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Ecosystems for Digital Automation Solutions an Overview and the Edge4Industry Approach

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Stakeholders' collaboration is a key to successful Industry 4.0 deployments. The scope of collaboration spans the areas of solution development and deployment, experimentation, training, standardization, and many other activities. To this end, Industry 4.0 vendors and solution providers are creating ecosystems around their project's developments, which allow different stakeholders to collaborate. This chapter reviews some of the most prominent ecosystems for Industrial Internet of Things and Industry 4.0 solutions, including their services and business models. It also introduces the Edge4Industry ecosystem portal, which is a part of the ecosystem building efforts of the H2020 FAR-EDGE project.

15.1 Introduction

The advent of the fourth industrial revolution (Industrie 4.0) is enabling a radical shift in manufacturing operations, including both factory automation operations and supply chain management operations. CPS (Cyber Physical Systems)-based manufacturing facilitates the collection and processing of

large volumes of digital data about manufacturing processes, assets, and operations, towards improving decision-making, driving the efficiency of processes such as production scheduling, quality control, asset management, maintenance, and more. In addition to access to CPS and Industrial Internet of Things (IIoT) platforms that realize these improvements, both manufacturers and providers of industrial automation solutions need a lot of support in testing, validating, and integrating novel applications in the factories. In support of these needs, a wide range of online platform and services have emerged, including:

- Online platforms for IIoT services, notably public cloud IoT services. These enable solution integrators to develop, deploy, and validate innovative services for manufacturers. Moreover, these platforms come with a wide range of support services, which are offered to the communities of developers, solution providers, and manufacturers working around them.
- Testbed platforms for manufacturers and automation solution providers, which enable them to test and validate solutions prior to actual deployment, while supporting them in research and knowledge acquisition.
- Software/middleware library providers. Instead of providing a complete online platform with a pool of related services, these providers focus on the provision of middleware services that could help other organizations to establish the CPS/IIoT infrastructure.

These online platforms and services enable the formation of entire ecosystems around them. A business ecosystem is generally defined as an economic community that is supported by a range of interacting organizations and individuals. This community produces goods, services, and knowledge that provide value to the customers of the ecosystem, who are also considered members of the ecosystem along with suppliers, producers, competitors, and other stakeholders [1].

The development of such ecosystems is a key success factor for the successful adoption of platforms such as the ones listed above. In this context, IIoT and Industry 4.0 projects and initiatives (such as our H2020 FAR-EDGE project that is described in previous chapters), should also undertake similar ecosystem building initiatives. In particular, one of the main objectives of FAR-EDGE is to create an ecosystem of manufacturers, factory operators, IT solutions integrators, and industrial automation solution providers around the project's results, which will facilitate access and sustainable use of the project's assets. The FAR-EDGE ecosystem services will be provided as part of an on-line platform, which will operate like a multi-sided market platform

(MSP), which will bring together supply and demand about digital factory automation services based on the edge-computing paradigm. A wide range of solutions and services will be provided by FAR-EDGE to its ecosystem community, including industrial software and middleware-related services (e.g., automation and analytics solutions), as well as business and technical support services (e.g., support on solutions migration).

This chapter aims at providing insights on the IIoT ecosystems in general and the FAR-EDGE ecosystem in particular. The presentation of the existing ecosystems provides a comprehensive overview of the different types of services that they provide, as well as of their business models. Likewise, the presentation of FAR-EDGE ecosystem portal (www.edge4industry.eu) provides an overview of the solutions, services, and the knowledge base that are provided as part of the project and are made available to the community. The chapter is structured as follows:

- Section 15.2 following the chapter's introduction presents a review of some of the most representative Industry 4.0 and IIoT ecosystems and their services;
- Section 15.3 provides a comparative analysis of the presented ecosystems, including a description of their business models;
- Section 15.4 introduces the Edge4Industry ecosystem portal and describes its structure and services; and
- Section 15.5 is the final and concluding section of the chapter.

15.2 Ecosystem Platforms and Services for Industry 4.0 and the Industrial Internet-of-Things

In the following paragraphs, we describe a representative sample of the IIoT platforms and their ecosystems, as well as a range of other Industry 4.0 platforms and testbeds, including their validation and experimentation services. Each ecosystem platform is presented both in terms of its technical/technological characteristics as well as in terms of its business model.

15.2.1 ThingWorx Foundation (Platform and Ecosystem)

The ThingWorx Foundation (www.thingworx.com) that is now part of PTC (<https://www.ptc.com>) provides a platform for the development and deployment of enterprise-ready, cloud-based IoT solutions. It is an end-to-end solution, which provides access to all elements that comprise an IoT application. Its main value proposition lies in the provision of a simple and seamless way for developing IoT applications, which reduces the development and deployment efforts.

