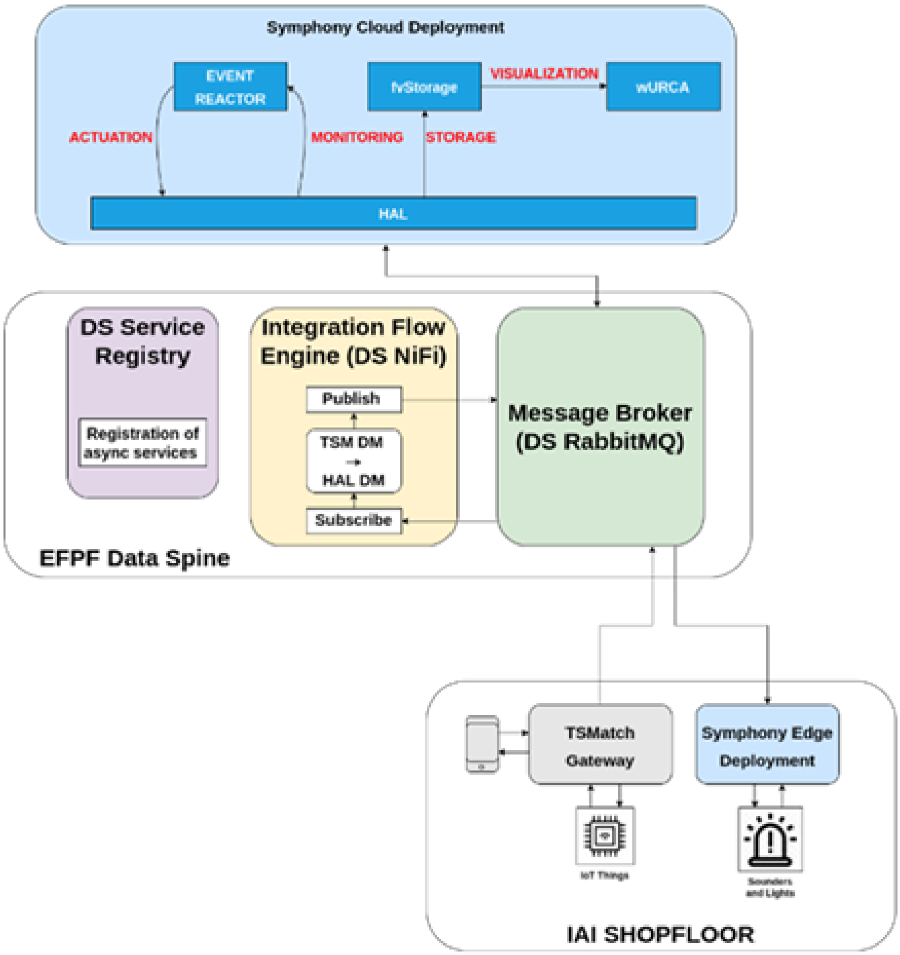

Figure 16.7 Interconnected components on the EFPF environmental monitoring pilot.

this purpose, two instances of Symphony have been deployed as illustrated in Figure 16.7. Sensors and actuators are managed by the edge instance of the platform, together with TSMatch, to provide low-latency functions (such as alerts requiring immediate action); historical storage, data analytics, and time-insensitive event reaction logic are provided by the cloud instance, together with a remote-control panel and visualization dashboard.

It is worth mentioning that the cloud instance of Symphony provides the digital twin models for some of the sensors and actuators in the shop-floor:

Figure 16.8 WOM settings for the control of temperature and humidity in a manufacturing area to ensure consistent quality and environmental conditions required for component tolerances.

the remote control panel reads values and performs actions using a cloud-based model of the devices, which is then synchronized with the actual state of the devices through the EFPF Data Spine, which is responsible for the edge-to-cloud communication and data model interoperability (as described in the previous sections).

The overall pilot requires the integration of sensors, which have been deployed based on embedded hardware as shown in Figures 16.8 and 16.9. The hardware has been installed in accordance with the strict requirements of aeronautics certification by the companies WOM and IAI.

