# The ReBorn Marketplace: an Application Store for Industrial Smart Components

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***Abstract*—Rapid changing product portfolios and continuously evolving process technologies require manufacturing systems that are themselves easily upgradeable and into which new technologies and functions can be readily integrated. This new context creates the need for novel manufacturing equipment and control systems able to cope with the increased complexity, required to manage product and production variability in mass customized manufacturing. To achieve this agility modern manufacturing environments need to encapsulate knowledge into sensors and machines, turning them into Smart Components. Based on the concept of logical encapsulation of manufacturing industrial equipment, this paper proposes the creation of a marketplace for Smart Components. This marketplace organises and stores information of industrial machines, not only for potential customers to check and compare different devices, but essentially to allow for (semi)automatic update of the industrial equipment controllers and functionalities on the fly.**

***Keywords*—*Smart Components; Smart Components Application Store; Intelligent Manufacturing Environments; Manufacturing Systems; Industrial Equipment Re-usability; ReBorn Paradigm.***

## I. INTRODUCTION

Increasingly, traditional top-down and centralized process planning, scheduling and control mechanisms are becoming insufficient to respond to the constant variability in high-mix low-volume production environments. These traditional centralized hierarchical approaches limit the adaptability, contributing to a reduced resilience of the system, as well as to reduced flexibility in planning and longer response times. The ability of manufacturing system, on all the functional and organizational levels, to reconfigure itself in order to quickly adjust production capabilities and capacities in response to sudden changes in the market or in the regulatory environment is nowadays a major requirement.

In order to respond to the current industrial environment requirements, the development of a **Marketplace for Smart Components** is proposed. The proposed marketplace organises and stores information of industrial machines, so potential customers can check and compare different devices from a broad perspective, as well as providing a web interface that allows users to insert and change equipment information. Additionally, the marketplace provides tools for integrating interfaces and systems used by the equipment manufacturers to easily update controllers firmware and equipment functionalities.

The concept of the Marketplace for Smart Components was first introduced and discussed within the scope of the European project **ReBorn**. The vision of ReBorn is to demonstrate strategies and technologies that support a new paradigm for the re-use of production equipment in factories. This re-use will give new life to decommissioned production systems and equipment, helping them to be reborn in new production lines. Such new strategies will contribute to sustainable, resource-friendly green manufacturing and, at the same time, deliver economic and competitive advantages for the manufacturing sector. ReBorn will make significant step towards 100% re-use of equipment focusing its approach on three main areas: modular Plug&Produce equipment, in-line adaptive manufacturing, innovative factory layout design techniques and adaptive (re)configuration, flexible and low-cost mechanical systems for fast and easy assembly and disassembly.

This paper is organized as follows. In section II, a literature review is presented, with a discussion regarding the current state of the art in manufacturing systems, electronic platforms and services. Section III, presents the needs and problem definition, followed by the concept and solution in Section IV. Section V describes a sample implementation of the proposed solution and section VI concludes the paper by exposing some final remarks about the implemented solution and next steps for future work are identified.

## II. STATE OF THE ART AND RELATED WORK

This section presents a short overview of the state of the art in areas related with the work described in this paper. Related work is reported from the areas of manufacturing systems, platforms and services.

### A. Manufacturing Systems

The manufacturing enterprises of the 21st century are in an environment in which market demand is frequently changing, new technologies are continuously emerging, and competition is global. Manufacturing strategies should therefore shift to support global competitiveness, new product innovation and customization, and rapid market responsiveness. The next generation manufacturing systems will thus be more strongly time-oriented (or highly responsive), while still focusing on cost and quality.

Such manufacturing systems will need to satisfy a number of fundamental requirements [1], including amongst other: full integration of heterogeneous software and hardware systems; capacity to accommodate new subsystems (software, hardware, peopleware) or dismantle existing subsystems on the fly.

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Next, a few approaches that intend to fulfill these requirements are described.