ThingWorx's services are accessible to the developers via a developers' portal and can be classified as follows:

- **Connectivity Services (Make):** Based on the ThingWorx platform, one can connect devices, sensors, and systems, among themselves but also with other systems. Connectivity and information exchange is facilitated in order to reduce the time and effort needed for rapid development of integrated solutions.
- **Data Analytics (Analyze):** The ThingWorx platform provides the means for analyzing the data derived from connected IoT devices.
- **Development/Coding Services (Code):** The platform offers development tools and APIs, which provide development flexibility and increase the overall productivity of solution integrators.

While ThingWorx is a general-purpose platform for IoT solutions, smart manufacturing is explicitly listed as one of the primary markets of application. In this direction, ThingWorx provides a wide range of functionalities for interconnected assets within factories, plants and supply chains with business information systems. Moreover, some of the components of the platform, such as its AR (Augmented Reality) and IoT-based immersion module, are demonstrated as a part of the manufacturing scenarios such as industrial maintenance.

Around the Thingworx platform, the foundation has been building an ecosystem, which is providing a complete set of integrated IoT-specific development tools and capabilities in order to ease the delivery of IoT solutions. The ThingWorx ecosystem comprises the following participants, concepts, structures and associated stakeholders' roles:

- **Partners:** Enterprises are offered the opportunity to join the ThingWorx ecosystem as partners on the basis of a variety of different (partnership) programmes, which cover various needs. In particular, the partner programmes are available for: (i) Enterprises building IoT solutions based on the ThingWorx platform; (ii) Companies that build products that are certified by ThingWorx and made available through the ThingWorx marketplace; (iii) Professional service providers who opt to offer consulting, solution design and technical delivery services based on the ThingWorx IoT platform. These partners are called "services partners" and are provided with cumulative educational attainment; and (iv) Reseller of ThingWorx's based technologies, which participate in the "ThingWorx Channel Advantage" program and can benefit from earning margins for reselling ThingWorx solutions.

- **Marketplace:** The ThingWorx Marketplace provides access to everything needed in order to build and run ThingWorx-based IoT applications, including extensions, apps, and partners that can facilitate the development of IoT solutions based on the platform. The marketplace component of the ecosystem is therefore a means for the extensibility of the ecosystem.
- **Academic Programme:** An academic programme is also offered to students, researchers, makers, universities, and trainers. It is an IoT education programme, which is built over the platform, leveraging its practical features and content.

15.2.2 Commercial Cloud-Based IIOT Platforms

All major IT and industrial automation vendors are offering cloud-based IIoT services. Likewise, they are also building ecosystems around these platforms or in most cases expanding their existing ecosystems in the IIoT space. A detailed analysis of each of the public IIoT services providers is beyond the scope of this chapter. Nevertheless, we can make a broad ballpark classification of the available services to the following:

- **General purpose public IoT cloud services**, which are typically offered by IT vendors. These include, for example, Microsoft's Azure IoT Suite, IBM's Watson IoT platform, SAP's HAN Cloud platform with IoT support and extensions, Amazon AWS IoT, LogmeIN's Xively platforms, and more. These platforms are not tailored to a specific vertical industry. Rather, they provide scalable and cost-effective cloud infrastructures for IoT, which can be used to develop, deploy, and operate solutions in the different industries.
- **IIoT services for industrial automation**, which are typically offered by industry leaders in industrial automation solutions including SIEMENS, Bosch, and ABB. In several cases, there are partnerships between IIoT vendors and providers of IT (IoT/cloud) infrastructure services as evident in the case of ABB and Microsoft, but also in the fact that Bosch's IoT services run over various digital plumbing platforms such as Amazon's. These partnerships are overall indicative of the distinction of business roles.

The scope of these services includes connectivity services along with the offering of tools for rapid and cost-effective application developments.

Each of the above-listed platforms is associated with an ecosystem of developers, solution providers, and business partners. In most cases, the above-listed vendors act as ecosystem expanders in the IoT/IIoT space, given that they primarily expand the ecosystem of their existing accounts, customers, and business partners in the area of IoT. Access to the IIoT services, including consulting, technical support, training, and hosting, but mainly turn-key solution deployments is provided on a commercial basis with appropriate SLA (Services Level Agreements). Both public cloud services and private cloud services are offered. Public cloud services are charged in pay-per-use modality (e.g., pay-per-use and pay-as-you-go services are offered by Microsoft Azure, Amazon AWS IoT, and Xively).

15.2.3 Testbeds of the Industrial Internet Consortium

The Industrial Internet Consortium (IIC) is an open-membership, international not-for-profit consortium that is leading the establishment of architectural frameworks and overall directions for the Industrial Internet. Its members represent large and small industries, entrepreneurs, academics, and government organizations. The Industrial Internet Consortium is a global, member-supported organization that promotes the accelerated growth of the IIoT by coordinating the ecosystem initiatives to securely connect, control, and integrate assets and the systems of assets with people, processes, and data using common architectures, interoperability, and open standards, in order to deliver transformational business and societal outcomes across industries and public infrastructure.

