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Integrating Smart Objects as Data Basis in Virtual Enterprise Collaborations

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Abstract. Small and Medium Enterprises of the manufacturing domain have to cope with a highly competitive market today. To establish flexible and efficient collaborations with partners in such an environment, new collaboration concepts and corresponding IT architectures are required, such as Virtual Manufacturing Enterprises. Therefore, we provide in this paper an overview of a generic IT architecture for realizing collaborations within Virtual Manufacturing Enterprises. However, besides an adequate IT architecture, a sound and up-to-date data basis is an essential necessity for inter-company collaborations to be successful. Smart Objects constitute a promising technology to gather and transmit a huge diversity of different process-relevant data in real time and can thus act as valuable data source in order to achieve such a comprehensive and up-to-date data basis. In consequence, we describe in this paper how Smart Object technology can be employed and integrated in our architecture for Virtual Manufacturing Enterprises in order to enable efficient data provisioning in such collaboration scenarios.

1.1 Introduction

In our globalized world, manufacturing companies have to cope effectively with various challenges, for example shorter product life cycles, quick response times, and a higher degree of customization [1]. Especially Small and Medium Enterprises (SMEs), which do not possess the financial strength to face all the upcoming challenges individually, need to focus on flexible and efficient collaborations in order to successfully address these challenges and remain competitive in today's markets.

The mentioned challenges can be addressed with a popular concept named Agile Manufacturing (AM) [2]. This concept focuses on setting up whole

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organizations for production across enterprise boundaries [3]. One core concept to achieve AM is the Virtual Manufacturing Enterprise (VME) [2], [3]. Such VMEs are created to address specific market opportunities [4]. A VME is founded by at least two companies and puts the partners into a position to easily collaborate in order to use common processes to achieve common goals [5], [6]. In such a collaboration form, the partners share costs, skills, and core competencies [4].

A basic building block for VME-based collaboration is Information and Communication Technology (ICT) [7]. In contrast to traditional ICT architectures, a high degree of flexibility and interoperability is required to seamlessly integrate business processes between collaborating partners [6]. An indispensable necessity for all affected processes and interactions in such collaboration is an up-to-date data basis. In this respect, Smart Objects provide a promising technology, which can be used to achieve a corresponding up-to-date data basis. Smart Objects possess sensing, processing, and communication capabilities and can thus be employed as one of the major information sources in VMEs [8], [9]. In the considered context of manufacturing and particularly collaboration in the form of VMEs within the manufacturing domain, Smart Objects can, for example, be machines or means of transport which are, e.g., equipped with technology to measure different environmental parameters, detect critical deviations, and wirelessly transmit the measurement results. In the light of the briefly sketched benefits that Smart Objects could provide to VME-based collaborations, we describe the integration and communication possibilities for Smart Objects in the context of VMEs in this paper.

The paper proceeds as follows: In Section 1.2, we present our approach for an ICT architecture for VMEs. We elaborate on possibilities of how to employ Smart Objects in a VME and integrate them in the proposed VME architecture in Section 1.3. Section 1.4 concludes the paper with a summary of our findings and an outlook on future work.

1.2 ICT Architecture for Virtual Manufacturing Enterprise-based Collaboration

The following section describes the architecture model for VMEs, which we take as a basis for all our considerations (cf. [10]). The proposed architecture model is depicted in Fig. 1.1. Within the architecture, we distinguish different components, which are grouped in layers. For the data exchange between these different components, a corresponding message routing infrastructure is foreseen as central element. To ensure the required degree of performance, reliability, and stability for the data exchange via this message routing infrastructure, the correspondingly required Message Routing component is deployed as a Cloud-based service.

