Cloud-based Virtual Supply Chain

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Abstract

Virtual enterprises and virtual supply chain concepts have been presented to propose solution for a seamless integration and data exchange between enterprises in the supply chain. Cloud computing technology enables centralized data storage and processing for operations and supply chain. This paper presents a prototype implementation of cloud-based virtual supply chain. The proposed solution offers functionality to initiate new sales orders for production, select needed resources, conduct planning and control activities and finally produce parts in virtual model of simulation.

Keywords
Virtual enterprise, supply chain management, cloud manufacturing.

1. Introduction

Today's manufacturing companies operate in complex networks. As each enterprise is focusing on own core competency and global competition requires cost effective operations, many industries have dispersed structure. Design and engineering may be conducted in one company or outsourced to special engineering companies to complete specific tasks. Operations may be conducted at different manufacturing sites supplied by local or global centralized suppliers. Use of same specifications and quality delivered is expected from all entities within the supply chain. Very often a non-hierarchical network with customized products is the target environment (Shamsuzzoha et al. 2016).

Another challenge is that many industries are project based. This means that both product specifications as well as project participants may change in large extend between different delivery projects. The configuration of the supply chain may vary from initial partner selection to final plans. The overall project objectives related to product specifications, cost and timing should be achieved despite these factors. Project management approach can be used to balance between efficiency and responsiveness (Gaudenzi & Christopher 2016).

In order to respond to these needs, information systems are required to have good connectivity and interoperability between enterprises. This paper presents a prototype implementation of cloud-based virtual supply chain. The proposed solution offers functionality to initiate new sales orders for production, select needed resources, conduct planning and control activities and finally produce parts in virtual model of simulation. The data related to design and manufacturing is stored on a centralized cloud solution as well as an up to date status for each order.

2. Literature

Information technology related to supply chains has developed much during the past years. Global access to reliable Internet connection allows building real-time systems with automatic information exchange. Virtual supply chains and cloud computing based solutions are leading this development.

2.1 Virtual supply chains

Virtual supply chain concept has been presented in the light of e-commerce systems to respond to the need for supply chain transparency. According to Gunasekaran and Ngai (2004) the concept includes tools to manage information flow related to planning, sourcing, making, and delivering activities, which are supported by data collection, information processing and information sharing activities for a network of companies. Sharing up to date information along the network by using information technology enables to have a virtual model of supply chain operations in addition to enterprise level systems.

Theoretical models have been developed for information system designers. Manthou et al (2004) presented Virtual e-Chain (VeC) model for collaboration and key concepts to describe each partner's organization, capabilities and roles. Verdouw et al. (2016) designed a solution to support large scale data processing solution tracking and tracking, quality monitoring and planning activities. The approach presents a method for object virtualization and demonstrate several cases related to flower supply chains. Other case study descriptions of virtual supply chains have been presented in the literature. Gunasekaran and Ngai (2004) report the case of Logistics information network enterprise (LINE) which operated on third party logistics serving several international customers on global inventory and logistics services.

Virtual supply chains share many objectives developed in virtual factories, which is a corresponding concept related to manufacturing. Some elementary objectives for the virtual factories are:

(1) possibility to utilize global production system (Fujii et al 2000);

(2) interoperability between companies (Hao et al 2013);

(3) up to date visualization of operational status (Helo et al 2014).

Networked manufacturing, virtual manufacturing and decentralized manufacturing share many aspects with virtual supply chains (Ford et al., 2012, Xu, 2012; Zhan et al 2014). There is empirical support for IT improving the company performance and supply chain agility as concluded by DeGroote and Marx (2013). They studied 193 US manufacturing companies and found the link on responsiveness and IT implementation based on management survey.

2.2 Cloud based solutions

Cloud computing has been applied to several applications. In short, this refers to delivery of information technology resources on-demand over the internet and consuming these resources based on pay-for-use. Cloud Manufacturing is a manufacturing model enabled by the cloud computing (Xu, 2012; Zhan et al 2014). This allows geographically distributed companies collaborating in various aspects during the entire manufacturing lifecycle. Companies can provide and request manufacturing resources and capabilities as servers to fulfill specific customer's requirements.