The IIC scope includes the identification and location of sensor devices, the data exchange between them, control and integration of collections of heterogeneous devices, data extraction, and storage plus data and predictive analytics. The challenge for the IIC is to ensure that these efforts come together into a cohesive whole. The IIC Working Groups coordinate and establish the priorities and enabling technologies of the Industrial Internet in order to accelerate market adoption and drive down the barriers to entry. There are currently 19 Working Groups and teams, broken into seven broad areas, including Business Strategy and Solution Lifecycle, Legal, Liaison, Marketing, Membership, Security, Technology, and Testbeds.

One of the areas of focus of the IIC is the development of Testbeds. A testbed is a controlled experimentation platform that:

- Implements specific use cases and scenarios,
- Produces testable outcomes to confirm that an implementation conforms to expected results,

- Explores untested or existing technologies working together (interoperability testing),
- Generates new (and potentially disruptive) products and services, and
- Generates requirements and priorities for standards organizations supporting the Industrial Internet.

Testbeds are a major focus and activity of the IIC and its members. The Testbed Working Group accelerates the creation of testbeds for the Industrial Internet and serves as the advisory body for testbed proposal activities for members. It is the centralized group which collects testbed ideas from member companies and provides systematic yet flexible guidance for new testbed proposals. Testbeds are where the innovation and opportunities of the Industrial Internet – new technologies, new applications, new products, new services, and new processes – can be initiated, thought through, and rigorously tested to ascertain their usefulness and viability before coming to market.

15.2.4 Factory Automation Testbed and Technical Aspects

One type of Testbed known as Platform as a Service (PaaS) for Factory Automation (FA), is expected to facilitate the integration of the IoT systems to connect the manufacturing sites and head offices for strengthened operations, such as the globalization of supply chains and improved production quality, delivery time, and productivity when responding to sudden changes in markets. The FA testbed provides connectivity between the Factory and Cloud, a data analytics platform, and security resources, in order to ease the FA application development for Application Providers and FA Equipment Vendors. Based on the facilities of the testbed, the Application Providers and FA Equipment Vendors have the opportunity to develop and provide solutions to the manufacturers and factory operators at minimum effort and cost, by engaging in the development of the core logic of each application only, rather in the development of industrial middleware as well. Overall, the Testbed provides the following features to reduce application development process:

- Connectivity between Factory and Cloud where architectures differ;
- APIs specialized in FA, which are re-usable for FA applications: Edge Applications, Cloud Applications, and Domain Applications;

- Security to protect the Factory brown field from the outside network; and
- Integration of data from the Business Systems.

IIC testbeds are privately funded by member companies or publicly funded by government agencies, while Hybrid models involving both public and private funding are also possible.

15.2.5 Industry 4.0 Testbeds

As part of the platform “Industrie 4.0” in Germany, several testbeds have been established at specialist centres within universities and research institutions in Germany. These testbeds enable the testing and validation of complex production and logistics systems under realistic conditions. They are intended to be used by mechanical and plant engineering companies, notably Small and Medium Enterprises (SMEs). The latter are provided with facilities for testing their I4.0 developments in real-life nearly operational conditions, prior to their deployment in actual production environments. The testbeds are also addressed to factory operators wishing to take advantage of CPS manufacturing in a way that reduces barriers and risks.

As already outlined, the Industry 4.0 testbeds is a public sector-supported/funded initiative for evaluating innovative approaches to CPS manufacturing. This initiative is addressed to equipment manufacturers and operators. Along with access to the testbeds infrastructure, members of the Industry 4.0 platform are offered access to a range of advisory and coordination services. A central coordination office at the Federal Ministry of Education and Research (BMBF) provides funding support for testing innovative Industry 4.0 components by SMEs at the various testbeds. As part of the offered advisory services, BMBF provides SMEs with advice about the most appropriate testbeds to be used, while at the same time undertakes the focused dissemination of the results towards specialist communities. In this way, BMBF’s initiatives complement the activities undertaken by the Centres of Excellence (CoE) funded by the Federal Ministry for Economic Affairs and Energy (BMWi). The latter CoEs are primarily destined to support operators of machine and plant equipment.

15.2.5.1 SmartFactory pilot production lines – testbeds

The FAR-EDGE project partner SmartFactory participates in the provision of various testbed services for Industry 4.0, which will herewith be presented as indicative examples. In particular, the SmartFactory provides several

production lines to integrate, customize, test, and demonstrate CPS solutions in a realistic industrial production setup. All of its experimental production lines are designed to be strictly modular and are comprised of devices coming from several different vendors, being identical to those found in most modern industrial plants. The open and modular design facilitates the usage as test-bed for various experiments. Several demonstrators have been built along four main production lines:

15.2.5.2 Industry 4.0 production line

The first test-bed is a multi-vendor, highly modular factory system with “plug n’ play” module extension. The independent modules are thereby fulfilling vendor-independent standards defined by SmartFactory, which are based on the widely accepted communication protocols. This test-bed representing the key concept of “Industry 4.0” has the following features: 1) Service-oriented production line with modular CPS-based field devices, 2) Multi-vendor, highly modular factory system with “plug n’ play” module extension, and 3) Demonstration platform for distributed processes based on communicating component. As shown in Figure 15.1, items 1 to 10 are production modules, while 11 to 15 are infrastructure boxes connecting with 16 to 22 into an integrated IT system.