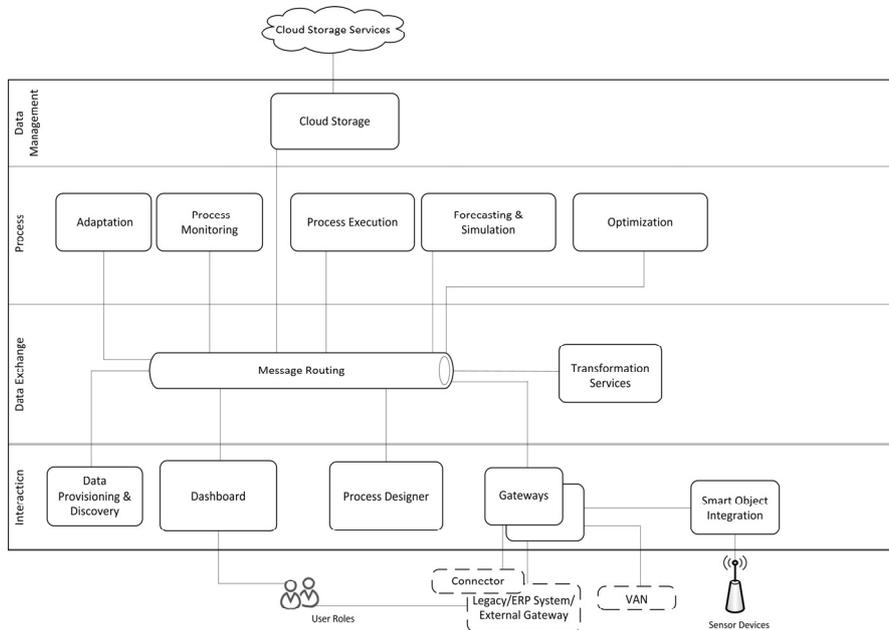


Fig. 1.1. Virtual Manufacturing Enterprise ICT Architecture [11]

Besides the central message routing component, another vital component of our architecture is the Dashboard component. It constitutes the central point for user interaction. It provides the user interfaces to all other components and offers users the functionality to configure, monitor, and access all VME information, whereas we understand users in the context considered here as responsible employees of companies participating in a VME or actively pursuing the participation in a VME.

The initial step to deploy a VME is designing the required processes. For this process design, a corresponding Process Designer component is used. It enables a broker, understood simultaneously as the process designer as well as the person who controls a process during its execution, to design all production steps including all relevant parameters for individual activities. Suitable partners for participation in the VME and execution of single process activities can be found with the Data Provisioning & Discovery component. Furthermore, the Data Provisioning & Discovery component allows users to provide various data about their company, e.g., descriptions of factories, products, delivery time, and costs. A Cloud Storage component serves as the central data storage within the architecture for such and other data. This component allows to create and to use different storage spaces for different data, e.g., binary, structured, semi-structured, and semantic data stores (cf. [10]).

To find individually fitting partners or a combination of partners who are able to fulfill previously designed process steps, a Forecasting & Simulation component is included. This component allows to conduct simulations of the devised process and the corresponding forecasting of process behavior and process results based on

the retrieval of information provided from partner enterprises, e.g., via their ERP systems, and process step-specific information like possible lead times. The results of such process forecasting and simulation support the broker to decide which partner should be included in the process and assigned to which tasks within the process. Further, based on the forecasting values, the broker can estimate the robustness of a process. In addition, recommendations of a set of best fitting partners are provided based on mathematical optimization models, which are realized within the Optimization component.

After the process design has been conducted and partners have been assigned to all required activities, the process execution is initiated by the Process Execution component. To monitor the running manufacturing processes within the VME and compare them with pre-defined values – for example, to detect any deviations – a Process Monitoring component is provided. This Process Monitoring component uses and aggregates information from internal and external data sources. In case unexpected events are discovered, it may become necessary to change running processes. Correspondingly, a Process Adaption component is included in the architecture. Examples of such deviations can be changed prices or updated delivery times of partner services.

As already mentioned, a sound and up-to-date data basis is a fundamental requirement for successful collaboration. In consequence, it may be necessary to provide means to integrate external third-party systems, like an ERP system, within the VME. To enable the required communication with such external third-party systems, Gateways are required. These Gateways provide the connection between the VME's ICT infrastructure and external systems serving as data sources, for example, ERP systems or Smart Objects. Due to the possible heterogeneity of the different systems employed by the various participants within a VME, translation of data formats might be required. Such data transformation is covered by the Transformation Services component within our architecture.

Information is the basis for successful collaboration, as already mentioned, and information is processed in all the above described components. For gathering external information, our proposed architecture includes two major parts: Smart Objects, e.g. in the form of (wireless) sensor devices, and the corresponding Smart Object Integration component. These will be described in detail in the following section.

