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AN INVESTIGATION INTO THE CLOUD MANUFACTURING BASED APPROACH TOWARDS GLOBAL HIGH VALUE MANUFACTURING FOR SMES

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ABSTRACT

Considering the high labour costs and intensive competitions in the global market, improving the effective deployment of innovative design and manufacturing and utilisation of all existing technical information, for the full life cycle of the product, is essential and much needed for manufacturing Small and Medium sized Enterprises (SMEs) in particular. Cloud Manufacturing , as a powerful tool supported with 'big data', will likely enable SMEs to move towards using dynamic scalability and 'free' available data resources in a virtual manner and to provide solution-based, value-added, digital-driven manufacturing service over the Internet. The research presented in this paper aims to develop a cloud manufacturing based approach towards value-added, knowledge/solution driven manufacturing for SMEs, where there are many constraints in engaging responsive high value manufacturing. The paper will present the framework, architecture and key moderator technologies for implementing cloud manufacturing and the associated application perspectives. The paper concludes with further discussion on the potential and application of the approach.

Keywords: Cloud manufacturing, Virtualised resources, Service-orientated manufacturing.

1 INTRODUCTION

In an era of globalisation, design and manufacturing of the product cause all manufacturing organisations to face issues such competition in market, emergence of new technologies, and better utilisation of existing resources. To deal with complexity in the manufacturing processes and manage the market diversity, manufacturing organisations try to develop and realise scalable integration of many kinds of manufacturing resources (Wu and Yang 2010). Managing and sharing manufacturing resources globally becomes more complicated due to their possession by geographically distributed enterprises (Tao *et al.* 2008).

Cloud computing, known as a powerful tool, indicates a main change in the way information technology (IT) services are invented, developed, scaled, deployed, updated, maintained and funded. Nowadays, computing power becomes an essential commodity as computers constantly become more important and the cost of per unit consumption of computing continues to drop quickly (Hackett 2008). Although computing continues to become more universal within the whole organisation, computing becomes more costly than ever before for an enterprise due to the growing complication in the management systems of the infrastructure of various information architectures and dispersed data software (Roehrig 2009). In fact, manufacturing SMEs now desire to employ 'pay per demand' methods, due to the lack of enough capital and human resources to own, develop, support, and maintain the computing resources. Therefore, cloud manufacturing is inspired by cloud computing technology to take some advantages, such as resource integration, resource sharing and collaboration among global enterprises.

The rest of the paper is organised as follows; Section 2 explains the concept of cloud manufacturing, Section 3 proposes a cloud-based manufacturing structure for SMEs. While Section 4 defines benefits and challenges of the proposed cloud manufacturing, some conclusions and future works will be considered in Section 5.

2 CONCEPTION OF CLOUD MANUFACTURING

Surviving in global manufacturing competition, manufacturing SMEs have to realise and deploy existing services, knowledge innovation, and scaling the customer requirement. However, different types of current manufacturing requirements cannot be covered and supported by existing advanced manufacturing models, such as Agile Manufacturing (AM) (Yusuf *et al.* 1999), application service of provider (ASP) (Factor 2003), networked manufacturing (NM) (Fan 2003), and Manufacturing Grid (MGrid) (Tao *et al.* 2010).

Table 1 provides some features of existing advanced manufacturing models, indicating the necessity of a new model to transform product-orientated manufacturing to a service-orientated manufacturing model. Hence, cloud manufacturing as a potential solution (CMfg) is suggested.

Table 1: Features of existing advanced manufacturing

	Advantage	Disadvantage
AM	• Design innovation based on the customer`s requirement • Respond quickly to emerging crisis • Flexible organisation structure	• Intensive planning and management of system • Shortage of proper platform supporting for resource sharing
NM based on ASP	• Provide leasing and management for software resource • Realising the platform of the resource and information sharing	• Lack of sharing the hard resources and manufacturing capabilities
MGrid	• Sharing of distributed resources • Workforce development	• Lack of proper operating business model

The core concept of cloud manufacturing, developed from employing service-orientated manufacturing model, advanced computing technologies, Internet of Things (IoT), and virtualisation, is based on enterprise information technologies and existing advanced manufacturing models (Tao *et al.* 2012). Therefore, cloud manufacturing provides the utilisation of manufacturing resources separated geographically but available globally through the internet, and facilitates a virtual manufacturing resource environment for both individuals and enterprises to share and integrate all resources.

