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# Movement towards service-orientation and app-orientation in manufacturing IT

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**Abstract**

Current trends in production e.g. the shift to mass personalization lead to significant changes in manufacturing IT. The traditional automation pyramid is dissolving and manufacturing IT is moving towards service-orientation and app-orientation. To support especially small and medium-sized enterprises (SMEs) in mastering this challenge, an appropriate IT infrastructure and secure cloud platform have been developed. Based on this cloud platform, apps have been developed which provide the interface between humans and manufacturing IT as well as the integrated cyber-physical systems. Challenges concerning app development for manufacturing environments are illustrated using the example of an app collecting sensor data and sending this data to a cloud service for further processing.

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*Keywords:* Digital Manufacturing System; Cloud platform; Service-orientation

## 1. Introduction

Social megatrends such as globalization, urbanization, demographic change, growth of population and sustainability have great impact on manufacturing enterprises and lead to a paradigm change for all production factors [1]. In addition, the trend towards personalized production leads to an enormous rise of product variants while quantities per product and variant are decreasing [2]. Simultaneously, manufacturing enterprises are forced to deal with highly volatile market conditions [3]. Therefore, the capability of rapid adaption has become a key factor in international competitiveness.

Rising market complexity also leads to more complexity in companies in the manufacturing sector. A propagated solution addressing this complexity by technologies of the fourth industrial revolution is the smart factory, the next evolutionary stage of the fractal factory. Key skill of the smart factory is decentralized and autonomous self-organization based on cyber-physical systems (CPS) providing real time data from the shop floor. In cooperation with humans, networked CPS are capable of solving problems within the factory [2].

To enable the smart factory, not only new IT architectures are necessary, but also new forms of interaction between humans and CPS as well as between humans and collected data in the form of services and apps. Therefore, this paper presents an approach to adapt manufacturing IT flexibly to changing and volatile conditions by using a cloud platform as well as services and apps deployed on this platform.

## 2. State of the Art

Nowadays, manufacturing IT is undergoing a fundamental change from the traditional automation pyramid to service-orientation, also indicated as Everything as a Service (XaaS), a paradigm, which originates from the three main cloud computing service layers Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). In order to identify diverse services, the terms service and app are divided into several subspecies. Below, the ongoing changes in manufacturing IT are described.


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**Differentiation between the terms "service" and "app"**
Services and apps are the building blocks of cloud applications and are capable of interacting with other services as part of a defined workflow. There are different types of services and apps:

1) Integration services: integration of systems linked to the cloud. (e.g. factory machines, equipment, etc.)
2) CPS services: services with special sensors and actuators that can form a highly dynamic part of processes. (e.g. work piece carriers, machines, etc.)
3) Back-end services: services that provide defined, clearly delineated features. (e.g. data archiving, specific analyses, scheduling mechanisms, etc.)
4) Web apps: operating system-independent apps, combination of front-end and one or multiple back-end services. (e.g. dashboard, task tracker, etc.)
5) Native apps: operating system-dependent apps, communication with one ore multiple back-end services. Especially used when high computing power or direct access to hardware layer is required. (e.g. sensor data acquisition, augmented reality, etc.)

### *2.1. Traditional manufacturing IT*

Traditional manufacturing IT is characterized by a hierarchical structure integrated in the automation pyramid. The automation pyramid is divided in three levels: the operational shop floor level, the tactical manufacturing execution system (MES) level and the strategic enterprise resource planning (ERP) level (see Fig. 1). Various planning and control tasks are performed on each level [4, 5].


Fig. 1. Traditional automation pyramid [4]

Tools such as MES or ERP are centralized large software suites. Very often they are monolithic and stick to self-defined interfaces instead of open standardized interfaces. Therefore, separate interfaces between each component have to be developed, integrated and maintained. Due to this enormous effort, a holistic vertical and horizontal integration is usually not realized. This missing integration leads to delayed information about the factory which results in a gap between the physical factory and the virtual representation in IT systems. This lack of real-time data also often requires short-term and expensive intervention to production control [2, 4–6]. In addition, traditional software suites require a significant invest in license fees. Furthermore, the process from requirements analysis via implementation and customization to roll-out is very inflexible and takes months to years depending on the specific solution for a use case [4, 5].

### *2.2. Emerging concept for manufacturing IT*

Today, the manufacturing IT is undergoing fundamental changes enabled by technologies such as cloud computing and associated concepts. The traditional automation pyramid is dissolving and manufacturing IT is moving towards service-orientation and app-orientation (see Fig. 2) [7, 8].