1.3 Smart Objects as Integrated Data Sources in VMEs

Smart Objects, being objects with sensing, processing, and communication capabilities [8], [9], can provide diverse context data in real-time in a broad range of relevant areas within VME-based collaborations, e.g., in logistics transport processes [12] as well as in storage processes [13], and the manufacturing process itself [14]. Hence, they can contribute to the provision of in-depth and up-to-date process-relevant data. In this context, Smart Objects can be constituted of, e.g., machines or means of transport which are for example equipped with wireless sensor technology to measure different environmental parameters like temperature,

shock, or tilt values during production and transportation. However, to be of any use the data gathered by Smart Objects must be efficiently integrated in the overall VME architecture. Therefore, the provisioning of adequate communication possibilities and means to integrate a corresponding wide range of possibly different Smart Objects is required. Thus, in the following, we provide a detailed description of how the integration of heterogeneous Smart Objects in our proposed overall VME architecture can be realized.

From an overall view of the VME architecture, Smart Objects can be treated like (external) third party systems. Consequently, Gateways (cf. Section 1.2) as mediators between these third party systems and the VME can be employed as a basic means to integrate Smart Objects within VMEs and act as technical bridges for establishing the required communication possibilities, as well. Nevertheless, against the background that Smart Objects can be realized in very different ways, using different hardware platforms, different communication channels and communication protocols and consequently possess quite distinct characteristics, the corresponding heterogeneity of Smart Objects has to be explicitly accounted for. This implies, for example, that different communication protocols as well as different physical communication technologies and data formats have to be supported. Thus, to account for this technological heterogeneity, the usage of dedicated Smart Object Integration components is proposed (cf. Fig. 1.2.).

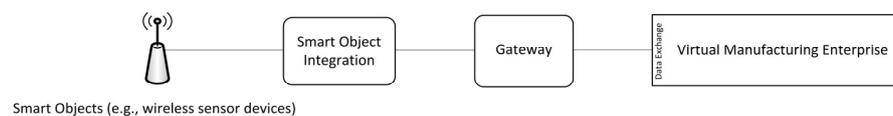


Fig. 1.2. Integration of Smart Objects in the proposed overall VME Architecture

Depending on the characteristics and capabilities of the employed Smart Objects, Smart Object Integration components can be realized on the Smart Object itself or, in case it is technologically not capable of this, a realization in a distributed manner can be used by implementing selected functionalities on the Smart Object itself and realizing remaining functionalities on a Gateway. In this context, specifically the establishment of a physical communication channel has to be provided as well as adaptation of data to different data formats employed by different Smart Objects and Gateways. Thus, the Smart Object Integration component has to comprise a Connector, which establishes the (physical) communication channel between Smart Object and Gateway, and an Integration Engine, which can provide required data transformation operations (cf. Fig. 1.3.).

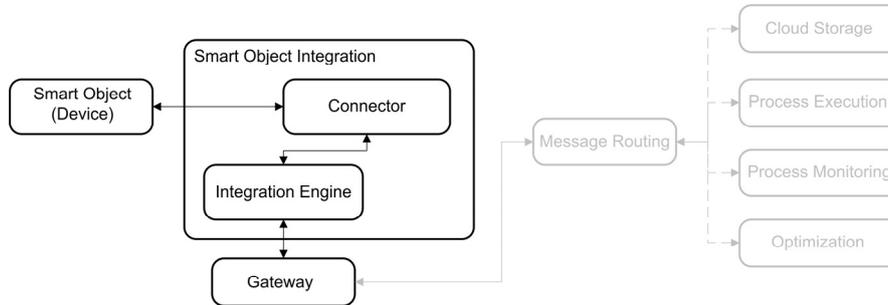


Fig. 1.3. A detailed view on Smart Object Integration

For example, in the case of monitoring storage or transport sub-processes in the context of a manufacturing process, e.g., realized by intelligent packaging using wireless sensor network (WSN) technology [12], [13], it has to be considered that WSN technology is usually designed for short range communication, for example making use of IEEE 802.15.4-based or Bluetooth-based communication. As a consequence, in such a context wide-range communication possibilities and corresponding protocol and data transformations have to be provided to enable data exchange with other components in the VME architecture, for example, to store data in the Cloud Storage. One realization possibility for this is the usage of smartphones as technological bridges, which provide protocol and data transformation as well as wireless communication channels to Smart Objects and into the VME [14].