From technical point of view, cloud manufacturing relates to following implementation technologies (Tao et al 2011, Wu et al. 2013, Wu et al 2014, Wei et al 2013):

(1) service oriented software technologies for data exchange,
(2) virtualization and cloud computing for data storage and processing
(3) Internet of Things for machine level connectivity,
(4) and other advanced computing technologies.

An important part of cloud based concepts is about servitization (Huang et al., 2013; Luo et al., 2011). Operations and logistics within the supply chain can be perceived as services provided to potential network. The ultimate objective is to have a plug and play type of interface between the companies, enabled by shred processes and cloud based infrastructure. Shamsuzzoha et al. (2016) presented a portal based system for creating collaborative platform for design and supply chain information exchange. In this system the portal provided centralized services for partner search, design sharing, planning and supply chain event messaging.

Cloud based solutions combined with virtual supply chain concept allow development of distributed supply chain systems, where each firm can provide services and standardized automatic data exchange should keep transaction costs low.

3. Case example – Cloud-VSC prototype development

In order to demonstrate a cloud-based virtual supply chain in the manufacturing context, a system was designed and developed. The prototype is named as Cloud-VSC and the domain is sheet metal products. First, the requirements for such system were collected from a sheet metal manufacturing company and then based on analysis, functionality was designed. The key requirements were related to exchange of ordering information from design phase of products to actual production, which includes CAM phase to translate the product designs into specific resource level parameters and executable code. This phase has been typically work intensive and required knowledge of machinery. Raw materials used for each product are depending on product types as well as production plans. The purpose of production planning phase is to outline a schedule and generate an executable plan to meet due dates and maintain operational efficiency. Both supply and customer sides in the virtual supply chain should be up to date with current operational plans and adjust operations when needed.

The cloud solution offers functionality to manage designs released to production, resource planning and status monitoring for work in execution. User management allows access based on roles. Figure 1 illustrates the overall functionality of the developed cloud based virtual supply chain system. The system has been implemented by using a centralized Microsoft Azure server and MongoDB cloud database.