15.2.5.3 SkaLa (scalable automation with Industry 4.0 technologies)

In today’s market, the customers do not only need products that they can configure individually, but they also desire products that are cost-effective and readily available. Meeting these requirements calls for a flexible and efficient approach to manufacturing. One way to meet these challenges is provided by “SkaLa”, a demonstration unit that offers a scalable automation process.

The mobile demo unit can, if necessary and depending on the situation, be scaled to the automation process. The unit’s scalability is based on

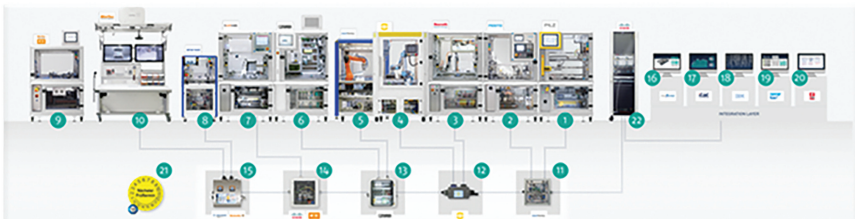


Figure 15.1 SmartFactory’s Industrie 4.0 production line.



Figure 15.2 SkaLa production line.

a fully decentralized, controlled manufacturing process, made possible by cyber-physical systems (CPS). For each work step, independently operating modules are used, which communicate with each other and control the process. The system can be expanded with a robot module via standardized interfaces to add an automated production component. In the manual mode, workers are provided with support in the form of projected recommendations for work steps. For improved flexibility, both order management and service activities are supported via mobile devices.

15.2.5.4 Key finder (The keyfinder production line from SmartFactoryKL)

SmartFactoryKL has presented a unique demonstration plant as the central exhibit of the Forum Industrial IT together with the German Research Center for Artificial Intelligence (DFKI) at the Hannover Messe industrial trade fair in Hanover. On the basis of a complete production line, the relevant aspects of the fourth industrial revolution were exemplified for the first time using innovative information and communication technologies. The modular plant shows the flexible, customized manufacturing of an exemplary product, the components of which (housing cover, housing base and circuit board) are handled, mechanically processed and mounted.

15.2.5.5 SME 4.0 competence center kaiserslautern

The SME 4.0 Competence Center Kaiserslautern is one of the several regional centers of excellence launched by the Federal Ministry for Economics and Technology (BMWi). The aim of this nationwide funding initiative is to highlight the importance of Industry 4.0 for the future of SMEs, to inform SMEs about the great opportunities in this area, and to actively support them with the implementation of projects.

As part of its mission, the SME 4.0 Competence Center Kaiserslautern assists companies from Rhineland-Palatinate and Saarland. The aim is to assist, offer an extensive, up-to-date knowledge base and valuable practical experience in the area of Industry 4.0. Focus, in particular, is on sharing know-how from many years of research and implementation with small and medium enterprises.

The SME 4.0 Competence Center Kaiserslautern consists of four partners, namely Technology Initiative SmartFactoryKL e.V., the German Research Center for Artificial Intelligence GmbH, the Kaiserslautern University of Technology and the Institute for Technology and Work e.V.

15.2.6 EFFRA Innovation Portal

To foster information exchange and collaboration between innovation projects and the EC, the European Factory of the Future Research Association (EFFRA) has created an Innovation Portal, which serves as a single entry point to information about FoF projects and their results. The EFFRA Innovation Portal stimulates clustering, maps projects on the ‘Factories of the Future 2020’ roadmap, and allows for project monitoring and impact measurement. Within the portal, each project profile provides a summary of the project work and information on its consortium.

The portal is currently accessible to EFFRA project members. However, it also contains publicly accessible pages. It is maintained by EFFRA with support by EU projects involved in the association.

15.2.7 FIWARE Project and Foundation

The FIWARE’s Community led by the EU industry and supported by the academic community, has built an open sustainable ecosystem and several implementation-driven software platform standards that could ease the development of new Smart Applications in multiple sectors. Its main goal is to enable an open community of developers including entrepreneurs, application

sponsors and platform providers. FIWARE provides one of the most prominent operational Future Internet platforms in Europe. Its platform provides a rather simple yet powerful set of open public APIs that ease the development of applications in multiple vertical sectors. The implementation of a FIWARE Generic Enabler (GE) becomes a building block of a FIWARE instance. Any implementation of a GE is made up of a set of functions and provides a concrete set of APIs and interoperable interfaces that are in compliance with open specifications published for that GE. The FIWARE project delivers reference implementations for each defined GE, where an abstract specifications layer allows the substitution of any Generic Enabler with alternative or custom made equivalents.