Figure 16.9 shows some of the sensors installed in the pilot environment. The pressure sensor at the vacuum machine has been used to set up an AI/ML pipeline to remotely monitor the operational status of the machine itself and provide a predictive maintenance function. The pressure sensor at the vacuum machine has been used to set up an AI/ML pipeline to remotely monitor the operational status of the machine itself and provide a predictive maintenance function. The ML algorithm has been deployed as a service on the cloud instance of Symphony, again using the Data Spine as a message bus and data model interoperability tool. The continuous training of the model is performed in the cloud and fed by the data streams coming from the shop-floor. A user-friendly interface, built with the Symphony Visualization App, gives the user real-time feedback of the algorithm outputs (number of pump cycles and efficiency of the machine), together with a graphical plot of the sensor time series, as shown in Figures 16.10 and 16.11.

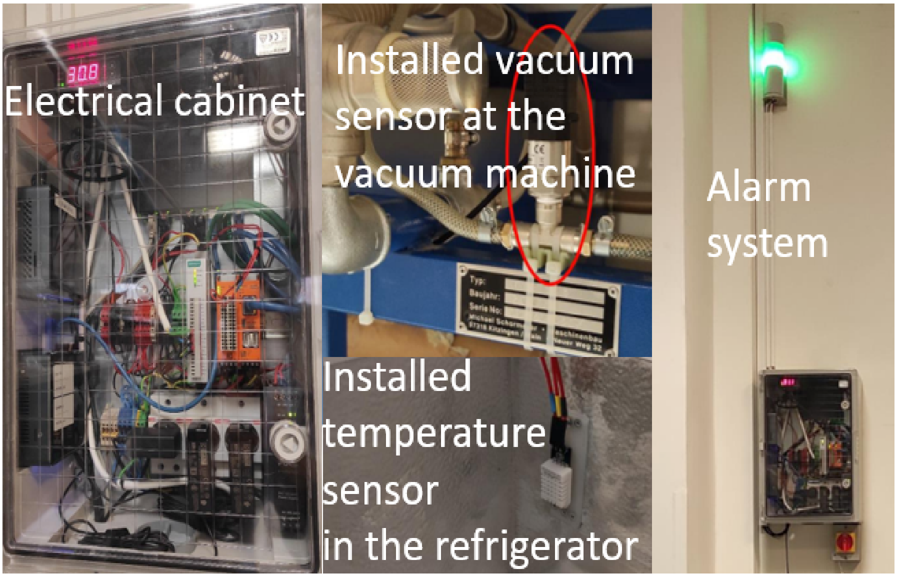

Figure 16.9 IAI settings for the remote monitoring of a vacuum forming machine to enable immediate actions when pressure values fall out of tolerance.

The setup of this pilot has clearly demonstrated the modularity and flexibility of the EFPF platform, which, on one side, allowed the seamless integration of edge-based tools, such as TSMatch, with an IIoT cloud platform, the Nextworks Symphony, providing data model interoperability; on the other side, it enabled edge−cloud communication between the two instances of Symphony, effectively decoupling low-level hardware interfacing, semantic data exchange, and high-level services provision.

The pilot further demonstrated how easily an effective solution can be deployed and applied to real-world scenarios, when the right tools and technologies are available.

16.5.2 Furniture manufacturing pilot: factory connectivity

The EFPF furniture manufacturing pilot[13] is represented by LAGRAMA as a furniture manufacturer SME based in Vinaròs, Spain, producing youth rooms, home offices, and specific home items such as lounges and wardrobes. Today's market requires permanent innovation in product development due

