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Interoperability as a key enabler for manufacturing in the cloud

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Abstract

The emerging cloud paradigm has a prominent effect on manufacturing. The move from hardware bound systems to requirements based service provision is enabling the transition to cloud manufacturing. A networked manufacturing service provision system requires vast amounts of information to be exchanged in a non-ambiguous and timely manner to meet production requirements. In this paper, interoperability is identified as a key enabler for cloud manufacturing and a framework for realisation of interoperability across heterogeneous computer aided manufacturing systems is proposed. Using this framework, manufacturing resources can be shared by a large number of clients based on requirements and priorities.

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1. Introduction

Cloud Manufacturing, has been introduced as the emerging manufacturing service-oriented paradigm. This paradigm utilises cloud computing technology along with Internet-of-things and state-of-the-art manufacturing technologies to integrate manufacturing resources and capabilities to offer on-demand, reliable and affordable manufacturing services for the entire manufacturing product life cycle [1]. Through the intelligent integration of manufacturing resources and capabilities, a shared pool of resources is created in the cloud manufacturing platform, promoting cloud users to acquire manufacturing tasks as a service [2]. The integration of the deployed manufacturing resources and capabilities is achieved through virtualisation, as resources are enabled for access as cloud services [3]. Manufacturing resources (i.e. equipment, materials, software, knowledge, and skills) and manufacturing capabilities (i.e. design, production, management, and communication) are advertised and shared on a large unified network using the internet.

Interoperability is therefore one of the essential requirements for enabling cloud manufacturing application [4], providing a framework of open standards and application protocols to enable easy migration and integration of manufacturing applications and data between different cloud service providers [5].

In this paper, the current architectures for forming cloud manufacturing systems are discussed together with their enabling technologies. An interoperable framework for cloud manufacturing resource sharing system (C-MARS) is then defined, aiming to execute various part designs with different features, through the intergeneration of heterogeneous manufacturing resources. formerly, in section 4 a discussion of challenges in the implementation of the framework, followed by the conclusion and future work in section 5.

2. An overview of cloud manufacturing

Cloud manufacturing requires collaboration between various technologies in order to enhance its capabilities to execute complex, large-scaled manufacturing services and tasks [6]. The fundamental technologies used are cloud computing and the Internet-of-things, as the former provides computing as a service to enable computer based manufacturing applications to be dissociated from hardware and the latter allow resources to be formed into networked technology structures [7]. Multi-layered architectures with modular approach are commonly used to build cloud manufacturing systems[4]. Ding et al [8] proposed a compact three layered architecture that further decomposed into more specific layers: A cloud service provider layer that is divided into manufacturing resource layer, virtual interface layer, and virtual resource layer to collect and virtualise hardware and software manufacturing resources on three subsequent layers, a cloud service centre layer which supports the system with the available services and functions by publication, retrieval, aggre-

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gation and scheduling; and, a cloud service demander layer that handles the interface between the system and different cloud users. Jiang et al [9] introduced a five layered structure of basement layer; access layer; functional layer; portal layer; and, application layer, supported by cloud-agent technology within the functional layer to control and coordinate various service transactions within the cloud manufacturing system. This was followed by Wang and Xu [10] who approached the intelligent-agent technology within the smart cloud manager layer to analyse, optimise and control the cloud manufacturing service interactions between the user layer and the manufacturing capability layer. Lv [11] analysed a four layered architecture based on multi-view model that integrates different views (function view, resource view, information view and process view), each view depicts different aspect of the cloud manufacturing architecture. Figure 1 summarises the typical layered structure of cloud manufacturing systems and provides examples of components in each layer. The application layer encompasses cloud enabled applications such as new product development where the initial order for part production is issues. The application interface layer which is the topmost layer of the cloud manufacturing middleware, manages the order received from the application layer and coordinates with the core service layer to match the part requirements with virtual resource capabilities. The core service layer then passes the order to the virtual machine tool on the virtual resource layer that corresponds to one or several cloud enabled physical machine tools. The order which is now translated into executable instructions on the physical machines is executed and the produced parts are delivered to the user who initiated the order.