FIWARE's main contribution is the gathering of the best available design patterns, emerging standards and open source components, putting them all to work together through well-defined open interfaces. There is a lot of knowledge embedded, lowering the learning curve and mitigating the risks of bad architecture designs. The scope of the platform is also very wide, covering the whole pipeline of any advanced cloud solution: connectivity to the IoT, processing and analyzing Big data, real-time media, cloud hosting, data management, applications, services, security, etc. But FIWARE does not only accelerate the development of robust and scalable cloud based solutions, it also establishes the basis for an open ecosystem of smart applications. In the FIWARE sense, be SMART means to be Context Aware and to be able to interoperate with other applications and services; and this is where FIWARE excels.

FIWARE has over the years developed an ecosystem of developers, integrators and users of FIWARE technologies, which includes several SMEs. An instrumental role for the establishment and development of the FIWARE ecosystem has been played by the FIWARE Acceleration Programme, which promoted the take up of FIWARE technologies among solution integrators and application developers, with special focus on SMEs and start-ups. Around this programme, the EU has also launched an ambitious campaign where SMEs, start-ups and web entrepreneurs can get a funding support for the development of innovative services and applications using FIWARE technology. This support intends to be continuous and sustainable in the future, engaging accelerators, venture capitalists and businesses who believe in FIWARE.

The FIWARE ecosystem is supported and sustained by the FIWARE Foundation, which is the legal independent body providing shared resources to help achieve the FIWARE mission. The foundation focuses on promoting,

augmenting, protecting, and validating the FIWARE technologies, while at the same time organizing activities and events for the FIWARE community. The latter empower its members (end users, developers, integrators and other stakeholders in the entire ecosystem.

Note that the FIWARE Foundation is open, as anybody can join and contribute to a transparent governance of FIWARE activities. The foundation operates on the basis of the principles of openness, transparency and meritocracy.

15.2.8 ARROWHEAD ARTEMIS JU Project and ARROWHEAD Community

The Arrowhead project implemented a framework for developing service-oriented industrial automation solutions in five business domains, namely: production (process and manufacturing), smart buildings and infrastructures, electro mobility, energy production and virtual markets of energy. The project's framework ensures the interoperability between different systems and approaches for implementing Service-Oriented Architecture (SOA)-based solutions in the target industries. To this end, Arrowhead provides and enables the following:

- A system to make its services known to service consumers;
- A system for service consumers to discover the services that they want/need to consume;
- Authorized use of services provided by some service provider to a service consumer; and
- Orchestration of systems, including control of the provided service instances that a system shall consume.

The Arrowhead Framework contains common solutions for the core functionality in the area of Information Infrastructure, Systems Management, and Information Assurance as well as the specification for the application services carrying information vital for the process being automated.

Arrowhead is a recently concluded project, which offers a range of industrial middleware solutions to developers and deployers of industrial automation systems. It also provides resources that facilitate developers to develop, deploy, maintain, and manage Arrowhead compliant systems, including technical resources that boost a common understanding of how the Services, Systems, and System-of-Systems are defined and described. The latter resources include design patterns, documentation templates, and

guidelines that aim at helping systems, newly developed or legacy, to conform to the Arrowhead Framework specifications.

Arrowhead has managed to establish around its framework an ecosystem of solution developers, along with end-users for the target industry areas, as well as associated use cases where the framework has been deployed and used.

15.3 Consolidated Analysis of Ecosystems – Multi-sided Platforms Specifications

15.3.1 Consolidated Analysis

In the following paragraphs, we perform a consolidation of the services and business models which have been outlined in the previous section. The following table provides a high-level taxonomy of the services that are presented in the following paragraphs, including the different ecosystems that offer them.

The business and sustainability models of the various ecosystems are essential for their longer-term viability. The main monetization strategies are as follows:

- **Revenues from sales or use of services on a commercial basis (licensed or pay-as-you-go models):** The ecosystems of the large vendors provide commercial services for end-users and providers of the IIoT

Ecosystem /Services	Hosting & Support of IIoT solutions	Solution Design and Integration Services	Training & Education	Advisory & Consulting Services	Solution Experimentation and Validation Services	Standardization Services	Access to software/middle ware libraries	Information and News Updates
ThingWorx and IIoT/cloud platforms	X	X	X	X			X	
IIC Testbeds			X		X			
I4.0 Testbeds			X		X			
EFFRA Innovation Portal				X				X
FIWARE							X	
Standards Bodies						X		

Figure 15.3 Overview of Services offered by various IIoT/Industry 4.0 ecosystems and communities.

solutions. The services are provided based on either licensed models or pay-as-you-go models. The latter is the primary monetization modality for public cloud services, yet they are considered as part of the private cloud services that vendors build for manufacturers.

- **Sales of complementary services:** Complementary services (notably training, education, advisory, and consulting services) are also provided on a commercial basis as part of the presented ecosystems). These services are offered separately or bundled with IIoT solution development, hosting, and deployment services.
- **Public funding support services:** Several of the services (such as some of the testbed services) are financed by public funding (including projects) or even by the combination of private and public funding sources.
- **Membership fees:** In foundations (such as FIWARE) and associations (such as EFFRA) there income is also generated from membership fees.