[13] https://www.efpf.org/_files/ugd/26f25a_753cd1c1db194c39b66c74957520a5f8.pdf

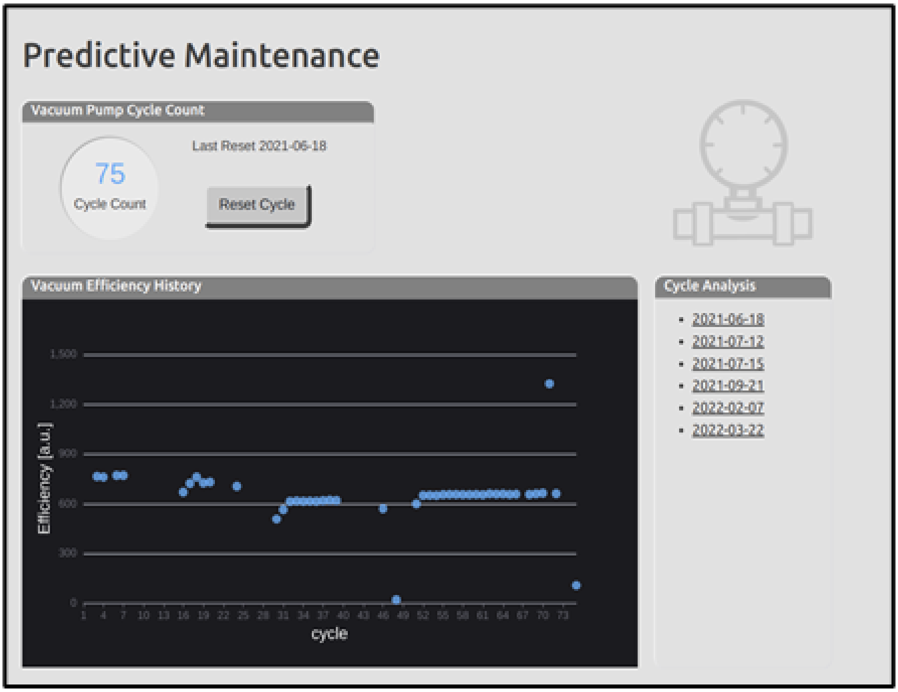

Figure 16.10 The Symphony Visualization App shows the output of the AI/ML Predictive Maintenance App.

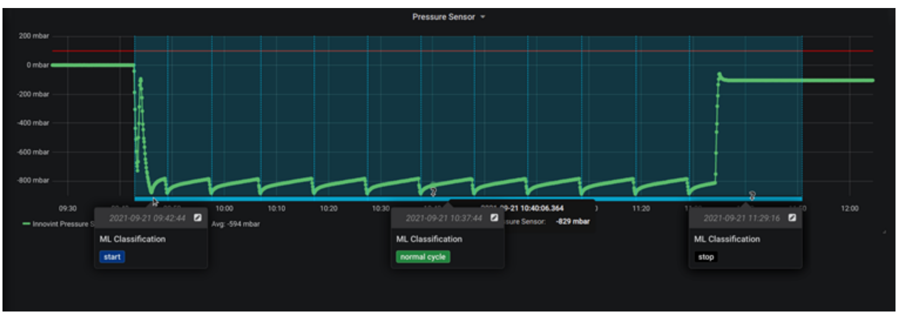

Figure 16.11 Symphony Visualization App displays the behavior of the remote pressure sensor.

to the changeability of the behavior of the new customers. This customization of the products implies dynamic changes in the production workflow where problems detected in machines and processes mean a reduction in the efficiency. The furniture pilot covers various aspects related to the daily production activities, such as machine operation, process definition and execution, monitoring, supply activities, and catalog management. Among all these features, the current description focuses on the behavior of the edge banding machine where wooden pieces are processed between the cutting and the drilling stages. This point is especially relevant; so any unplanned maintenance task comprises the overall capacity of the factory. In this case, the production is based on batches of parts of heterogeneous size and shape. Sensors are placed in selected motors in the machine and connected to an interface board on a factory connector, which monitors the measured values and publishes them to the Data Spine Message Broker. Data collected from the machine includes temperature, pressure, and electrical current. At this point, parameters such as the size of the datasets, the frequency of the data gathering, and the reliability of the prediction algorithms become extremely important [14].

The factory connectivity topic, represented by the edge banding machine operation at LAGRAMA, involves two main targets: the production improvement and the predictive maintenance.

The improvement of the efficiency of the edge banding machine of LAGRAMA to speed up the production reducing the overall time to serve the customer is the target of the production improvement objective. This has been achieved by displaying clear instructions to the operator about how to proceed with the processed pieces. This capability avoids mistakes in the classification process and detects any machine operation error. To this end, the barcode labels attached to the pieces that process the machine are scanned with a camera connected to the Industreweb Factory Connector, which queries an enterprise system to retrieve the information of the piece. Then, the instructions associated with the scanned piece are shown on a display to the worker. Figure 16.12 depicts the position of the elements involved in the solution around the edge banding machine.

The Edge Factory Connector allows the monitoring of the selected machine data by measuring KPIs, revealing opportunities for improvements in productivity and efficiency.