*1)* ***Networked Factories****:* Modern Industries have a continuous need to satisfy their markets at better costs in order to keep competitive. This simple fact creates the continuous need for new products, new production lines and new control methodologies. The XPRESS (FleXible PRoduction Experts for reconfigurable aSSembly technology) project [4], a cooperative European project involving industry and academia studied this issue in order to define a new flexible production concept. This concept, based on specialized intelligent process units, is able to integrate a complete process chain, and includes support for production configuration, multi-variant production lines and 100% quality monitoring.

*2)* ***Reconfigurable Manufacturing Systems****:* Reconfigurability has been an issue in computing and robotics for many years. In general, reconfigurability is the ability to repeatedly change and rearrange the components of a system in a cost-effective way.

According to [5] it is possible to define a Reconfigurable Manufacturing Systems **(RMS)** as being designed at the outset far rapid change in structure, as well as in hardware and software components, in order to quickly adjust production capacity and functionality in response to sudden changes in market or in regulatory requirements.

Furthermore, Merhabi *et al.* [6] complement this definition with the notion that reconfiguration allows adding, as well as removing or modifying specific process capabilities, controls, software, or machine structure. This reconfiguration aims at improving or upgrading the existing manufacturing systems or its components, rather than promoting its replacement.

RMS are seen as a cost-effective response to market changes, that tries to combine the high throughput of dedicated production with the flexibility of flexible manufacturing systems **(FMS)**, and is also able to react to changes quickly and efficiently. For this to be accomplished, the system and its machines have to be adapted for an adjustable structure that enables system scalability in response to market demands and system/machine adaptability to new products. RMS are composed of reconfigurable machines and open architecture reconfigurable control systems to produce variety of parts with family relationships. Structure may be adjusted at the system level (e.g., adding/removing machines) and at the machine level (changing machine hardware, control software or parameters).

Intelligent Reconfigurable Machines, Smart Plug&Produce and the extensive integration of sensors - in line with the Cyber Physical Systems (CPS) and Internet of Things (IoT) concepts - are becoming more and more present in the industrial shopfloor [11] [12]. Monitoring the current machines process state, and increasing shop-floor analysis, enables rapid decision making according to the production system demands.

### *B. Platforms*

According to Smedlund and Faghankhani [2], it is possible to define a platform as:

*Definition 1: Any physical or virtual space where different participants compose a market and a platform that participants orchestrate can be defined as a platform.*

Platforms are composed of onion-like multilayered structures in which the technological core element is necessary for complementary technologies that in turn provide ground for software. It is possible to identify a wide range of different types of platforms based on the nature of interactions between its participants. There are, for instance, platforms that aim to help members of some participant group find a match in another group, platforms that bring sellers and buyers together, platforms that measure transactions between participants, and platforms where participants share their input with other participants.

*Definition 2: Any virtual or physical venue that enables all participating groups to co-create and co-capture value by interactions which result in offering a system of products, services or both.*

Depending on the number of participating groups, platforms make a one-sided, two-sided or multi-sided market possible. In n-sided platforms, which include social media platforms and smartphone ecosystems, the users connect to each other, communicate and co-create value for themselves and for the other users and participants. The user is no longer a passive recipient and object of value delivery, but active co-creator of value. This means that in order to fully benefit from platform offering, the end-user must give something back to the platform.

Platforms are evolving systems capable of adaptation. They can be expanded by either building upon new components or connecting to other systems, or other platforms. After reaching a certain threshold of momentum in the number of participants and relationships between them, platforms develop in an evolutionary manner (i.e. random variation, selection and retention processes). An evolutionary attribute is necessary because it allows the platform to maintain its current participants and simultaneously attract new ones.

Platforms create a network of relationships among the participants. Smedlund and Faghankhan describe and identify two different trajectories on which networks are formed: **Goal-Directedness** and **Serendipity**. In goal-directed networks, the participants see themselves as a part of network committed to some common goal. The network is formed to achieve this goal. In serendipitous networking, there is no preexisting goal, and the network develops in an evolutionary manner.