There are different types of legal entities that support the above-listed monetization models. These include commercial entities, associations and non-profit foundations.

Based on the analysis of the above ecosystem platforms and services, it is important to highlight some important considerations for anyone attempting a similar ecosystem building initiative:

- **Critical Mass:** The formation of a critical mass of stakeholders is a prerequisite for establishing an ecosystem.
- **Viability of Service Offerings:** In addition to creating a range of services, ecosystems should ensure that the offered services are viable.
- **Business Models and Sustainability of Service Offerings:** A viable business model should also support the sustainability of the ecosystem services.

15.3.2 Multi-sided Platforms

It should be also outlined that the reviewed platforms provide services for both demand-side stakeholders (i.e. users of IIoT/Industry 4.0 services) and the supply-side ones, i.e. vendors and solution providers. As such, these platforms offer a range of base features such as a catalogue of services, services for registering and managing participants, authentication and authorization (as a prerequisite for accessing these services) and more. A basic set of such functionalities has been listed in the following figure (Figure 15.4) and illustrated in the literature (e.g., [2–4]).

MSP Platform Functionality	Short Description
Registering Participants & Business Entities	Registration of participants to the ecosystem (i.e. manufacturers, factory operators and factory automation solution providers)
Publishing service offerings	Publication and presentation of the ecosystem services (notably the services listed in the following subsection)
Search and discovery of service offerings	Search engine for discovering available services based on appropriate metadata for the services descriptions
Review and rating of service offerings	Tools for rating service offerings from the end-users / participants viewpoints
Provision of recommendations	Context aware proposition of relative service offerings
Pricing and Payments Support	Services for pricing services and supporting payment modalities
Manage and tracking registered services	Access to the status of subscriptions and services
Authentication and Authorization	Ensuring authenticated and authorized access to the various services
Localization	Support for an international environment through appropriate localization of the services including currency and language support

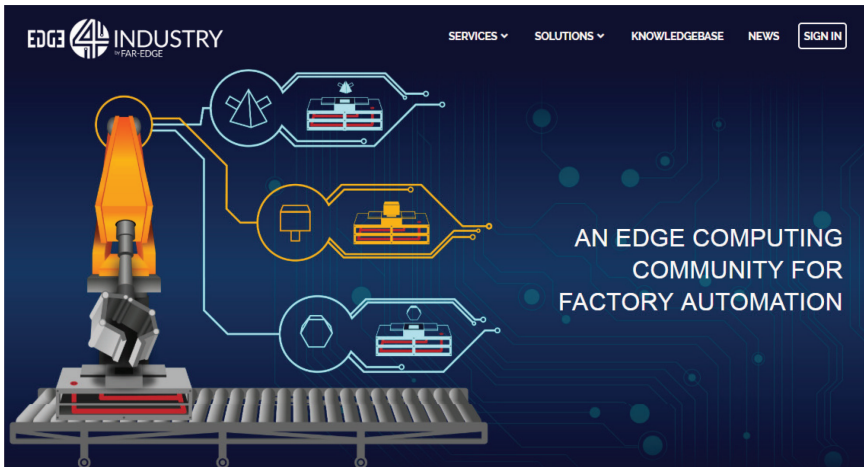
Figure 15.4 Baseline functionalities of a Multi-sided market platform.

15.4 The Edge4Industry Ecosystem Portal

The FAR-EDGE Ecosystem portal (publicly accessible at www.edge4industry.eu) is a vertical IIoT ecosystem on factory automation, focusing on FoF/I4.0 applications for manufacturers, with the objective to ensure EU's leadership in the manufacturing sector. It presents all the research work and innovation developed in the FAR-EDGE project and aims to advance the competitiveness of the participants, manufacturers, and providers of the industrial automation solutions. Figure 15.5 presents the home page of the ecosystem portal.

As the goal for the Edge4Industry Ecosystem portal is to remain active, functional, and independent beyond the FAR-EDGE project, having broader adoption aspirations, a new unique brand and domain name has been specified to support the ecosystem evolution and branding beyond the duration of the FAR-EDGE project. Figure 15.6 provides a mind-map with the structure of the portal that includes the FAR-EDGE services and solutions, a knowledge-base, a blog, and a registration/sign-in section. These pages can be accessed through the main menu and contain the following information:

- **Services:** Provides all relevant information about each FAR-EDGE service.
- **Solutions:** Provides information and access to the FAR-EDGE solutions.



MISSION STATEMENT

FAR-EDGE provides a blueprint solution for industrial automation based on edge computing, which emphasizes the use of blockchain technologies to synchronize digital information models with the actual status of the factory.

