Elastic Manufacturing Process Landscapes

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Abstract Because of increasing competition and cost pressure, the manufacturing industry is currently undergoing massive changes that are facilitated by the usage of Information Technologies. Two particular aspects are the usage of Business Process Management (BPM) and Cloud technologies concepts in the manufacturing domain. Rapid elasticity is crucial for the enactment of manufacturing processes in the Cloud. This work in progress paper aims at presenting some basic principles of elastic processes in the manufacturing domain. Henceforth, an approach towards adaptive infrastructure provisioning that allows for predefined Quality of Service (QoS) and Service Level Agreement (SLA) metrics in manufacturing Cloud environments is considered.

Keywords: Elastic Processes, Cloud Manufacturing, Cyber-Physical System, Industry 4.0, Cloud Computing

1 Introduction

The manufacturing industry is now supported by means of a systematic approach of Business Process Management (BPM). Since companies in this industry have to cope with volatile process landscapes, the usage of Cloud resources is a promising approach. However, Cloud support is hardly seen in the BPM area, since most BPM frameworks only support a fixed amount of resources for process execution [6]. In the manufacturing domain there is a need of flexible scaling of manufacturing assets [9] (e.g., sensors, Cyber-Physical System objects) and of instant access to efficient and innovative business technology solutions on a pay-as-you-go basis [8]. Such flexible business processes enacted on the basis of smart resource provisioning in the Cloud are called *elastic processes* [1]. In real-world scenarios, a BPM framework for elastic processes, also known as *elastic BPM System* (eBPMS), needs to be able to solve optimization problems, specifically of scheduling and resource provisioning under a potentially heavy load [3]. Elasticity in manufacturing process landscapes establishes a new infrastructure provisioning approach aiming at the achievement of a minimax effect: minimization of the product life-cycle expenses of the manufacturers and maximization of the production efficiency providing agile accommodation of available manufacturing assets to variable demands of the customers [5,4].

This work in progress paper aims at presenting a methodology for elastic enactment of manufacturing processes in the Cloud. The contribution of this paper

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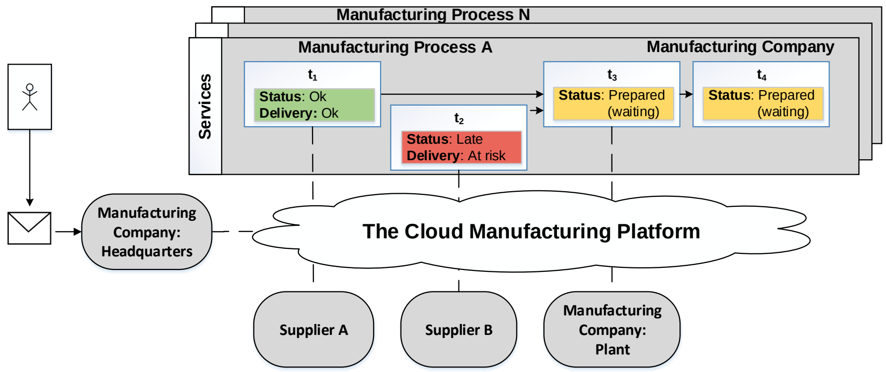

Figure 1. Cloud Manufacturing Scenario

is a motivational scenario of how to apply elasticity principles in manufacturing process landscapes and an overview of instrumentation for its implementation, specifically, of service scheduling and resource provisioning mechanisms.

2 Scenario and Research Questions

To motivate our work we consider a scenario from the manufacturing industry called Cloud Manufacturing. Cloud Manufacturing is a new concept of networked manufacturing that makes use of crowdsourcing and outsourcing models for manufacturing processes. Manufacturing processes here has to be considered as a set of process steps to be performed to create a certain manufacturing product. These process steps are in reality single services, which are responsible for a certain manufacturing asset on the shop floor. Ideally, Cloud Manufacturing offers means to integrate single services of the manufacturing processes from distributed locations as if the complete manufacturing was carried out on the same shop floor (Fig. 1). For this the manufacturers virtualize their single services of manufacturing processes. An integration is possible via a Cloud Manufacturing platform, where these services are presented, advertized, leased, and sold as a part of manufacturing processes maintained in the platform.