*1) Platform Participants:* Platform participant groups include **End-Users**, **Platform Owners**, **Platform Providers**, **Complementors** and **Orchestrators**. For instance, when taking a look at a generic social media network model, Smedlund *et. al* proceeds to describe and identify the mentioned participant groups. The user account holders are the **End-Users**, which can also be called the demand side. **Platform Owners** are the entity which in turn owns the social media network, they can be easily differentiated from the other participant groups as they hold the technological solution for the system that defines its evolution. **Platform Providers** can be exemplified as Internet access providers. Their role is to play the part of an intermediary between a user and the platform, by doing so they become the primary contact points of the platforms end-users. **Complementors** are a platform participant with the ability to add value to the platform itself, they offer complementary services or products to the value proposition of the platform, and they comprise the supply side

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of the platform. Complementors can be labeled according to the complement they provide to the platform, by doing so its then possible to differentiate them in different segments. Regarding social media networks, a complementor might be an application developer or for instance an advertiser.

It is then important to identify a focal actor, who strives to uphold the platform standards, as well as maintaining its integrity and its evolution according to the industry vision. This focal actor, has been referred to by different terms in different studies, as stated by Smedlund *et. al* it is possible to define this central role as the platform **Orchestrator**.

### C. Services

Service activities across industries are now widely recognized. Information and Communication Technology **(ICT)** powered evolution of services is one of the main sources of modern economic growth. Business logic has evolved from the product-dominant logic into service-dominant logic [3]. According to this new business logic, services are conceptualized as processes (rather than something that produces a unit output) and its dynamics are driven by resources, such as knowledge and skills. In this new mindset, value is now understood as a collaborative process between providers and consumers.

The mobile phone industry has revolutionized the way consumers look at a simple phone. Mobile phones have transcended their original form, and through mobile information and communication technology, they have long past surpassed the form of a telephone. Instead, it is now evolving into a platform like format, where it is possible to develop a broad variety of complementary innovations. These surges of platform-like services have now imprinted a heavy mark on todays society and completely changed the recent social interaction format as well as affecting a broad variety of business models and approaches. Mobile internet, e-mail, personal productivity tools, entertainment services, such as games, music, and mobile TV, are all examples of platform oriented services.

Platform as a Service **(PaaS)**, are continuously gaining importance as n-sided markets, offering Software as a Service **(SaaS)** to the respective platform participants. PaaS are bound to co-habit ecosystems with users and autonomous SaaS suppliers. In order to be successful an attempt is made to shape the ecosystems form according to the platforms basic value proposition, and control the service quality according to the users requirements.

## III. ReBorn Marketplace Concept & Solution

This section describes the ReBorn Marketplace **(RBM)**. Starting from a motivation example from an industrial component supplier, the concept for the marketplace and its requirements are elicited. The proposed solution is also discussed in this section.

### A. Component Supplier Needs & Problem Definition

Component Suppliers play an important part of in the deployment of any production line. They feature control and monitoring systems for all kinds of operations and processes, as well as specialized individual process solutions. Harms&Wende **(HWH)** is a component supplier specialized in welding control systems for various sectors. Harms&Wende customers often are welding machines manufacturers who use the Harms&Wende welding control units. They offer resistance welding equipment in form of control devices, quality assurance systems and complete packages to well-known machine construction companies. Once these components are integrated in a production line, they face however a major implication.

Nowadays production line systems, thanks to the highly competitive industrial environment, are required to be highly flexible. Flexibility directly translates into production systems that need to be easy to update, and in which new technologies and new functions can be quickly integrated. However, that is not the case in the current industrial standard, from a component supplier perspective, offering additional component features and technologies in the form of services is not yet the usual practice.

### B. The ReBorn Marketplace Concept

RBM will offer its services in an online platform format, as a platform as a system (PaaS). PaaS enables the creation of an evolving market between actors who would not connect on their own without the platform. PaaS comprises different participant groups, making a multi-sided market possible.

Fig. 1, depicts the RBM platform participants.