Mainly, three layers of user participate in a cloud manufacturing platform, namely, manufacturing cloud, operator, and cloud customer (Fig.1).

Figure 1: Cloud manufacturing main layers

All manufacturing resources and capabilities are owned and provided by the manufacturing cloud. The operator facilitates the services for both the cloud customer and the manufacturing cloud through the cloud manufacturing platform. Hence, the cloud customer who is the subscriber of the services can take advantage of the ‘on demand’ or ‘pay as you go’ model.

3 THE CLOUD MANUFACTURING BASED APPROACH AND ITS IMPLEMENTATION ARCHITECTURE

As shown in Fig.2, the proposed architecture of the high value-added cloud manufacturing for SMEs is categorised into three main layers, Cloud Customer Layer, Operator Layer, and Manufacturing Cloud Layer, in which each layer includes some sub-layers. Moreover, there are three intermediate layers among the main layers, namely, transaction layer, business model layer, and basic supporting layer.

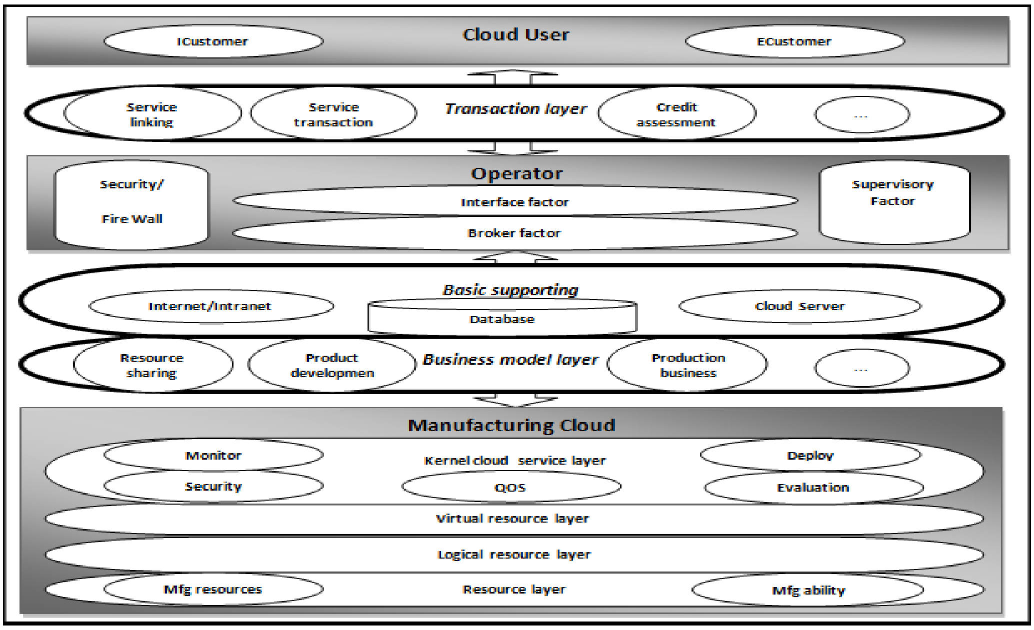

Figure 2: Cloud manufacturing platform

3.1 Cloud Customer Layer (Main Layer)

The cloud service users are the main layer which consists of two different types of consumer seeking to obtain the appropriate service (Fig.3): Individual customer (ICustomer) and Enterprise customer (ECustomer).