The existence and popularization of virtual enterprises sets the challenges to this new concept of Cloud Manufacturing. Virtual enterprises imply plugging together independent virtual factories to manufacture a certain product [7,2]. In contrast, Cloud Manufacturing assumes encapsulation of manufacturing assets into services in the Cloud Manufacturing platform as an inevitable part of its scenario. Cloud Manufacturing provides means to abstract single manufacturing assets, like sensors and Cyber-Physical System objects, and present them as services in the Cloud Manufacturing platform. The aim is to inform about available services on the Marketplace, suggest appropriate services or needed substitutes to the manufacturers, and optimize manufacturing processes.

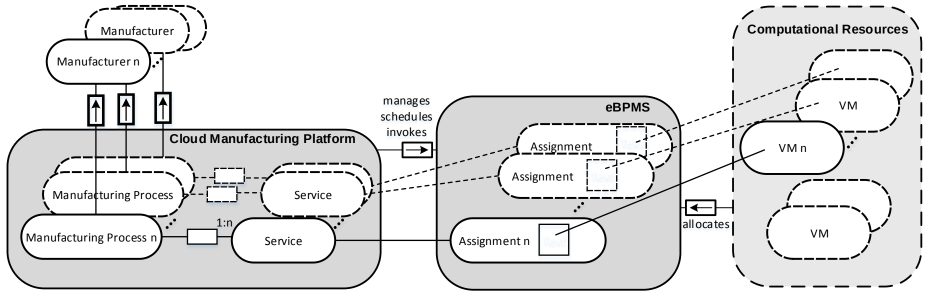

Figure 2. High-Level View on Resource Provisioning in Cloud Manufacturing

The challenge here is that thousands of manufacturers must be simultaneously served. Correspondingly, a large amount of interdependent processes with different QoS and SLA demands may be requested at any point of time. Therefore, elastic processes are a promising approach in Cloud Manufacturing [5]. To adhere to these principles, resource elasticity allowing on-demand scaling of computational resources has to be established inside the Cloud Manufacturing environment. However, computational resource elasticity is not the only dimension to be regarded: cost and quality elasticity bring flexibility in price levels of Cloud services and close the tradeoff between QoS metrics and cost. To enact elastic processes, a BPMS with features to control the Cloud is needed, as depicted in (Fig. 2). Allowing for the demand in computational resources and taking into account QoS demands, such an eBPMS schedules process instances (respectively, the single services used for the enactment of these processes) and allocates Cloud-based resources as necessary. To correlate with elasticity metrics (resources, quality, and cost), it is assumed that the manufacturing processes mentioned in the scenario are composed from single software services instantiated on Virtual Machines (VMs) in the Cloud. With this in mind, achieving elasticity implies leasing VMs when needed, deployment of services onto those VMs, invocation of service instances using a calculated schedule, and releasing resources after services are finished.

In real-world manufacturing processes an eBPMS needs to be able to solve these optimization problems in very short time and under potentially heavy load. Existing exact methods can provide a solution for small-scale scenarios. However, applying exact methods in large-scale manufacturing process landscapes is time-consuming or may not provide any solution in polynomial time, since the underlying decision problem is NP-hard [3]. Therefore an elastic manufacturing process enactment requires reasoning methodologies based on heuristic algorithms. The research question that is tackled in this work is the following: "What is an appropriate reasoning model for smart resource provisioning in elastic manufacturing process landscapes, and what are the methodologies and instrumentation to support an application of this model in the manufacturing domain?" Specifically, this work at progress is focused on presenting an underlying optimization model, and on implementing a heuristic reasoning mechanism for an eBPMS to adaptively select services for service orchestration in manufacturing processes, optimizing service scheduling and resource allocation.

To conclude, the use of elastic processes within the Cloud Manufacturing domain facilitates machine- and human-collaboration in the manufacturing industry. The aim of Cloud Manufacturing is to perform a transformation from production-oriented manufacturing processes to service-oriented manufacturing process networks by virtualizing manufacturing assets as services similarly as Software-as-a-Service or Platform-as-a-Service solutions are already provided by the Cloud providers. Clouds bring benefits to the manufacturing process management, and adaptive elastic enactment of manufacturing processes is intended to take into account QoS and SLA metrics and to perform an optimization and a runtime adjustment of infrastructural components.

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