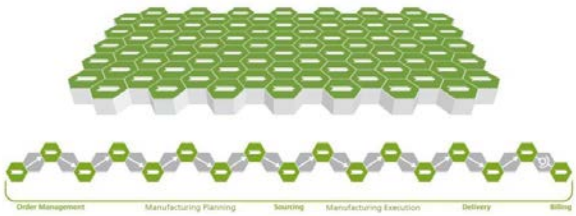


Fig. 2. Service-orientation in manufacturing IT [4]

Software functionalities will be divided into services and apps, decentralized offered by CPS and cloud platforms. Everything will be treated as a service. Due to this division of functionalities, communication between services, based on open standards will become a key factor for success. This also allows the communication of real-time information. Besides technical changes, service-orientation also enables new business models based on pay-per-use or subscriptions as well as flexible and upgradable processes of service introduction within minutes according to the customers' requirements [2, 4, 5, 7, 8].

According to forecasts, the introduction of mobile IT infrastructures in manufacturing companies will push business efficiency and transformation in production environments [9]. The simplified development of apps for the manufacturing sector by means of a standardized software and hardware infrastructure will thus strongly contribute to improve efficiency because it will be possible to aggregate cloud manufacturing concepts with individualized workflows. This trend is already widespread in the consumer world with established software products such as office suite products being offered on a yearly subscription service in connection to cloud-based services for online storage of documents or proprietary cloud storage solutions for document sharing. Many manufacturing companies have noticed this trend and have started to build their own cloud- based ecosystem and platform to offer additional services to their customers, for example the Axoom platform offered by Trumpf or Bosch offering their own cloud platform. However, most of these platforms are tailored around the products and services offered by the company and lack interoperability with other platform providers or integration of external systems. The research project eApps4Production [10] is working on a solution for this problem and some of the results are presented in this paper.

## 3. Concept

Compared to consumer-grade cloud services, industrial-grade services have additional requirements. In spite of that consumers care for security and privacy of their information, the mechanisms to ensure this, must not interfere with the user experience. Companies, on the other hand, of course also have usability requirements, but the mechanisms for security and IP protection are essential and are expected to be more pronounced than the ones which can be found in consumer-grade platforms. The platform shouldn't be implemented in the form of a closed ecosystem, but quite on the contrary, it follows a federative approach. This means that independent service vendors (ISV) are able to offer their services on the platform and users should be able to orchestrate services according to their needs in order to flexibly adapt to changing market conditions.

### *3.1. Platform*

From these requirements, a comprehensive system architecture for a cloud-based platform is derived which allows ISVs to offer services with manufacturing-related IT features, turn them into solutions and thus enable services and apps to be efficiently developed and implemented in the manufacturing and engineering sectors. Figure 3 shows the proposed platform high-level architecture and the platform's components.

The platform portal (Front-End) is the point of entry for users and vendors of services and solutions. The base components (Back-End) include supplementary services, enabling onboarding, management, configuration, execution, monitoring and billing the services and solutions. The factory layer is abstract and depicts the integrated equipment, CPS and also the sensors and actuators of a user's production facility. All components should be integrated via a manufacturing service bus but still be directly responsive via integration services. This also allows the users to integrate their manufacturing equipment on the platform in the form of manufacturing services and thus incorporate them directly in an orchestration or solution.

The infrastructure layer encompasses all other layers of the platform. The components contained are primarily responsible for security mechanisms which guarantee both the operational security and data security of the manufacturing data concerning all components managed on the platform. The infrastructure is realized in the form of a classical IaaS layer which automatically supplies the necessary hardware for the solutions and scales them as required [11].

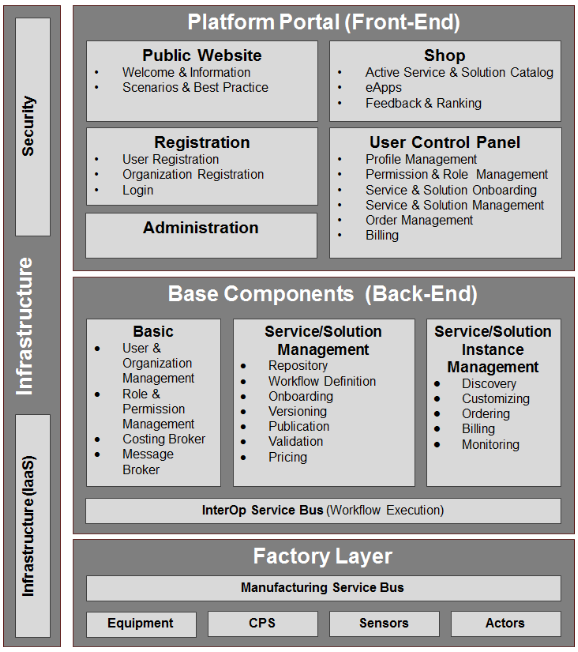


Fig. 3. Overview of cloud platform components [11]