Reliable instructions and complete traceability of the manufactured pieces are provided by this deployment. The collected data is available to be used by other tools focused on other areas such as analytics and machine learning, risk evaluation, and reporting. This production optimization solution demonstrates an improvement in the overall production performance. From

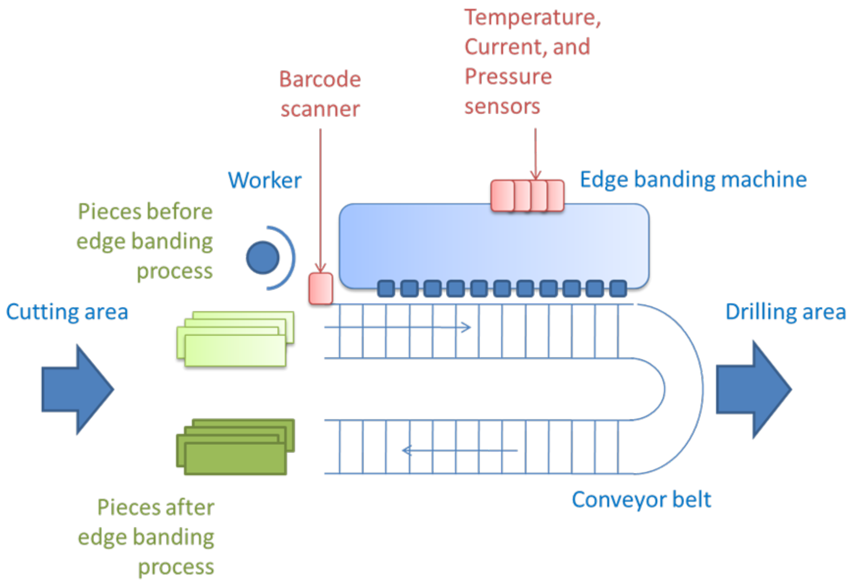

Figure 16.12 Basic layout representing the placement of devices in the machine.

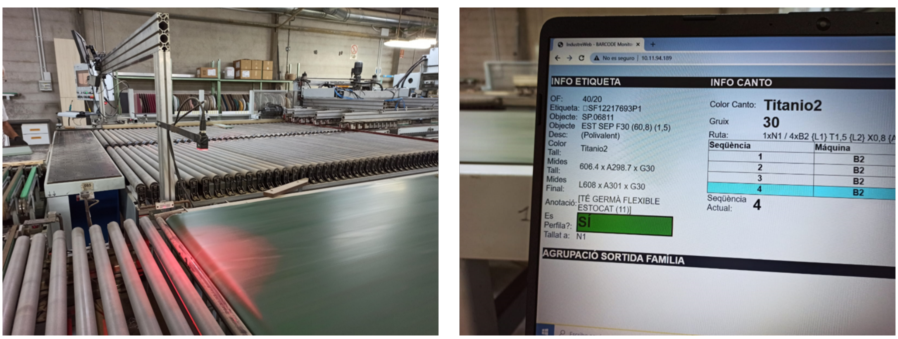

Figure 16.13 Camera for pieces' label scanning and display showing the instructions to the operator.

a business perspective, the vision system provides time saving in the classification process and reduction of errors leading to benefits related to production costs, ensuring the quality level of the products. From the workers' perspective, the system supports the human tasks in the edge banding area, making the operators feel more confident during the handling of pieces. The overall solution for the production optimization increases the productivity of the workers at the edge banding stage of the production line [15].

The predictive maintenance target – which makes use of the sensors deployed in the machine – increases the machine availability by avoiding potential failures that take longer than the regular maintenance activities.

Data analytics applied to the industrial processes and equipment improves the manufacturing by reducing the machine downtimes and improving the quality of the deliveries. The data collected can be then processed by the analytics tools integrated in the component, as follows:

- The **anomaly detection service** is used to detect problems during the machine operation. This makes use of machine learning algorithms that take several months of machine operation to provide reliable information. The system also manages thresholds that represent the acceptable values of machine operation and are used to monitor the behavior of the line.
- The **Risk, Opportunity, Analysis, and Monitoring (ROAM)** transforms the data streams collected from the sensors into metrics. This provides a visualization to get insights about costs, risks, and opportunities. The tool sends warning emails to the users and manages recipes that can be adjusted to the production environment under consideration.
- The **Deep Learning Toolkit (DLT)** is another analytics tool that consumes the sensor data to predict machine failures. The collected data is labeled as right or wrong depending on thresholds and is processed through a neural network for training. The DLT brings real-time prediction of the machine operation on a short-term basis, keeping a confidence score that depends on the training process considering that, the more data is collected and processed, the more insights can be retrieved from the obtained results.
- The **Visual and Data Analytics Tool** provides the anomaly detection functionality with dashboard visualization. The EFPF Data Spine enables the integration with the pilot site and the EFPF Portal used by the end-users to access the different tools. This is depicted in Figure 16.14.