Industry 4.0 is the integration of Information Technology and Operational Technology into what is sometimes called the “smart and connected factory”. The goal is having more efficient and flexible production systems on the one side, enabling new business models on the other. This fourth industrial revolution was started by the convergence, over time, of several innovative concepts like IoT, Cloud Computing, Cognitive Computing and Digital Simulation.

Today, FAR-EDGE is raising the stakes: reshaping the highly hierarchical structure of factory systems (the “automation pyramid”) into a peer-to-peer collaboration of local actors on the shop floor. The catalysts of such transformation are, once again, new paradigms: Edge Computing and Blockchain. FAR-EDGE follows a unique approach, using Edge Gateway devices to inject Edge Computing powers into the legacy factory with a minimum of disruption. A virtual, decentralized coordination layer is provided by means of Blockchain and Smart Contracts.

The FAR-EDGE Platform is the tangible result of this effort. It is a reference implementation of the FAR-EDGE Reference Architecture with baseline functionalities tailored to automation, simulation and analytics solutions. Around the FAR-EDGE Platform, a multi-sided Ecosystem is growing that brings together developers, integrators and final users, all sharing the common goal of advancing the smart and connected factory to the next level. This site supports this Ecosystem by providing resources and services to the community.



Figure 15.5 Home page of Edge4Industry portal.

- **Knowledgebase:** This is a dedicated page with articles, training and presentations regarding the project.
- **Blog:** This section provides articles, news, and latest publications about the Edge4Industry community.
- **Sign in:** This is a sign in area that enables users’ registration/login.

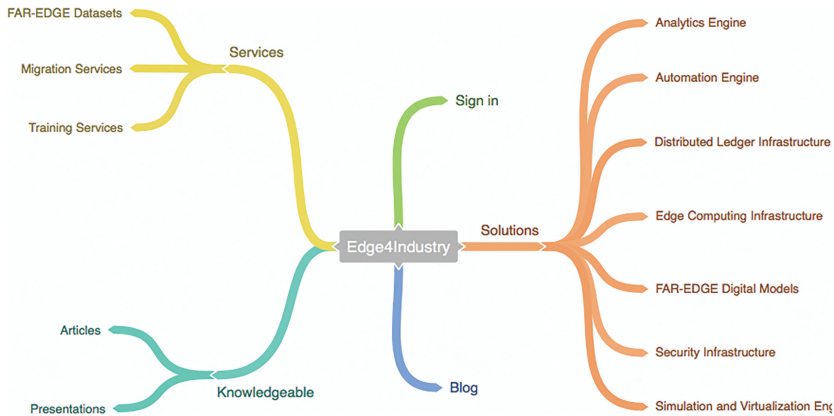


Figure 15.6 Content structure of the Edge4Industry portal.

15.4.1 Services

The Services section can be easily accessed through the main menu by clicking in the Services button and intends to present to the users community all the available FAR-EDGE services. At this stage, the following services are available:

- FAR-EDGE Datasets:** Provides access to open datasets that can be used for experimentation and research. The first datasets provided include data related to individual production modules such as their power consumption, their status, operating mode (maintenance, active, etc.). The datasets include all module production-related information, including Module ID, module description, production status, conveyor status, operating status, error status, uptime information, power consumption, order number, process time etc.
- Migration Services:** The FAR-EDGE Migration Services supports manufacturers, plant operators and solutions integrators in planning and realizing a smooth migration from conventional industrial automation systems (like ISA-95 systems) into the emerging Industry 4.0 ones (like edge computing systems). The service provides a Migration Matrix Tool, which includes all the essential improvement steps and plans needed to enable a smooth migration from traditional control production systems towards the decentralised control automation architecture based on edge computing, CPS, and IoT technologies.
- Training Services:** This service delivers technical, architectural, and business training to Industry 4.0-related communities, as a means of raising awareness about digital automation in general and FAR-EDGE

solutions in particular. It includes specific courses and training presentations. The latter are appropriate for stakeholders that wish to understand opportunities stemming from the deployment of edge computing and distributed ledger infrastructure for industrial automation use cases.

15.4.2 Solutions

Similar to the Services section, the Solutions section intends to present all the available FAR-EDGE solutions and can be accessed too through the main menu by clicking in the Solutions button. At this stage, the FAR-EDGE solutions that are available are as follows:

- **Analytics Engine:** The Analytics Engine solution is a middleware component for configurable distributed data analytics in industrial automation scenarios. Its functionalities are accessible through an Open API, which enables the configuration and deployment of various industrial-scale data analytics scenarios. It supports processing of large volumes of streaming data, at both the edge and the cloud/enterprise layers of digital automation deployments. It also supports data analytics at both the edge and the cloud layers of a digital automation system. It is extremely flexible and configurable based on the notion of Analytics Manifests (AMs), which obviate the need for tedious data analytics programming. AMs support various analytics functionalities and are amenable by visual tools. Note that the Analytics Engine is provided with an open source license.
- **Automation Engine:** This solution provides the means for executing automation workflows based on an appropriate Open API. It enables lightweight high-performance interactions with the field for the purpose of configuring and executing automation functionalities. It provides field abstraction functionalities and therefore supports multiple ways and protocols for connecting to the field. It also facilitates the execution of complex automation workflows based on a system-of-systems approach. It offers reliable and resilient functionalities at the edge of the plant network, based on Arrowhead's powerful local cloud mechanism. Finally, it leverages a novel, collaborative blockchain-based approach to synchronizing and orchestrating automation workflows across multiple local clouds.
- **Distributed Ledger Infrastructure:** This solution results in a runtime environment for user code that implements decentralized network services as smart contracts, which are used for plant-wide synchronization of industrial processes. It enables the synchronization of several