### *3.2. Services*

The platform has to offer a range of base services which allow service providers and end-users to easily create and consume services. Access and identity management should be provided as a built-in tool, allowing for single-sign on authentication of users, CPS and IT services like web applications or apps. An integration service needs to act as an integration layer to connect production environments and manufacturing equipment to the platform. This service should offer interfaces for all established standard protocols used in industrial applications, like OPC-UA or MTConnect. Service instances need to be monitored for two main reasons. First, it has to be ensured that a service is running stable and is available according to the service level agreements. Second, the activity of a service has to be monitored to allow precise accounting and billing of the used functionality based on actual data. Billing of a number of orchestrated services has to be done in a unified fashion, to ensure usability and transparency for the user, respectively customer. Therefore accounting and billing also have to be base services offered by the platform to be utilized by ISVs.

### *3.3. Apps*

The future of engineering is characterized by collaborative and mobile working methods. Engineering activities are performed where they are most economical and most efficient. To do so, engineers are using apps in a service-oriented architecture. In a further step, engineers are even able to create their own apps based on app software development kits (SDK) [6, 12]. This development is not limited to engineers, but App-orientation is nevertheless the current development in manufacturing and manufacturing-related departments, e.g. maintenance and logistics [5, 6, 8].

One possibility to develop and provide these apps is the already described solution by web-based apps. On the other side there are native apps for mobile devices: operating system-dependent apps written and compiled for each operating system. There is a higher effort to develop native apps but there are also significantly more possibilities for functionalities in native apps. Only native apps are capable of accessing the whole hardware stack of sensors such as accelerometers or gyroscopes, communication technologies such as GPS or WiFi and actuators like vibration motors. However, especially sensors and actuators are needed to integrate humans and their mobile devices into smart factories and to enable new forms of interaction with data.

The proposed approach is the division of different functionalities based on each app type's strengths. Solely functionalities which could only be implemented in operating system-dependent code are realized as native apps. All further functionalities are moved to back-end services and web apps, running on the proposed cloud platform for companies of the manufacturing sector.

## 4. Implementation

### *4.1. Platform*

Figure 4 shows a simplified architecture of the implemented platform. Additionally, a list of exemplary services is depicted in the PaaS layer of the platform. The IaaS layer has been omitted in the picture, since the platform has been built in a fully service-oriented fashion using state of the art web technology which allows deployment in any kind of currently available cloud stack. The virtualization technology used in the PaaS layer supports generic virtual servers (e.g. VMWare) and container-based virtualization (e.g. Docker) which is particularly suitable for micro services, such as data base services or simple web apps. The integration layer comprises the Manufacturing Service Bus (MSB), a component which has been developed to cater to the specific requirements of production environments by offering interfaces supporting the currently established industrial standards like OPC-UA and protocols, primarily WebSocket, REST and MQTT. This allows integrating production equipment, external production IT systems or mobile devices into the platform [13].

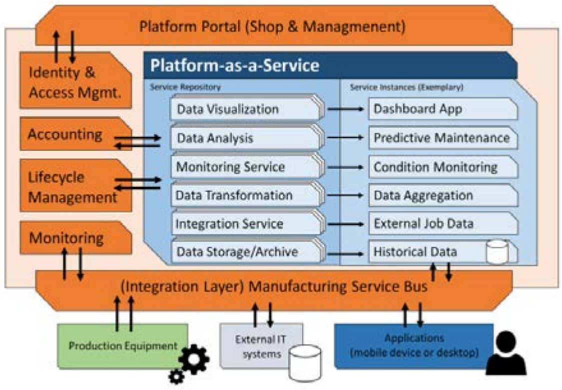


Fig. 4. PaaS platform architecture

### *4.2. Services*

IT services can be either implemented as back-end services, which offer specific functionality users do not directly interact with, or apps, offering a front-end which can be accessed and interacted with by a user. Since the platform provides a number of base services out of the box, ISVs can focus on development and deployment of services which provide a specific functionality. Database services for example can be provided by the platform, but also by ISVs if additional features or functionality need to be added to the database service. Services offering functionality in the form of a web-based application can range from simple dash boards for data visualization to more complex web based applications, like cloud MES or ERP systems. Data transformation, visualization, or storage can each be performed by a different service. Data and information flows between services are controlled via MSB.