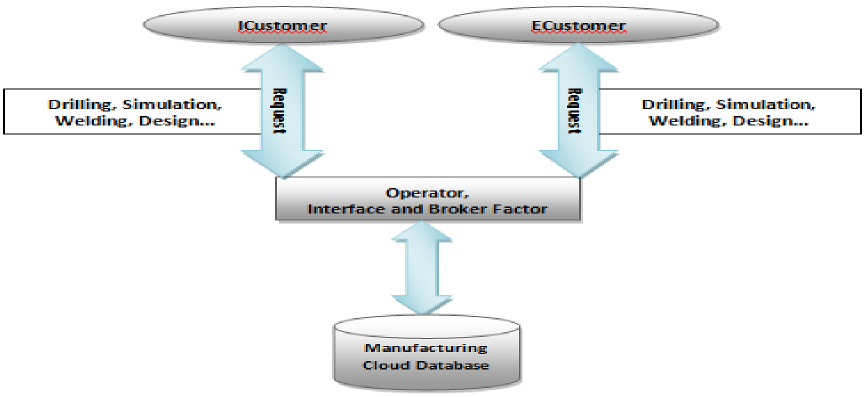

Figure 3: ICustomer/Ecustomer

The former includes an individual customer or organisation based on the request of different ranges of self-contained operation activities for the entire production life cycle. All their requests are captured, analysed, and delivered by an interface factor, such as, drilling, simulation, welding, and design (Vincent and Xu 2013). Simply, the customer submits their request, the provider starts to search into the manufacturing cloud database and allocates the best service for the customer, in terms of cost and time. The latter consist of enterprises that need extra manufacturing services and capabilities, for instance, customers requiring a unique or unusual service which the enterprise cannot perform itself. Therefore, the enterprise can obtain different, possible solutions suggested by the operator on the basis of factors, such as, cost, time, and quality.

3.2 Transaction Layer

The transaction layer is an intermediate layer which should facilitate all business related to the cloud manufacturing platform, such as, service linking, transaction services, and credit assessment.

3.3 Operator Layer (Main Layer)

The Operator layer is a main layer whose location is based on the intelligence factor. Complexity in manufacturing processes, different types of machines and devices, and geographical distribution of manufacturing resources make manufacturing decisions difficult (Xu 2012). Therefore, intelligence factor technology plays an important role in providing this layer. The Operator layer is categorised into three parts under firewall protection , namely interface, broker, and supervisory. An interface is responsible for communicating with a customer in order to help them in executing computational tasks (Laurel 1997). After collecting the customer request, the order is referred to the broker where availability of services are searched and evaluated in the manufacturing cloud database. The procedure from making requests to the final delivery of the services is shown in Fig.4:

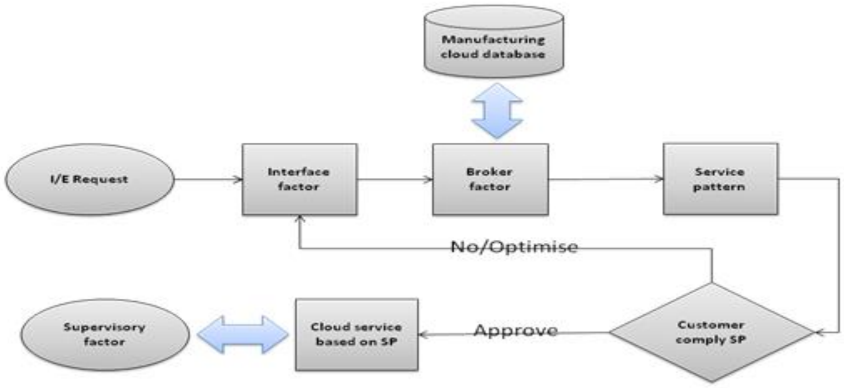

Figure 4: Request, discover and deliver process

1. Interface collects the request made by I/E Customer, transforms the demand into a standard template to make an related document, and finally refers to the broker.
2. Broker starts searching and providing the best solution into the manufacturing cloud database.
3. According to circumstances, such as time to make, time to delivery, cost, and quality, a primary service pattern is generated and returned to the I/E Costumer to be evaluated and modified.
4. Once the service pattern is approved by I/E Costumer, the designated cloud service is proceeded by the supervisory function that has the duty of supporting, monitoring, and controlling the entire functionality through the cloud service platform.