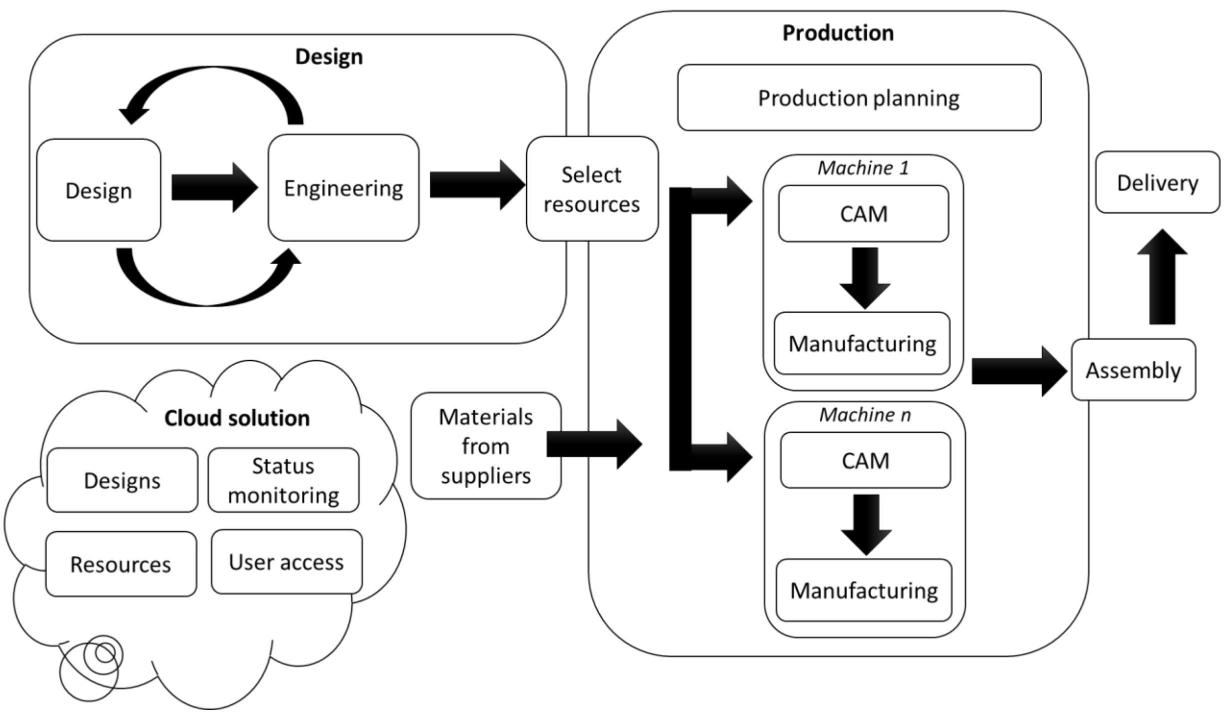

Figure 1. Cloud-based solution controlling the flow from design to production and delivery.

The cloud based system offers communication interfaces for participants. The data models for storage and exchange of information are built specific for sheet metal context and not generalized to other industries. However, the developed prototype system allows creating remote user interfaces to see operation status of the supply chain. This allows users to build virtual "war room" type of user interfaces to oversee the activities. This virtual approach is similar to "Obeya" rooms used in lean manufacturing. Figure 2 illustrates a setup of virtual control room equipped with three PC computers connecting the centralized cloud system. Four separate monitors are presented to view information as follows: -

(1) Production planning and control view displays the current schedule. The functionality of this planning tool is to offer lot sizing and scheduling decisions as a service. This part is related to overall information exchange of orders and run entirely in the cloud as web based application.
(2) Simulation of production is a virtual model of the production. This model is connected to actual production orders released from the customer orders according to production plan stored in the cloud.
(3) Manufacturing execution system (MES) is communicating with the actual machinery and receive status information directly from the line. In this case MES builds the Internet of Things connection to device level. This data is used for operations records, quality records and source for key performance indicators.
(4) Product information, and visualization of parts are displayed in fourth monitor. This is a touch based screen that allows to rotate 3D parts on the screen and give more context for the manager to see a virtual model of the actual product in addition to virtual view of the production and supply chain.

The control room creates a view on the virtual models of product and process, which should have corresponding status in the real supply chain.