### *4.3. Apps*

Based on the proposed platform architecture and back-end services such as a database service, the native app Wear@Work has been developed. In its current development state the app is running on an Android-based smartwatch collecting all available sensor and communication data and is sending it via the MSB to a database service on the platform for further processing. In addition, manual data collection can be performed by voice recognition. A more detailed description of the Wear@Work approach is presented in [14]. Subsequent challenges of developing such apps for manufacturing environments are explained.

From the manufacturing environment perspective the main challenge is the communication between apps and the cloud platform. There are various disturbing sources for wireless connections on the shop floor such as metal housings or welding processes. Therefore, a fallback for communication technologies is necessary, e.g. the use of 4G if no WiFi network is available. But even the last available fallback can fail. That is why a buffer has been implemented. Every time there is no network connection available or the transfer of data fails due to other reasons, all data is stored to a local buffer. Especially this verification of successful data transfer is necessary to ensure a complete collection of manufacturing data without any losses.

The possibility to use a buffer can be limited by the smartwatch's hardware capabilities. Today's Android-based smartwatches are often equipped with 4GB memory, where about 3GB can be used by apps. With various apps installed and a lot of sensor data collected, it is possible to run out of memory and loose valuable manufacturing data. Besides, not every smartwatch is equipped with the full range of communication technologies from near field communication (NFC) to 4G to offer suitable fallback solutions. In addition, battery capacity is limited by smartwatches structural shape.

Therefore, the Wear@Work approach uses the smartwatch to collect sensor data, but only buffering limited parts before sending it to the smartphone via Bluetooth Low Energy (BLE). Subsequently, the data is transferred from there to the cloud platform. Using this setup, various challenges can be addressed. First, by only buffering sensor data before sending it to the smartphone less memory is needed, because short-range BLE is more reliable. Second, smartphones are often supporting more communication technologies than smartwatches. Third, BLE is more energy efficient than other technologies such as WiFi and, therefore, enables longer battery life of the smartwatch.

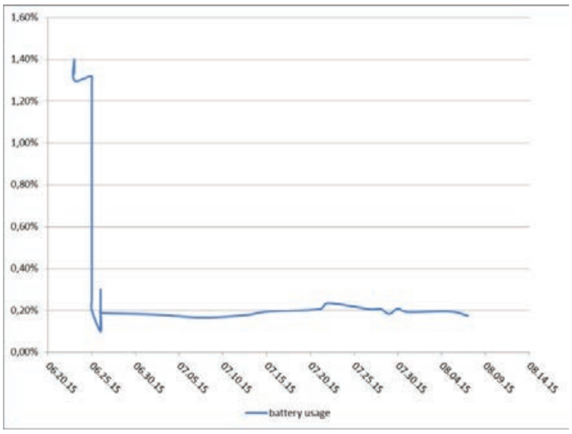


Fig. 5. Development of battery usage

Fig. 5 shows the battery usage trend within the app's development process. Major improvements have been achieved by the already described setup of using BLE and buffering of sensor values before sending them to the smartphone. Ideal buffer size has turned out to be 750 values including meta data. There has been no difference in battery usage when changing values e.g. by removing or adding meta data. While using smaller buffer sizes battery usage increased, with larger buffer sizes the app ran out of memory and crashed. Furthermore, when using smaller data packages, the connection between smartwatch and smartphone is blocked for a longer time. That means, even when data acquisition has been stopped, there is still data arriving at the smartphone. This leads to the conclusion, that considering current communication technologies such as BLE or WiFi, a substantial protocol overhead has to be taken into account. Therefore, less connections but larger data packages are more useful for energy efficient mobile apps.

## 5. Conclusion and Outlook

The concept of using apps allows flexible software with a defined set of features and functionalities. But traditional consumer-grade apps are mostly characterized by data processing and data storage on the device. This concept has been expanded for industrial production. Data from various manufacturing equipment and CPS is integrated, using back-end services on the proposed cloud platform architecture. Apps are then capable of consuming data from all these services regardless of the respective data source. Within the implementation various challenges of applying apps to manufacturing had to be addressed.

However, research on this topic is not finished yet. Currently, plant equipment providers as well as software vendors are developing proprietary platforms and ecosystems. But future cloud platforms for the manufacturing sector need to be interoperable, allowing services and apps to consume data from services on multiple platforms, to prevent vendor lock-in like effects. This challenge is already being addressed by the Fraunhofer Initiative Industrial Data Space (IDS) and the research project MultiCloud, funded by the German Federal Ministry of Education and Research (BMBF).

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