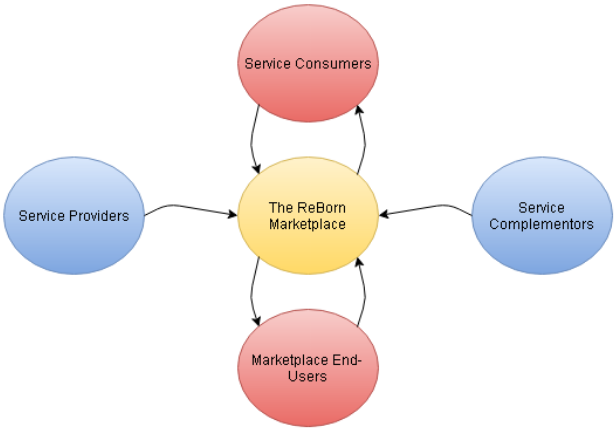


Fig. 1. The ReBorn Marketplace Platform Participants

The RBM is a n-sided market, with service providers on one end and service consumers on the other. This will attract service suppliers in order to respond to the demand side of the platform. The demand side, in the marketplace, is comprised of any potential **End-User** to the platform offerings. **Service Consumers** comprise the marketplace participants which mainly relate to the RBM service offerings. The Marketplace **Service Suppliers** can normally be instantiated by any entity capable of offering its services to the platform while altogether adding value to the platforms base proposition. Service Suppliers are industrial machine builders who provide equipment, as well as equipment information, functionalities (software), and operations. Entities capable of providing complementing services to the platform, in order to co-create value, are labelled as **Complementors**. These can be for instance independent software developers that provide additional equipment functionalities.

*1) RBM Case Application:* Original Equipment Manufacturers **(OEM)**, constitute a major segment of the marketplaces

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end-users. When considering OEM as a potential platform end-user, some forethought is needed. As stated previously, the RBM attempts to implement a marketplace solution that is adequate to a wide spectrum of platform end-users. As such, it must be able to cope with multiple application scenarios for any type of production system and factory environment.

When considering that each major OEM entity in the industrial market potentially has a different set amount of production facilities, each of them having a varied amount of production lines, the marketplace when offering its services must satisfy a huge variety of needs and requirements. Also, production facilities from the same OEM can differ greatly. Although they fall under the same company, they can possibly follow different business model approaches, quality inspection guidelines, and for instance factory floor communications protocols. Todays industrial environment is characterised by a lack of business models standardization, which means that each production facility acts uniquely and in independently of each other, while altogether engaging in a highly competitive environment.

In order to test the ReBorns online marketplace on a factory floor, its necessary to take some considerations into account. Usually production lines equipments are closed off to outside networks, which in turn makes any information flow from the inside of the factory plant to the outside an impossibility. Fig. 2 depicts the RBM OEM Case Application.

