FROM CLOUD MANUFACTURING TO CLOUD-BASED MANUFACTURING EXECUTION SYSTEM

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Abstract: *Cloud manufacturing, a service oriented, customer centric, demand driven manufacturing model is explored in both its possible future and current states. A vision for the field is documented and the current state of technology is presented from academic viewpoints. This paper illustrates the needs and challenges for the management of distributed manufacturing in a multi-company supply chain and processes considering new IT systems. Requirements are collected from literature in the field of current ERP/MES system drawbacks, advantages, needs and challenges.*

Keywords: CLOUD, CLOUD MANUFACTURING, DISTRIBUTED MANUFACTURING, SUPPLY CHAIN AND PROCESSES

1. Introduction

The force of globalization has served to instantaneously connect peoples from all across the globe, bringing with it game-changing opportunities to share knowledge and expertise to benefit in a collective manner (sometimes called share-to-gain). Friedman [1] explains that the latest globalization phase, which he coins Globalization 3.0, began around the year 2000 and was enabled by the expansion of the internet on a global basis during the dotcom boom. According to Friedman, Globalization 3.0 is defined by individuals and small groups from across the globe collaborating in areas once dominated by less-connected western economies.

Many engineering paradigms have evolved as result of Globalization 3.0, some of which are mentioned by Tapscott and Williams (mass collaboration and self-organization, for example). Of the many paradigm shifts still in their infancy, cloud manufacturing (CM) will be the focus of this paper [8,9]. CM, as will be defined shortly, benefits from the share-to-gain philosophy as a wide number of manufacturing resources and expertise are shared to provide consumers with enhanced experiences. CM follows naturally from the introduction and success of cloud computing, for which the National Institute of Standards and Technology (NIST) offers the following definition [7]:

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

Today's business supply chains for complex products are likely to involve a number of autonomous organizations. The competitive market requires that these supply chains are highly agile, effective and efficient. Agility and effectiveness are obtained by forming highly dynamic virtual enterprises (VE) within supplier networks [14]. All these highlight the importance of information technology in integrating suppliers and other partners' firms in a virtual enterprise and supply chain [13]. Interoperable enterprise systems are the key to enterprise integration. Supply chain management (SCM) is a way of obtaining horizontal integration benefits without its formal ownership costs. SCM, the integration of key business processes among industry partners, adds value to customers, tightly links together several consecutive elements of the industry value chain, from upstream suppliers, to subassembly manufacturers, to final manufacturers, to distributors, to retailers, to end-customers, in order to make the processes more efficient and the products more differentiated [11].

The internet has brought forth numerous possibilities to increase this flow of information, and encouraged companies to form closer integration of their information services (IS). The adoption of the internet and turbulent market conditions have forced small and medium-sized enterprises (SMEs) to adapt their way of undertaking business, from traditional practice to e-business [2].

This paper will focus on the needs and challenges for the management of distributed manufacturing in a multi-company supply chain and processes considering new IT systems.

2. Current situation and approaches

CM will require interaction between three groups: the users (consumers), application providers, and physical resource providers. The needs of users will be matched with the capabilities of resource providers through the application layer. This three-group model represents the simple supply-demand market that will motivate the existence of CM. The provider–consumer model is shown in Fig. 1.