For the specific data exchange between Smart Objects and the other architecture components, the realization of two communication paradigms is proposed (cf. Fig. 1.4.):

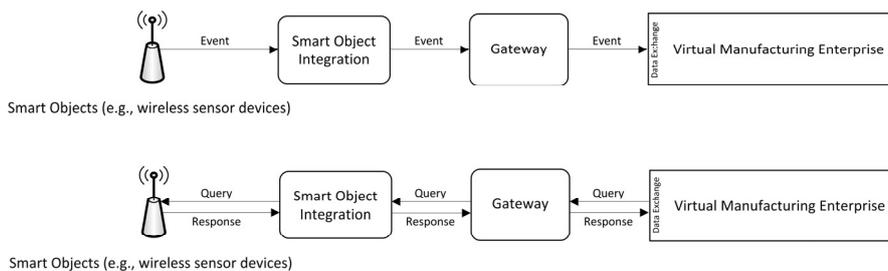


Fig 1.4. Access to Smart Objects Data via Push and Pull Communication

Since users within a VME, respectively system components of the VME architecture, might need certain data from Smart Objects at certain points in time, the possibility for a request/response-based pull communication must be provided. This means that in case a user or a software component requires data, a query can be issued for this data and a corresponding response with the requested data is returned. In this context, Web Service technologies can be used so that a Web Service is called and a corresponding query is issued to the appropriate Smart Object, which in return provides the queried data via the Smart Object Integration

component and the corresponding Gateway as Web Service response. In case smartphones are used as technical bridges between the VME and Smart Objects – as described in the example above –, mobile Web Service technologies could be used in this context, like i-jetty [15] or the Sphinx Mobile Web Server [16].

In addition, usually not only data as answer to specific requests is required, but in the sense of real-time monitoring and data availability, the transmission of alarm messages should be provided in case critical situations have been detected by Smart Objects autonomously. Consequently, besides the described request/response-based pull communication, event-based push communication should be possible as well. This accounts for situations where critical deviations of normal behavior shall be detected locally by Smart Objects and corresponding users and systems should be informed automatically. In such circumstances, Smart Objects make use of their processing capabilities and perform regular checks of their measured status data and compare it by target-performance comparisons to given thresholds, which can be previously specified by domain experts. In case a deviation (usually called an “event”, cf., e.g., [17]) is detected, the Smart Object pushes a corresponding alarm message into the VME system in real time. With such early warnings, corresponding early process adaptations and countermeasures are made possible. Furthermore, the described event-based push communication reduces communication overhead, because no regular polling with high polling rates of data from Smart Objects is required and data is only transmitted if it is necessary. So, appropriate real-time monitoring with required alarm messages and sufficient data fidelity can be ensured employing the described event-based push communication.

The described approach for Smart Object integration allows the exploitation of an always accessible up-to-date data basis of process-relevant data provided by Smart Objects. Thus, it constitutes a central building block for real-time process monitoring and corresponding control within VME-based collaborations.

1.4 Conclusions and Future Work

Small and Medium Enterprises (SMEs) in the manufacturing domain usually face strong competition within the market. To remain competitive, new and agile forms of collaboration, such as Virtual Manufacturing Enterprises (VMEs), are required. For the realization of such collaborations the underlying Information and Communication Technology (ICT) plays an outstanding role. Because current approaches in ICT do not fulfill the requirements of VMEs, we presented an architectural model to enable VME-based collaborations across the boundaries of different SMEs. It consists of different components, with each of them offering specific functionality contributing to enabling a more efficient and effective collaboration within VMEs.

A sound and up-to-date data basis constitutes a major foundation for any kind of successful collaboration. Thus, means to gather and provide a wide range of process-relevant data are required as well in VME-based collaborations. In order to provide a correspondingly broad range of real-time process data, we propose to

make use of Smart Objects as data sources. This allows for a continuous process monitoring in real-time and furthermore enables active data retrieval by user queries when data is needed as well as active pushing of immediate alarm messages by Smart Objects themselves in case critical deviations are detected. In consequence, we described means of how to employ and integrate Smart Objects as data sources in VMEs.

In the future, we plan on prototypical implementations of the described components in cooperation with industry partners. Especially for the Smart Object integration, we strive to evaluate different technologies and implementations, ranging from different smartphone platforms to specialized routers and a prototypical shop floor deployment.

Acknowledgement

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