edge analytics processes, as well as various edge automation processes. The solution is a first of a kind implementation of permissioned ledger infrastructure for the reliable synchronization of distributed industrial processes.

- **Edge Computing Infrastructure:** The Edge Computing Infrastructure solution is a pool of components, which provide the means for high-performance connectivity and data acquisition at the edge of the industrial automation network. The solution leverages the capabilities of popular connectivity protocols (like MQTT) and high-performance data streaming frameworks (like Apache Kafka). It also enables dynamic connectivity and data acquisition for the field, in order to facilitate edge computing configurations. Its implementation is containerized (i.e. Docker based), which facilitates usage and deployment.
- **FAR-EDGE Digital Models:** This solution offers the means for representing, exchanging and sharing information in the scope of an edge computing system for industrial automation. Also support is provided for the development of digital twins for field configurations and digital simulations. These Digital Models are based on ideas from several standards for plant modeling, while being tailored to the needs of edge computing for factory automation. They are among the few publicly available digital models for edge computing implementations of industrial automation systems.
- **Security Infrastructure:** This solution is a system designed following the principles of the Industrial Internet Security Framework (IISF) of the Industrial Internet Consortium (IIC) that provide superior integrity of distributed security functions within an Edge Computing based system. It can operate in conjunction with the Distributed Ledger in order to host the security policy and to provide consistent security across various edge analytics and edge automation processes. It is a first of a kind distributed ledger implementation of an IISF compliant security system.
- **Simulation and Virtualization Engine:** This solution provides the means for configuring and executing digital simulations. It includes a real-to-digital synchronization tool, which allows simulation services providers and integrators to improve the reliability of simulations predictions and develops synchronization functionalities between physical world elements and their digital twin. This tool regards any related data source based on appropriate digital models while offering all steps necessary to translate the messages from the physical world element format to the data model format used by the simulation.

15.4.3 Knowledge Base

The Knowledgebase section is a dedicated area of the portal that provides direct access to articles and presentations concerning the latest research and innovation work provided by the FAR-EDGE project and the Edge4Industry community.

The goal of this section is to enable the Edge4Industry members to acquire an in-depth knowledge regarding all the FAR-EDGE project issues, the information, and the resources available; while the access to them is user-friendly and dynamic.

15.4.4 Blog

The blog section presents to the ecosystem community publications about topics that are related to the industry, including those that have been published by members of the Edge4Industry community as well as other sources such as other blogs and electronic magazines. Similar to the Knowledgebase section, access to the Edge4Industry Blog section publications is user-friendly and dynamic.

15.4.5 Sign-in and Registration

The Edge4Industry portal includes a user management system that enables access to different user's types and determines which portal resources are applicable and authorized for each user. At this stage are two user types:

- **Guest**, which is assigned to unauthenticated users and grants lowest-level permission within the portal.
- **Registered member**, which is assigned to members that can access all the relevant resources that are provided in the knowledgebase.

The Edge4Industry Register members can authenticate in the portal by the Sign in section. Members can use a set of different authentication tools to access the Edge4Industry portal.

15.5 Conclusions

In the era of digitization, the development of proper ecosystems is as important as the development of digital platforms. In many cases, most of the value of a digital platform lies in its ecosystem and the opportunities that it provides to stakeholders' in order to collaborate and advance the digital transformation

of modern organizations. Digital automation platforms are no exception, which is the reason why all major vendors of IIoT and Industry 4.0 platforms have established ecosystems around their products and services. Likewise, several public and private funded initiatives have established testbeds, where industrial organizations can experiment with digital technologies without disrupting their production operations.

As part of this chapter, we have reviewed several IIoT/Industry 4.0 ecosystem building efforts, including ecosystems established around commercial platforms, experimental testbeds and community portals. Moreover, we have provided the key building blocks and success factors of multi-sided platforms. Furthermore, we have presented the Edge4Industry portal, which is providing a single point of access to the full range of digital automation results of the FAR-EDGE project, including results presented in previous chapters such as the project's analytics engine, digital models and approach to supporting smooth migration from ISA-95 to decentralized automation.

The Edge4Industry community is gradually growing in size and expanding in terms of stakeholders' engagement. In support of this growth, we plan to provide a range of collaboration and engagement features, which will also be supporting its growth based on an ambitious dissemination and communication plan during the next couple of years.

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