The factory data is sent to the Data Spine through the Factory Connector and is adhered to a raw/custom data model. The API of the Factory Connector together with the specification of this custom data model is registered to the service registry of the Data Spine. The API metadata of the data APIs from the registry are fetched to create iFlows, while the integration flow engine is used to transform the raw data into heterogeneous data models, as expected

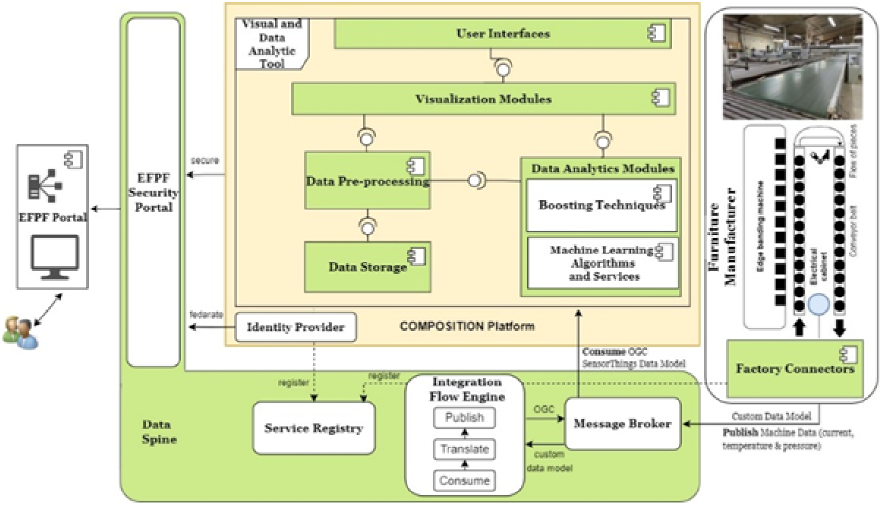

Figure 16.14 Overall architecture of the Visual and Data Analytics Tool and information flow [14].

by the tool. The data is then published to a topic through MQTT; so the tool can retrieve it to provide a graphical view through the visualization modules. The user interface is accessible from the EFPF portal ensuring the security by the use of the SSO capabilities provided by the platform [14].

The monitoring of the operation of the edge banding machine is particularly relevant when manufacturing in batches. Therefore, predictive maintenance enables LAGRAMA as furniture producer to prevent some parts of the machine from being damaged, leading to a decrease in productivity, losses, and bad reputation when deliveries are late. The machine learning model requires considerable time to be profoundly exploited. However, abnormal values can be detected outside the defined ranges according to the selected parameters. Getting warnings about the need for maintenance when any failure risk is detected in the machine operation provides a huge value from the business perspective.

16.5.3 Circular economy pilot – a waste to energy scenario

In this scenario, a circular supply chain loop has been enabled using the EFPF core infrastructure and tools [16]. Three companies participate in this scenario: (a) KLEEMANN, a global manufacturer of lift systems, escalators, moving walks, etc., which acts as a waste producer for this scenario; (b)

ELDIA, the largest waste management and recycling company in northern Greece that acts as waste transporter and pre-processor; and (c) MILOIL, an SME that produces Biodiesel, which acts as a transformer of the pre-processed wastes. The (wood) wastes are turned to energy that is finally used by KLEEMANN for its production processes. The latter closes the waste to energy loop, as illustrated in Figure 16.15.

EFPF provides various tools and services to enable the realization of the aforementioned circular economy scenario through EFPF portal interfaces, as described next.

16.5.3.1 Predictive maintenance services

Effective waste management, which is a core concept of this scenario, starts from waste reduction during production processes. Anomaly detection services have been applied to KLEEMANN's polishing machine in order to reduce defect parts and scrap metal wastes. The Visual Analytics tool from EFPF/CERTH has been used in this case [14]. The real-time anomaly detection is enabled from IoT vibration sensors. The data of sensors are pre-processed at the edge and, after that, are available to the Visual Analytics tool (cloud-based tool) through the EFPF Data Spine.