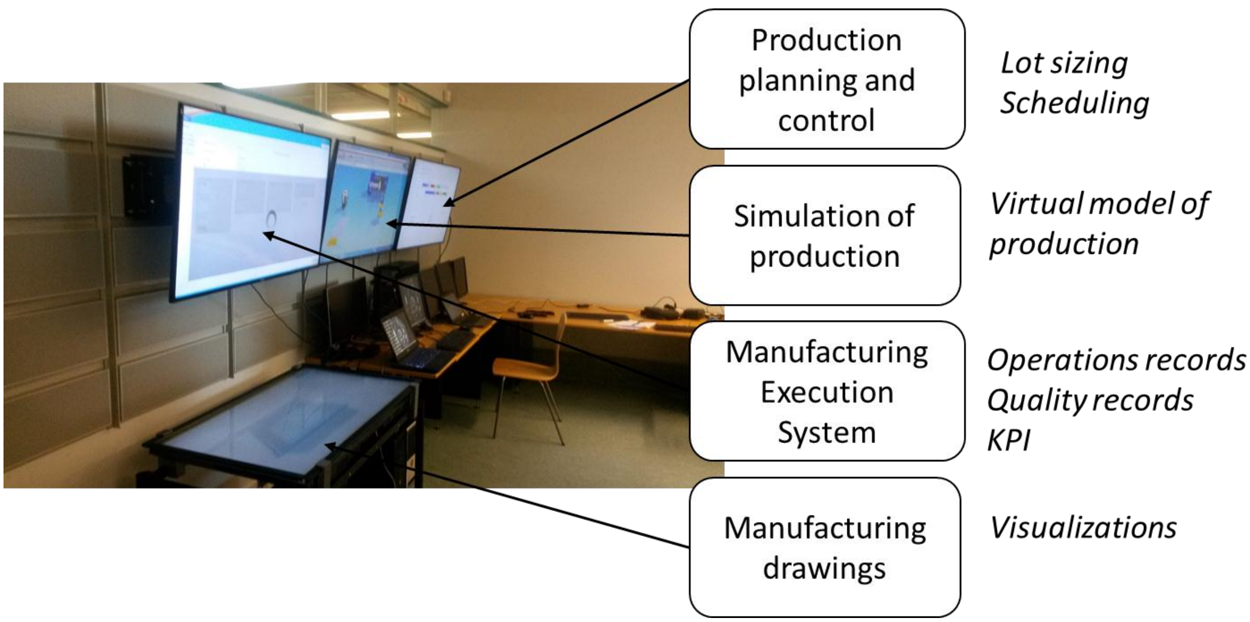

Figure 2. User interface of cloud based "war-room" for virtual supply chain.

Cloud based virtual supply chain system can bring the virtual model of both the product and supply chain to locations beyond a single site or an enterprise. As up to date information and virtual models are maintained in a centralized cloud, the dynamics and agility of the supply chain should be enhanced by better response. Table 1 shows aspects enabled by virtualization of supply chain and cloud based solution in dimensions of product, process and performance. Virtualization of products, processes and performance are increasingly available as most part of the data is in digitalized format already. Standardization is important to enable the benefits of having digital twins of physical and digital models of product and process. Cloud based solutions are centralized by nature, but the benefit is to have domain specific systems which have scalability and flexibility.

Table 1. Product, process and performance aspects enabled by cloud-based virtual supply chain system.

	Virtual supply chain	Cloud based solution
Product	• Virtual model of product visualization • Virtual model of product data • Resources needed • Availability of materials	• Centralized storage of product data
Process	• Virtual model of the supply chain - simulation	• Centralized storage of jobs and job status information • Data exchange with factory level MES • Production planning as a service • Data exchange with ERP systems related to order status and process events
Performance	• Virtual dashboard for supply chain and factory level items	• Key performance indicators analysis and benchmark as a service

4. Conclusions

Cloud based virtual supply chain environments are not yet commonly used despite the availability of software building blocks (Shamsuzzoha 2016). The developed cloud based virtual supply chain prototype system has demonstrated possible functionality of centralized sheet metal manufacturing related system. The experiment has gained some interested feedback from the industry who is managing global manufacturing networks where response on both new product introduction phase and actual product delivery phase is important. The level of virtualization seen in 3D printers is a good objective for traditional manufacturers to approach. Translating product models to printing facilities and monitoring the progress of the work remotely could be done in similar way by using a cloud based virtual supply chain system.

As distributed manufacturing results on configurable networks and products are complex, both standardization work and domain specific approaches are needed. Companies engineering manufacturing solutions can have a potential on this by applying IoT. Another challenge is the dependency on Internet connection when all important master data is stored in the cloud. Further work on local synchronization and data security is needed for real world applications. However, despite its limits the prototype implementation has shown that virtualization of supply chains and cloud-based solutions have a good potential to develop a multi-company hub for managing the real supply chain.

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Biography

Petri Helo is a Research Professor of the Logistics Systems Research Group at the University of Vaasa, Finland. He received his PhD in Production Economics from the University of Vaasa, Finland in 2001. He is also involved in developing logistics information systems at Wapice Ltd. as a partner. His areas of expertise include agile manufacturing, technology management and system dynamics. He has published several research papers in international journals and conference proceedings.

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