2.1. Service management

The management of services within cloud manufacturing is considered to be a critical issue, as it requires effective managing and coordinating between the manufacturing resources and manufacturing capabilities to execute on-demand services through the cloud [4]. Additionally, integration of resources and capabilities can occur between different clouds, as Zhang et al [1] identify, there may be two types of clouds (public clouds and private clouds) and therefore resources interact depending on the business needs. In order to ensure service performance of cloud manufacturing, various methods have been proposed: Wang and Liu [12] analysed the ontology of virtualised manufacturing resources; Liu et al [13] deployed a multi-agent system to implement manufacturing resources sharing within

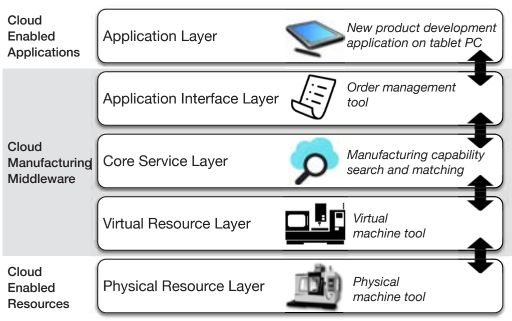

Fig. 1. Generic cloud manufacturing architecture with examples for each layer

a three different cloud manufacturing models to suit different sized enterprises (small, medium, large); Jiang et al [9] similarly introduced agent technology to reflect capabilities and behaviour in manufacturing resources, thus integrating its services within the cloud manufacturing; and more recently, Tao et al [14] addressed the uncertainty issue in the service composition and optimum selection of manufacturing resources, by applying an algorithm based on the adaptive chaos operator.

2.2. Interoperability

ISO16100-1 defines interoperability as the ability to share and exchange information using common syntax and semantics to meet an application-specific functional relationship across a common interface. Wang and Xu [15] proposed a four layered architecture for cloud manufacturing to address interoperability: (i) manufacturing resource layer; to abstract manufacturing capabilities into self contained modules, in order to be launched depending on user request. STEP/STEP-NC was applied to enhance the portability and longevity of the manufacturing resource data modelling, subsequently, data is backed up in the storage cloud database that is embedded within the layer; (ii) virtual Service layer; it organises the service request information into a compliant format; (iii) the global Service layer; promote Enterprises to gain a logic control over the work-flow and processes of the service; (iv) and, the application layer that provides the interface between the cloud user and the ICMS. Wang et al [16] addressed interoperability for manufacturing task description within the cloud manufacturing, by applying an ontology based framework. Lu et al [17] addressed interoperability through a Hybrid Manufacturing Cloud architecture that promote users to utilise different cloud modes; public, community, and private clouds. Enabling cloud users to have full control over the related resource sharing authorisation to enhance trustworthy and patent protection. Li et al [18] linked the cloud manufacturing models with STEP standards and application protocols. What is achieved previously in addressing interoperability within the cloud manufacturing field is the proposing of theoretical frameworks for the manufacturing tasks description, the switching between different cloud modes (public, community, and private cloud), and the approaching of a generic frame work of how information flows within the cloud manufacturing system. Consequently, a development of a interoperable cloud manufacturing framework that is able to identify the major machine tool types (i.e.manufacturing resources), their controller type and capabilities (i.e. table size, number of axis, maximum tool size, etc.) is required. This will ensure that only parts which are manufacturable being allocated to the available resources and additionally, can accept new models of manufacturing resources autonomously (Independent resource model that is only defined by available resources). Furthermore an investigation is still required to identify the communication and interaction protocols of the collaboration structure that merge service providers and service users within cloud manufacturing system. As the current literature lacks of adequate studies regarding the improvement of cloud manufacturing architecture, collaboration techniques, and resource sharing. Consequently, the development of state-of-the-art models, algorithms and techniques is a necessity in order to extend traditional manufacturing industries to be adopted within the cloud environment. Additionally, logical and real experimentation is needed