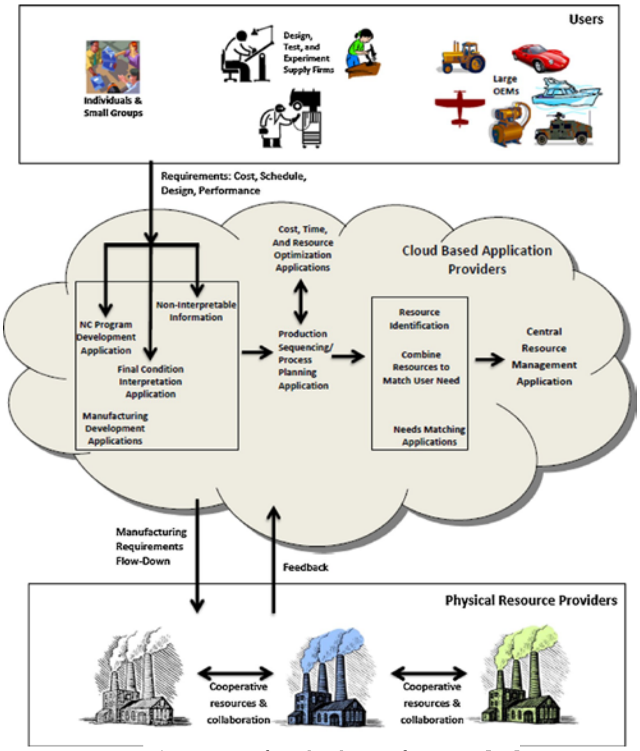

Fig. 1 *Vision for Cloud Manufacturing [14]*

Users are the consumers in CM; these individuals or groups have the need to manufacture something, but do not possess the capabilities to do so, or they possess the capabilities but stand to gain a competitive advantage by utilizing CM. Users can range anywhere from individuals to large OEMs – any group that can generate engineering requirements to be used in a manufacturing setting can participate in CM partnerships. These engineering requirements, which describe the desired object and its final conditions, are provided to the cloud based application layer for interpretation.

The cloud based application layer is responsible for managing all aspects of the CM environment and interprets user requirements into data required for production of the desired objects. Furthermore, production planning and sequencing can be carried out through automated applications that determine the numerous production paths that could lead to the desired object. Finally, the application layer is responsible for locating the required resources, pending them to the engineering job, and managing resources in the event of a service interruption. The application layer will be managed and controlled by application providers, who offer their services as an intermediary between users and resource providers for a portion of the product profit.

The possible impact of CM on three key sectors including engineering design, manufacturing, as well as marketing and service are formulated [10].

Engineering design: In the short term, the benefits of CM on engineering design are ubiquitous access to design information, improved efficiency, and affordable computing resources. In the long term, the impact area is collaborative design which is to support engineering design in geographically dispersed environments.

Manufacturing: In the short term, the benefits of CM on manufacturing are improved resource sharing, rapid prototyping, and reduced cost. In the long term, the impact area is distributed manufacturing.

Marketing and service: In the short term, the benefits of CM on marketing and service are reduced time-to-market, improved service, and enhanced user experience. In the long term, the impact area is customer co-creation.

In order for manufacturing enterprises to create value through collaboration, there is an increasing need to establish a new form of information, knowledge and resource sharing mechanism that emphasizes the generation and realization of various product stakeholders' value. CM has the potential to create new marketing channels for information and resource sharing which will transform the traditional product realization process into a value co-creation process. Specifically, the co-creation process enhanced by CM can engage customers, designers, manufacturing engineers, and production managers to communicate with each other through social media such as Facebook, Twitter, Blogs, and online forums.

As cloud manufacturing (CM) has been recognized as a promising paradigm for the next generation manufacturing systems, many research studies on CM have been conducted. This review aims to highlight the motivations and drivers of CM, propose a strategic vision, present current status of CM, and point out some of the key future directions.

The rapidly changing needs and opportunities of today's global market require a higher level of interoperability in data systems to integrate diverse information systems to share knowledge and collaboration among VEs. This includes partnership with the business partners which live in this dynamic environment on a day-to-day basis. Although the core of VE is to effective exchange information, it is not an easy task due to the heterogeneity of information resources [22].

The needs of networked supply chain coordination are associated with innovative processes in which new materials and components are designed. There is a need for interfaces for intelligent applications that will transfer the information into knowledge that can be used in decision making. Employees must be integrated with user-based interfaces with intelligent devices and applications when there is a need for new education methods that will be used in fast information distribution [21]. Panetto and Molina [21] suggest that the future of SCM software lays in malleable and intuitively user friendly software tools that can become an integrating factor, rather than a barrier, to development. Jacobs and Weston [16] predict a greater focus on SMEs in the development path of ERP developers, something that may bring simpler and lighter commercial versions to the market and end up making this kind of solution more attractive.