3.4 Basic Supporting Layer

The Basic supporting layer is an intermediate layer and consists of three sub-layers (cloud server, database, and network resource). This is covered by the Infrastructure as a Service equipment management model. In order to facilitate the basic operation support platform, the cloud server should have an efficient extensibility and the database should encompass different types of data format to simplify access by the operator (Huang *et al*. 2012) . Furthermore, network resources should be located and defined in the cloud manufacturing platform to provide the communication environment three users' category.

3.5 Business Model Layer

The Business model layer is an intermediate layer providing related customer's business requirement. The Manufacturing cloud must provide the platform by realising and designing the functional business model layer to enable customers to match the best service model according to their requests.

3.6 Manufacturing Cloud (Main Layer)

The Manufacturing cloud layer is a main layer. As mentioned before, all manufacturing resources and their abilities are provided through the entire life-cycle of the production procedure. This layer categorised into four sub-layers, resource, logical resource, virtual resource, and kernel resource layers.

1. Resource Layer

The Resource layer includes manufacturing resources and manufacturing ability. The former one is defined as tangible and intangible, distributed, manufacturing material provided by dissimilar organisations such as machinery equipment, tools, and devices which exist in the soft resources and hard resources. While soft resources mainly covers software, data, employees, and skills, hardware consists of physical manufacturing sources such as manufacturing equipments, servers, computers, and materials. The latter one is defined as the ability to use all manufacturing sources through the manufacturing process, such as, design ability, management ability, and experimental ability.

2. Logical resource Layer

Directly managing and understanding the manufacturing resources and abilities are quite difficult processes for customers. The Logical resource layer causes physical services and capabilities to be more sensible and provides the connection platform into the network, internet, broadcasting, and the telecommunication networks.

3. Virtual resource layer

In this layer, all manufacturing resources and abilities are virtualised and encapsulated into the manufacturing cloud services. The main aim is to realise interoperable resource management by using different technologies, such as, IoT, Radio-Frequency Identification (RFID) and Global Positioning System (GPS).

4. Kernel cloud service layer

Cloud manufacturing has to provide the required tools for the three category users (that is, customer, operator, and provider) in order to monitor and manage the service platform through, for example, operation environment including security, evaluation, and quality of service (QoS).

4 BENEFITS AND CHALLENGES OF CLOUD MANUFACTURING PLATFORM

The Cloud manufacturing platform could offer some advantages to SMEs in terms of cost and time efficiency, management issues, agility, and customer centric issues. The following section will mention advantages and disadvantages of the service-orientated, cloud manufacturing paradigm.

Cloud manufacturing focuses on the importance of optimising resource utilisation and capacity in order to increasing manufacturing productivity. For instance, IT sources utilisation was less than 20 % through product-orientated manufacturing, while the service-orientated cloud manufacturing sector has improved the IT utilisation up to 40% (Rosenthal *et al*. 2009). Moreover, Cloud manufacturing allows globalisation which is the main aim of advanced manufacturing in the current era of communication. Easy access to virtualised and encapsulated manufacturing resources facilitate an agile environment via the internet and networks for both user and manufacturer.

Cloud-based manufacturing not only provides more business opportunities and adequacy by mixing products as a special offer to consumers, but also estimates and evaluates the customer demand, hence, scaling the manufacturing according to the customer needs.

Besides all its advantages, it could be argued that a cloud manufacturing platform faces certain challenges, for example, (1) safety and security issues, (2) shortage of certain standards, (3) effective extension of management and optimisation, and (4) existing unstructured data.

5 CONCLUSION

Moving from traditional product-orientated manufacturing to a service- orientated type provides new manufacturing solutions to achieve cost-effective, manufacturing systems. However, the research on cloud based manufacturing approach is still in its infancy and has a long way to go before it is adopted and perfectly executed. In this paper, first the background and concept of cloud manufacturing has been introduced, followed by an explanation of the proposed service-orientated, cloud-based, manufacturing structure, its benefits and its difficulties.

In order to practical executing the proposed architecture, the next step is to explain the efficient data models. For instance, STEP standard (Standard for the Exchange of Product model data) among the various proposed data models could be an appropriate solution.

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