Changeable, Agile, Reconfigurable & Virtual Production

Development of a Novel Solution to Enable Integration and Interoperability for Cloud Manufacturing

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Abstract

Nowadays, manufacturing enterprises have been faced with a globalized competitive environment. In this fierce condition, Cloud Manufacturing paradigm emerged as a promising concept for competition. It provides effective solutions and tools for manufacturing enterprises to collaborate in globalized market. The revolution that Cloud Manufacturing has created is based on the redefinition of the classic methods to those which are appropriate for todays' modern and globalized manufacturing environments. In parallel with cloud-based revolution, the expansion of internet-based technologies has been started. These technologies previously have been applied in many fields and resulted in interoperability and integration among different technological solutions. This promotes this paper to fill the gap which of technologies in Cloud Manufacturing solutions as well and enabling integrated and interoperable communication among manufacturing clouds. This paper has focused on the idea of manufacturing cloud integration and interoperability. The paper has studied the dominant Cloud Manufacturing researches to find the opportunities for proposing a novel solution. This solution is capable to resolve the integration and interoperability consideration for different manufacturing clouds. The paper has applied the EDI X12 standards for insuring an integrated and standard data format for its contribution. An example in area of Supply Chain Management will be discussed to show the capabilities of the proposed solution.

1. Introduction

Todays' manufacturing markets face with a globalized environment which is extremely borderless and highly fluctuated [1-3]. One of the promising solutions which effectively can handle such concerns in manufacturing industry is Cloud Manufacturing paradigm [4, 5]. Cloud Manufacturing is an idea based on Cloud Computing paradigm [6]. Cloud Manufacturing causes a great impact on industry and changed the way that enterprises fulfill their businesses [7]. Researches indicate cloud-based solutions as promising tools for today's globalized manufacturing environments [8, 9]. Of the most dominant characteristics of Cloud Manufacturing is known to be its service oriented approach which has created new opportunities for manufacturing enterprises to provide or acquire resources as service [10]. These providing and acquiring happen among manufacturing clouds. So, such interactions among manufacturing clouds need to be

considered. A major reason which prioritizes these interactions is extreme growth of manufacturing clouds. As the number of manufacturing clouds increases, the need for integration and interoperability among manufacturing clouds intensifies.

On the other hand, there is a new trend in the application of Internet of Things (IoT) concept in industry sections, especially in cloud-based solutions [11]. Basically, IoT has been developed to create an internet-based environment [12]. Despite of preliminary expectations from IoT to connect everything to exchange information through internet, recent researches have discovered IoT as a key enabler for industrial purposes [13].

Considering the requirements for integration and interoperability for manufacturing clouds, the paper focuses on proposing a platform which supports manufacturing clouds' interactions in an integrated and interoperable manner. In this platform, IoT will be introduced as a bed which causes

heterogeneous manufacturing clouds components interact with each other by means of internet-based tools and its capabilities.

Proceeding the paper will review Cloud Manufacturing related researches in Section 2. The review will focus on the ideas which have applied Internet-based solutions for providing service oriented mechanisms in Cloud Manufacturing environments. Considering the gaps of the studied researches, the paper will propose a novel solution for enabling a Cloud Manufacturing platform to help integration and interoperability in Cloud Manufacturing environments in Section 3. Finally, a case study by focusing on Vendor Managed Inventory (VMI) concept has been considered by the application to clarify the aspects of this contribution using the EDI X12.

2. Review of Related Researches

In this section, the paper has conducted a review on Cloud Manufacturing researches. The studied papers have been discussed from contribution aspects, IoT utilization point of view, and the environment that clouds operate. The summery of the review presented in Table 1.

Wang *et al.* [14] have developed function block-based integration mechanisms to integrate various types of manufacturing facilities. It considered a cloud-based manufacturing system to support ubiquitous manufacturing which provides a service pool for maintaining physical facilities in terms of manufacturing services. The proposed framework has established an integrated manufacturing environment to provide hardware, like robots, as a service. The paper also has provided a flexible architecture for a Cloud Manufacturing system which contributed to the application of Cloud Robotic paradigm.