Manufacturing execution systems are software packages used to manage factory floor material control and labor and machine capacity, and to track and trace components and orders, manage inventory, optimize production activities from order launch to finished goods, etc. Some of the larger ERP-solutions providers have incorporated MES-related capabilities to offer this specialized functionality and fill the shortcomings of traditional ERP-solutions [12]. The integration of ERP and MES requires the easy sharing of information across the systems. MES systems typically take production orders from ERP systems and link quality control, scheduling and material information. Receipt of goods and some low level material handling functionality, including serial number generation for products may be supported as well. Performance dashboards and advanced statistics reporting may be included in the system to provide an overall view of production cells and lines. It is an information bridge between planning systems and manufacturing shop-floor control systems [20].

User interface development has also been discussed in the literature. User interface and general usability of MES software systems is a very important feature. For example, Cooper [3] has patented some transaction control features of a user interface. Later, when web technology has matured, web access systems and mobile terminal access have received increasing interest. There are patented solutions available on this side as well [4]. Lan et. al. [18] propose an integrated manufacturing service system which is a java-enabled solution, together with web techniques, employed for building such a networked service system. Simply integrating ERP with MES not solves the potential issues, such as the time lag between the actual occurrence of shop-floor control data and its recognition in the front office ERP systems at the management level. Broadly speaking, a clear picture of the entire shop floor is not available in real-time. High level managers cannot see what issues exist on the floor and what inventory shortages might impact delivery to the customers.

On the other hand, the information from front office may not be communicated to the shop floor until the MES download the data from ERP. Changes in ERP have been made in real-time do imply the real-time in MES. This disconnection may cause other issues. Due to the lack of capability of adaptability in current ERP systems and MES, new technologies are introduced to improve the capability.

The main benefit for companies in choosing a cloud-based solution is that almost no local IT resource investment is required. Companies can utilize the flexibility of cloud resources dynamically to meet peak demand without investing in in-house resources. Also, a cloud solution can handle the weaknesses of their current system regarding redundancy and high upgrade cost because Cloud is a virtualization of resources that maintains and manages itself [24,26].

Nevertheless, most of the challenges and risks are basically security concerns due to the migration from one business model to another. Besides, companies lose the governance over their valuable data and they have to accept that the cloud solution provider will control a quite large number of important issues and areas of their own business process. Some relevant issues are vendor lock-in, compliance challenges, and cloud provider acquisition [17,19].

Cloud computing is already practical in many business applications. Nowadays the major application vendors are actively building cloud-based application infrastructures, exploring relationships with cloud hosting providers.

For manufacturing companies, cloud-based MES solutions allow the standardization of manufacturing sub-processes across multiple plants in many countries. This concept is attractive because it acquires manufacturing assets around the world and leverage best practices internally within the entire organization [15]. However, there are still many challenges connected with bringing MES to cloud. MES tends to be highly industry and process-specific, which means highly customized for a specific process running at specific plants. It needs to be able to quickly change when processes or requirements change. However, customization is still a limitation for cloud-based solutions [19].

To summarize the results of the review from cloud technology point of view can be seen that the mentioned requirements have some features, which are not part of standard MES systems and where cloud technology could offer some solution:

- Routing of manufacturing operations may change within the supply chain and the companies that need to access the data may vary from time to time.
- Quality and test data need to be shared between manufacturing partners along the routing.
- The participating companies of manufacturing network may vary from project to project and ability to reconfigure the access should not require IT projects.

3. Prototyping a solution

To fulfill the requirements and challenges presented, software architecture is presented to illustrate a potential solution. Although the solution focused on key requirements, it includes new business process and planning, sequencing algorithms, and a new infrastructure based on existing MES technology. If successfully implemented, such a software solution could prove very beneficial to multi-company SME-intensive networks (fig.2).

In the proposed solution, the cloud plays a role as a platform in the evolution of MES. Since cloud computing is already practical at the business application level, it is very reasonable to build MES based on web service and provide a standard for information sharing/transferring environments. Cloud technology will be adopted in order to support monitoring, information exchange and also other real-time interactions.