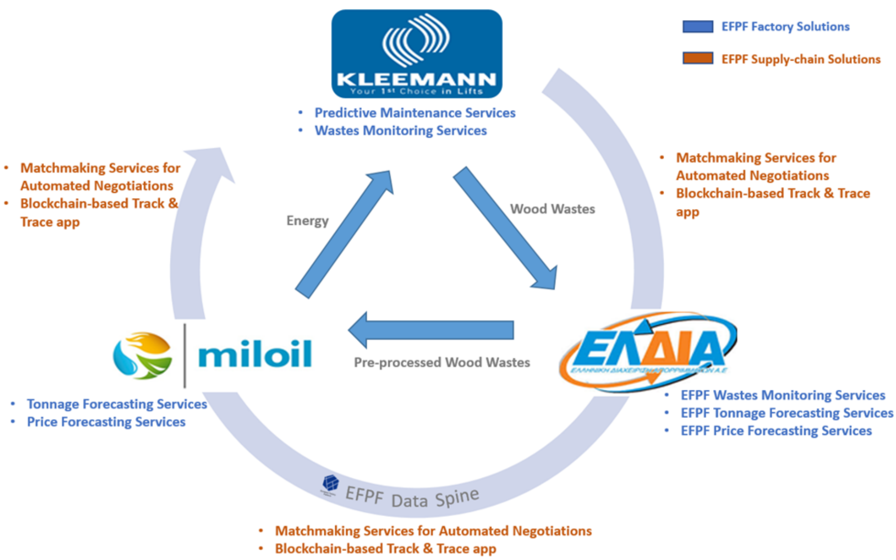

Figure 16.15 EFPF circular economy scenario and EFPF tools' usage.

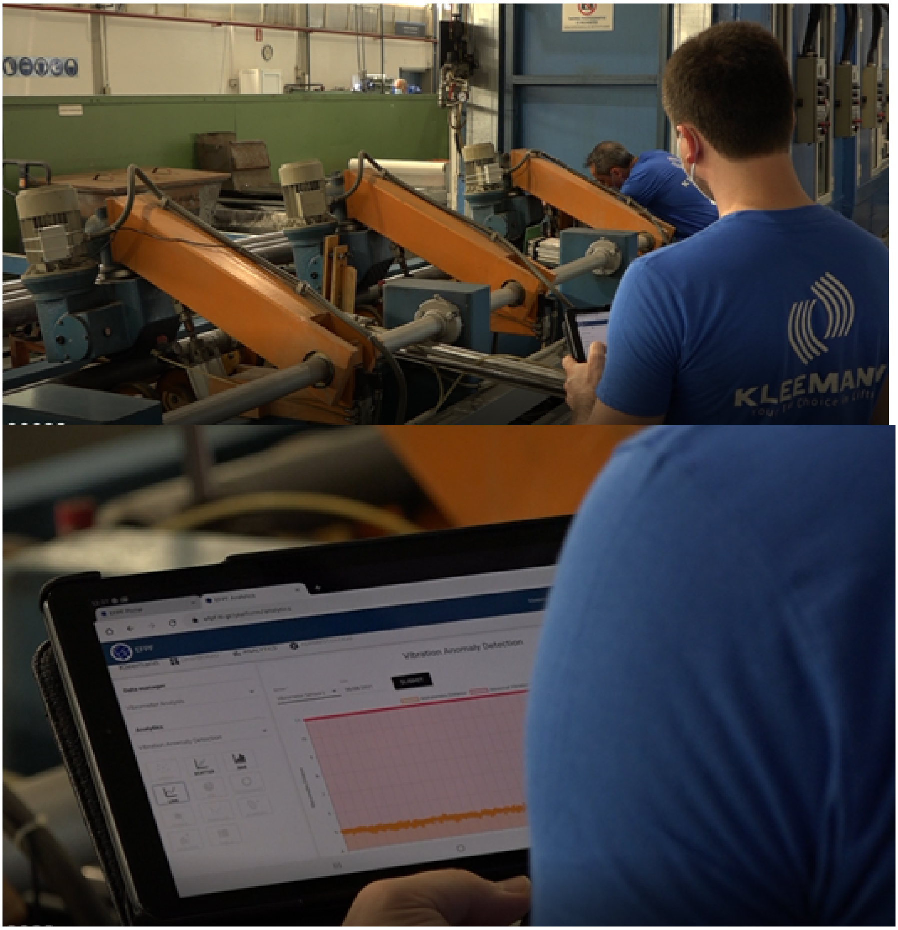

Figure 16.16 Real-time anomaly detection for polishing machine.