Yu *et al.* [15] have applied a Cyber Physical System (CPS) to link informational aspects of a cloud to physical aspects of a Computer Integrated Manufacturing (CIM) system. The CPS includes collaborating computational elements which control

physical elements of the CIM system and help to share its infrastructures in Cloud Manufacturing environment.

Chen *et al.* [16] have suggested Enterprise Resource Planning as a service and named it as CloudERP. The proposed CloudERP has a platform which provides ERP related software and hardware as a service. The paper also proposes a web-based solution for automating ERP service customization process and in this way has improved the serviceability of the ERP software and platform.

Stock *et al.* [17] have studied the basic requirement of Small to Medium Manufacturing Enterprises (SMMEs) and have followed the concept of a cloud-based architecture to insure the availability of SMMEs software in a Cloud Manufacturing environment. They have addressed some of relevant infrastructures for a manufacturing clouds such as security, equipment, IT management, workflow and operational issues to make a platform to facilitate collaboration in a cloud-based environment.

Huang *et al.* [18] have proposed a platform, named as SME-oriented Cloud Manufacturing Service Platform (SME-CMfgSP), which has considered key technologies for implementing a manufacturing cloud platform in details. The architecture of the platform classifies a manufacturing enterprise into the twelve layers. The architecture presents the structure of a SME to provide its resource as a service. The platform has used internet-based tools in the last layer (twelve layer) to connect to the other enterprise but has not encountered the integration and interoperability considerations.

The reviewed researches show there is a gap on the application of cloud-based solutions for enabling interoperability and integration in Cloud Manufacturing environments. According to prior studies on Cloud Manufacturing paradigm [19-21], there are some efforts to enhance manufacturing cloud communications and interactions to develop integration and interoperability among them. But they are still lack of a platform which considers the different

Researchers	Contribution	The role of the Internet	Multi-Cloud Environment Characteristics
Wang *et al.* 2016 [14]	Providing robots in the Ubiquitous Manufacturing environment with utilization of the function block-based integration mechanisms.	Proposes an architecture which supports providing Infrastructure as a Service over internet network.	The paper has a hybrid cloud perspective and integrates hybrid manufacturing clouds to provide Infrastructure as a Service, but does not consider a multi-cloud view to integrate different clouds of the environment.
Yu *et al.* 2015 [15]	Development of a Cyber Physical System (CPS) to share its hardware resource on Cloud Manufacturing environment.	The paper does not consider interaction aspects for CPSs and does not state that the CPSs environment is utilize from internet or not.	The paper highly contributed to distributed manufacturing concerns and providing CPS capabilities through Cloud Manufacturing but does not consider existence of different manufacturing clouds.
Chen *et al.* 2015 [16]	Proposes a platform for Enterprise Resource Planning (ERP) as a Service through Internet-based environments.	The paper provides a platform for ERP systems which serves ERP system via Internet and composes a web service for ERP providers and users.	The paper follows providing a serviceable ERP system over Internet-based clouds, but there is not considerations on integration and interoperability for CloudERPs.
Stock *et al.* 2014 [17]	Proposing a Cloud-based platform to facilitate providing manufacturing hardware as a service.	The platform developed for providing hardware as a service in a cloud environment and does not considerations for cloud connections.	The platform has not a multi-cloud view for providing its resource as a Service. It has developed a single cloud without any consideration on cloud interactions.
Huang *et al.* 2012 [18]	Developed a SME-oriented Cloud manufacturing service platform (SME-CMfgSP) for small and medium sized enterprises in Cloud manufacturing environment.	The platform utilizes Internet to connect manufacturing clouds and sharing their provided services.	The platform highly dedicated to the creation and implementation of a cloud for small and medium sized manufacturing enterprises and had not consideration in SME-CMfgSP for integration and interoperability of manufacturing clouds.