Andon systems are used when a problem occurs in the production lines and are core elements in the proposed solution. “Andon” is a visual control that is used to notify the status of machines and manufacturing line in the manufacturing process. This concept was first invented by the Japanese for Jidoka (automation in English) and refers to the principle of stopping work immediately when a problem occurs. Andons are used by Toyota and quickly adopted by many Japanese and American manufacturing companies [23,25]. They can be used to control the quality of production and improve the defect detecting processes.

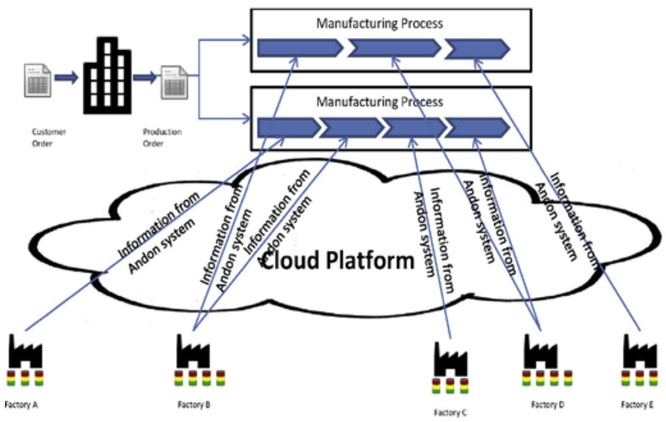

Fig.2 *Integrating ERP systems with MES systems [15]*

Most manufacturing companies use ERP or an equivalent system to determine product manufacturing and the production planning process. The proposed solution is used herein to translate this plan into work instruction, and elaborate the method of dealing with real resources and real plant floor execution. The proposed architecture is for a web browser based MES system for distributed (multi-site) production planning and control system. The key features of the system include:

- Support for multi-site manufacturing,
- No installation required-a web based system,
- Connections to external systems such as ERP,
- Tracking and tracing within the entire extended enterprise.

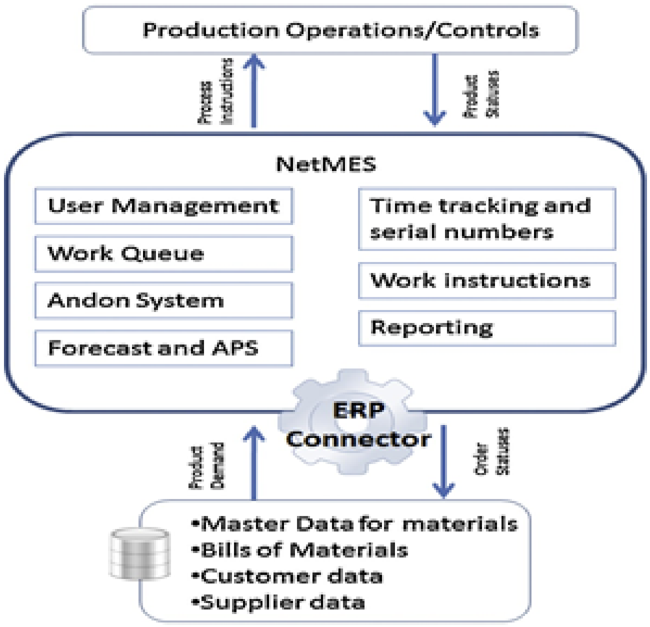

Figure 3 Key functionality blocks [15]

Figure 3 *shows the planned key functionality blocks in the proposed solution: (1) user management, (2) work queue, (3) Andon system, (4) forecast and APS, (5) time tracking and serial numbers, (6) work instructions, (7) reporting and last but not least, (8) ERP connectors.*

4. Conclusion

A cloud-based MES infrastructure to integrate information exchange between companies has been proposed for distributed manufacturing. The proposed system can operate in situations where suppliers need to input significant manufacturing related information and provide this to other participants of the delivery along the supply chain. The advantages can be summarized as follows:

- Users only need to install web browser to use this cloud-based solution. It minimizes technical complexities and infrastructure.
- It provides an easier way to supply chain and manufacturing execution and control and it maximizes the benefits of IT systems.
- It provides a flexible platform to integrate different applications.
- Different users can have different customized views to monitor different information.
- It support the decision making process and simplifies the business processes.

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