16.5.3.2 Fill level sensors – IoT-based monitoring system

IoT fill level sensors have been installed in various bins and open top containers at KLEEMANN premises in order to enable the distance monitoring and the speedy delivery of waste management services. The fill level sensors functioned based on ultrasonic and IR sensors and their connectivity with EFPF ecosystem was enabled by setting up a LoRa network. A monitoring dashboard for various bins' fill level was realized through EFPF Data Spine and Visual Analytics tool interfaces. Furthermore, trend analysis services are provided in order to enable users to estimate the date that a bin should be emptied.

16.5.3.3 Online bidding process

Aiming to automate the negotiations among the participants in the circular supply chain scenario, an online bidding process tool was provided. This tool provides a virtual agent that represents each company. A semantic framework at the backend that is used to model companies, wastes, etc., enables the matchmaking of the agents. Moreover, the matchmaking capabilities of the solution enables the matching of a request with the best available offer based on best score algorithms.

16.5.3.4 Blockchain Track and Trace App

An application based on blockchain and smart contracts, shown in Figure 16.17, enables the secure handshake in wastes being exchanged and ensures the monitoring of the wastes in all the stages of the circular loop. The immutable transactions in the blockchain nodes provide full visibility and transparency in all stages of the scenario. The stage monitoring is available through EFPF web-based interfaces that provide the functionality to waste

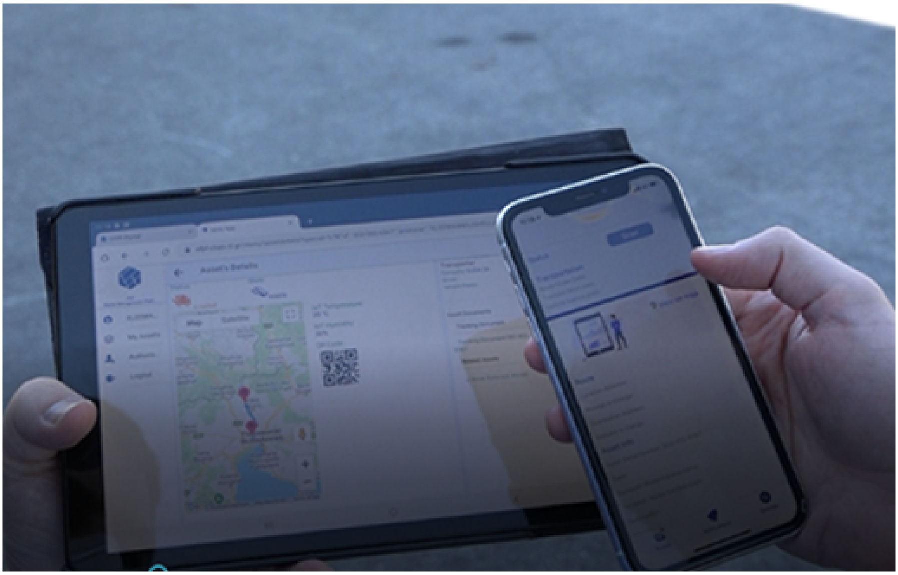

Figure 16.17 Secure handshake based on Blockchain Track and Trace App.

producers to issue a digitally signed certification of its waste management process. The secure handshake among the participants that exchange wastes is enabled by a dedicated mobile app (both Android and iOS devices are supported).

16.5.3.5 Tonnage and price forecasting services

Visual Analytics tool provides services to companies ELDIA and MILOIL regarding the forecasting of future wastes tonnage and future prices of waste materials. The forecasting services are based on machine and deep learning techniques. The services enable the end-users to optimize their planning services and their waste collection processes.

16.6 Summary

This chapter describes the EFPF MaaS, which integrates over 30 partners across the whole manufacturing value-chain (users, technology providers, consultants, and research institutes) from 11 European countries and provides several tools that can assist a flexible and speedier digitization of manufacturing stakeholders. The chapter described the EFPF architecture and its main components, in particular, its SDK. Then, several pilots that have been developed together between research partners and SMEs have been described, explaining how the realization and support for data communication and processing across edge−cloud can be performed.

The developed tools and the learnings thereof have been applied in several pilots and open calls and are available to be experimented via thirds, via the EFPF marketplace.

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