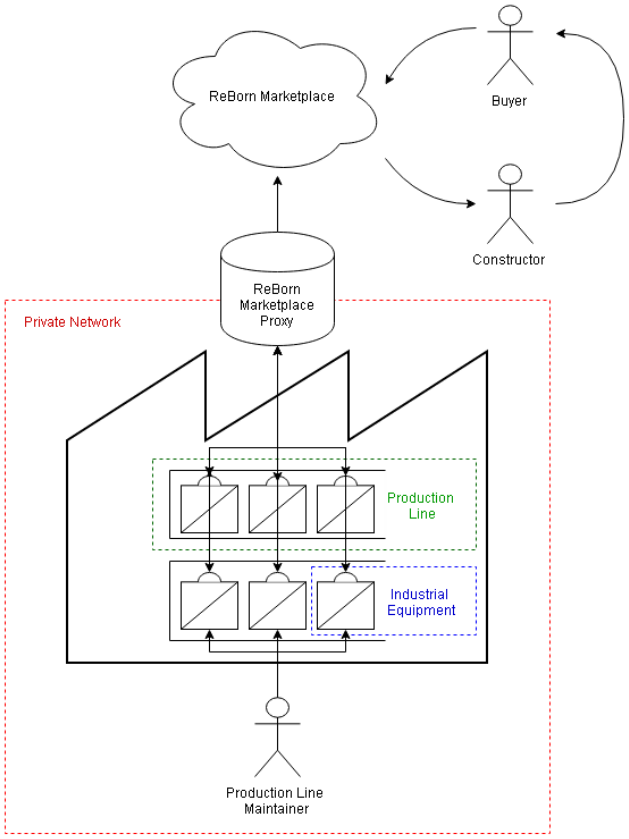


Fig. 2. The ReBorn Marketplace OEM Case Application

The local marketplace attempts to act as an exact copy of the ReBorns marketplace online solution, but instead of being hosted online it is instead hosted on a private network, accessible only to its participants. The local marketplace would employ all the features and available services provided by the original ReBorn online platform. The local marketplace acts as a proxy of the ReBorn marketplace. The local marketplace from a platform perspective acts as a two dimensional platform. Serving in one side each industrial equipment from the factory floor, and on the other side the online ReBorn marketplace. Having identified the local marketplace participants, it is important to discuss how the local marketplace interacts with the online platform.

One could consider the local marketplace to possess direct communication with the online platform, serving as a bridge between the industrial equipments private network and the ReBorn marketplace. On the other hand if the information flow between the local marketplace and the ReBorn marketplace to an outside environment will be strictly enforced the local marketplace can consider being manually updated, in order to have the latest software content made available by the online platform.

The later approach requires the local marketplace to be managed locally. The update batch is made available by the ReBorn marketplace, and then needs to be manually inserted into the local marketplace. The two approaches have very different results, whilst the first approach instantly updates the local marketplace with new content, the second approach requires that the local marketplace manager is notified of the available update batch. Only then he is able to proceed with the update operation. This means that industrial equipment would continue to work with out of date software for a longer period of time, which might be critical for the production line. In the worst case scenario, if a defect is found in an industrial equipment software version and the only available solution refers to a new solution contained by a software update batch yet to be implemented on the local market, this could possibly mean that the production would have to be put on hold until the solution is implemented.

### C. Problem Solution

The solution of the problem stated above is framed in the scope of the **ReBorn European project** - Innovative Reuse of modular knowledge Based devices and technologies for Old, Renewed and New factories - and its main purpose is study and implement a **Marketplace for Smart Components**, where the information related to industrial equipment is provided in a standardized way in order to make its use in the planning process of production lines easier and promote the re-use of equipment.

The main features to be developed in this project include also the creation of a solution to integrate the virtualization of the shop-floor equipment directly into the Marketplace. This integration must provide different information access control levels, as well as organize all the information at the cloud level.

The RBM aims to provide a pioneering service that is yet to be seen in the current industrial environment. One of the marketplace services key features is providing interfaces with tools and systems used by the industry, in an application format. From an industrial environment perspective, equipment update or actualization is mainly done at a software level.

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Each production equipment is represented by a cyber-physical entity called **Verson**. Versons act as logical encapsulation entities, which store and analyse information, enabling industrial equipment to perform dynamic and highly specialized tasks. It is through specific applications stored in the Verson, that these highly specialized tasks are made possible. The Versons modular architecture allows for individual component management at shop floor level, with a modular plug in and plug out application format. The Verson like product equipment is accompanied by a functional platform. The **Verson Platform** acts as an interface for the integration of the applications provided by the RBM, as well as a service handler for its requests.

An **Open-Source E-commerce Shopping Cart Solution** is used as the RBM platform base. Additionally, the RBM provides the Verson product equipment all the required application content, through a series of **Web Services** which follow a **RESTful Architecture**.

The RBM makes application management at a Verson level possible, as it provides the Verson with a broad variety of applications which feature a wide range of functionalities. By offering industrial equipment update on production runtime, the RBM makes industrial equipment monitoring, upgrading and refurbishment a reality.

## IV. Solution Implementation & Validation

The RBM includes a key set of features that are aligned with the new ReBorn paradigm. These features are directly related to the application management services implemented by the Versons and by the RBM. The application management service, as stated previously, aims to locally manage the application content of each equipment's Verson, while the equipment is installed in a production line. In the following section, the implementation process and the validation scenario of the marketplace application management services are described.

