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Robotics and Computer Integrated Manufacturing of Key Areas Using Cloud Computing

Ms. A. Sivasankari[1], **Ms. Radhika S**[2], **Mrs. P. Mohanalakshmi**[3]
[1]Head of the Department, Dept of Computer Science and Applications, D.K.M. College for Women (Autonomous), Vellore, Tamilnadu, India
[2]Research Scholar, Dept of Computer Science and Applications, D.K.M. College for Women (Autonomous), Vellore, Tamilnadu, India
[3]Assistant Professor, Dept of Computer Science and Applications, D.K.M. College for Women (Autonomous), Vellore, Tamilnadu, India

ABSTRACT

Cloud computing is changing the way industries and enterprises do their businesses in that dynamically scalable and virtualized resources are provided as a service over the Internet. This model creates a brand new opportunity for enterprises. In this paper, some of the essential features of cloud computing are briefly discussed with regard to the end-users, enterprises that use the cloud as a platform, and cloud providers themselves. Cloud computing is emerging as one of the major enablers for the manufacturing industry; it can transform the traditional manufacturing business model, help it to align product innovation with business strategy, and create intelligent factory networks that encourage effective collaboration. Two types of cloud computing adoptions in the manufacturing sector have been suggested, manufacturing with direct adoption of cloud computing technologies and cloud manufacturing—the manufacturing version of cloud computing. Cloud computing has been in some of key areas of manufacturing such as IT, pay-as-you-go business models, production scaling up and down per demand, and flexibility in deploying and customizing solutions. In cloud manufacturing, distributed resources are encapsulated into cloud services and managed in a centralized way. Clients can use cloud services according to their requirements. Cloud users can request services ranging from product design, manufacturing, testing, management, and all other stages of a product life cycle.

Keywords: Cloud Computing,Cloud Manufacturing,Service-Oriented Business Model

I. INTRODUCTION

Collaboration, Internet of things and cloud has been identified as key business technology trends that will reshape enter-rises worldwide. The manufacturing industry is undergoing a major transformation enabled by IT and related smart technologies. Cloud computing is one of such smart technologies. The main thrust of Cloud computing is to provide on-demand com-putting services with high reliability, scalability and availability in a distributed environment. The National Institute of Standards and Technology (NIST) defined cloud computing as “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.”

In Cloud computing, everything is treated as a service (i.e. Xara's), e.g. SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service). These services define a layered system structure for cloud computing. At the Infrastructure layer, processing, storage, networks, and other fundamental computing resources are defined as standardized Services over the network. Cloud providers' clients can deploy and run operating systems and software for their underlying infrastructures. More and more businesses are taking advantage of cloud computing, one of which is NEC. Its Cloud-oriented Service Plat-form Solutions play an important role in transforming enterprise systems, contributing to cost reduction, agile deployment of services, expanded flexibility and improved productivity. Cloud computing is also being used in other business and science sectors, e.g. inline commerce, conference origination, and biomedical information sharing. There are valid reasons and perhaps requirement for manufacturing businesses to embrace cloud computing and to "borrow" the concept of cloud computing to give rise to "cloud manufacturing", i.e. the manufacturing version of cloud computing. Such a lateral thinking is considered logical and natural as manufacturing businesses in the new millennium become increasingly IT-reliant, globalized, distributed-ted and Agile demanding. In the first-half of this paper, the essential requirements of a cloud computing system are briefly discussed. These considerations are useful for software architects and developers to design cloud-based applications. They also preface the main focus of this paper, i.e. cloud manufacturing, which forms the second-half of the paper. The rest of this paper is organized as follows. The key requirements of cloud computing systems. Cloud computing in the context of manufacturing businesses. In particular, Section 3.1 discusses utilization of cloud computing in manufacturing businesses and Section 3.2 presents the "manufacturing version" of cloud computing—cloud manufacturing. Section 4 concludes the paper.