The communication between a Verson device and the ReBorn Marketplace online platform was developed to demonstrate the application management service offered by the RBM. A Verson product was provided for requirement validation and testing. Fig. 3 depicts the applied test setup.

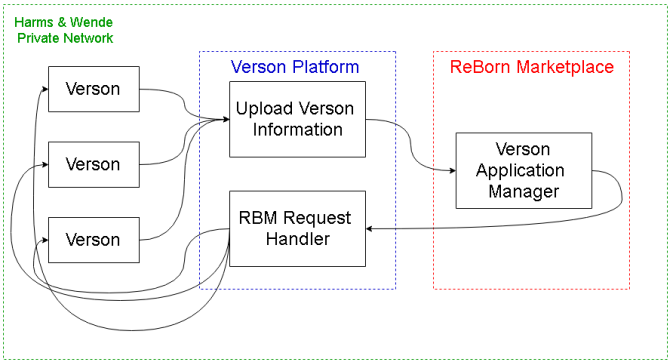


Fig. 3. REST Service Testing with HWH

The Verson acts as a logical encapsulation entity of the production lines equipment, which is responsible for collecting, storing and analysing information. The Verson extension of production equipment is realized on a dedicated hardware platform to enable an easy implementation of the concept. A **RaspBerry Pi** SBC was used for this purpose in the sample implementation.

By means of the Verson platform it is possible to see the Verson's currently installed device applications. The same platform allows to initiate a request, which portrays an application update nature, to the RBM. The Verson's applications serve a multipurpose nature. Through them it was possible to display the equipment status, information and statistics, alongside the current conditions on which the equipment is working. The applications developed by the ReBorn project were developed in **PHP**. Each application consisted of two PHP files and a .dat file. The RBM in turn is responsible to provide all the application content necessary to each request performed by the Verson through the Verson Platform.

In order to establish communication between the Verson and the RBM, the project solution was published on the HWH local server as the provided Verson equipment is restricted to the local private network.

In accordance to the system requirements, the Verson acts as a mediator between the industrial equipment and the ReBorn Marketplace. Requests made to the ReBorn platform are handled by a REST based web service. The ReBorn Marketplace is in turn responsible for providing the latest application content on demand to the Verson equipment.

## V. Conclusion & Future Work

The work presented in this paper only scratches the surface of a vast subject. By describing and demonstrating the solution for run-time (software) update and reconfiguration of industrial equipment, it highlights the underlining conditions of a real life application of the RBM.

The ReBorn Marketplace concept discussed in the paper is a potential solution adequate to different types of production systems. By managing the Versons application content, through the ReBorn Marketplace services, it is possible to integrate new technologies and functionalities in industrial equipment on the fly.

The Versons modular architecture allows for plug-in and plug-out application management. However, some considerations have to be made in order to apply it to a real industrial scenario. Applications can be easily installed and removed from a Verson like equipment, but it is necessary to understand if they are independent within the system architecture. Cross dependencies between applications further increase the complexity and create new challenges for the platforms application content management services.

Business and service models are also important for the industrial uptake of such a solution. One of the crucial points relates to the identification of the liable subject. The currently implemented solution, when considering the platforms application management service offerings, requires the Production Line Maintainer to individually access each industrial equipment in order to perform requests to the ReBorn Marketplace platform: application update, install, and remove. In this case, the Production Line Maintainer takes full liability of the newly integrated (or removed) application content, in case the application features are not up to the production lines standards and requirements. This approach when applied to a

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standard OEM production line, which might contain hundreds of Versons, is unpractical. Individually accessing each Verson in order to proceed with maintenance operations is not a viable approach.

Considering automated application maintenance operations at the Verson individual level, whenever new software content is released and or whenever the new application licenses are made available, sets new requirements for the RBM.

Further developments of the RBM include offering automated maintenance services as well as system restore service, that cover possible unpredictable outcomes of upgrading and installing new software content.

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