II. CLOUD COMPUTING SYSTEMS

This section provides an abridged version of general architectural requirements for cloud computing as presented. Rimalet al. classified architectural requirements into cloud providers, the enterprises that use the cloud, and cloud users.

A. Provider requirements

From the service provider's perspective, highly efficient service architecture to support infrastructure and services is needed in order to provide virtualized and dynamic services. This section explains the requirements of a provider service delivery model and other key requirements.

The middle layer, i.e. PaaS provides abstractions and services for developing, testing, deploying, hosting, and maintaining applications in the integrated development environment. The application layer provides a complete application set of SaaS. The user interface layer at the top enables seamless interaction with all the underlying XaaS layers.

a) Service Delivery Models

Software as a Service, Platform as a Service, and Infrastructure as a Service are three common types of service delivery models. These services are usually delivered through industry standard interfaces, such as Web services, service-oriented architecture (SOA) or Representational State Transfer (REST) services. Software-as-a-Service is sometimes referred to as Application as a Service (AaaS). It offers a multi-tenant platform whereby common resources and a single instance of both the object code of an application and the underlying database are used to support multiple customers simultaneously. To this end, SaaS is also referred to as the Application Service Provider (ASP) model. Examples of the key providers are the Sales force Customer.

As the name implies, Platform-as-a-Service provides developers with a platform including all the systems and environments comprising the life cycle of development, testing, deployment and hosting of sophisticated web applications as a service delivered by a cloud-based platform. Commonly found PaaS includes Facebook F8, Sales forge App Exchange, Google App Engine, Bunzee connect and Amazon EC2. PaaS may offer a number of readily available services, which means that PaaS can support multiple applications on the same platform.

Infrastructure-as-a-Service is sometimes called Hardware as a Service (HaaS). IaaS promotes a usage-based payment scheme, meaning that customers pay as they use. This service is extremely useful for enterprise users as it eliminates the need for investing in building and managing their own IT systems. Another important advantage is the ability of having access to, or using, the latest technology as it emerges. On-demand, self-sustaining or self-healing, multi-tenant, customer segregation are the key requirements of IaaS. Go Grid, Mosso/Rackspace, MSP On-Demand, and masterIT are some of the pioneer IaaS providers.

b) Other Essential Requirements

Other essential requirements are to do with service-centric issues, quality of service, interoperability, fault-tolerance, load balancing and virtualization management.

- **Service-centric issues**

Cloud architecture needs to have a unified service-centric approach. The cloud services should have the ability to dynamically adapt to changes with minimum human assistance. Services need to be self-describing so that they can notify the client exactly how they should be called and what type of data they will return.

- **Quality of Service (QoS)**

Like many services on offer, QoS provides a guarantee of performance, availability, security, reliability and dependability. QoS requirements are associated with service providers and end-users. Service Level Agreements (SLAs) are an effective means for assuring QoS between service providers and end-users. QoS may entail systematic monitoring of resources, storage, network, virtual machine, service migration and fault-tolerance. In the context of a Cloud service provider, QoS should emphasize the performance of virtualization and monitoring tools.

- **Interoperability**

Interoperability is about creation of an agreed-upon frame-work/ontology, open data format or open protocols/APIs that enable easy migration and integration of applications and data between different cloud service providers. It is an essential requirement for both service providers and enterprises. Services with interoperability allow applications to be ported between clouds, or to use multiple cloud infrastructures before business applications are delivered from the cloud.

- **Fault-tolerance**

Fault-tolerance presents the ability of a system to continue to operate in the event of the failure of some of its components. Application-specific, self-healing, and self-diagnosis mechanisms are for example enabling tools for cloud providers to detect failure. Once detected, fault is isolated and revision mode is activated.

- **Load balancing**

Load balancing represents the mechanism of self-regulating the workloads within the cloud's entities (e.g. servers, hard drives, network and IT resources). Load balancing is often used to implement failover in that the service components are monitored continually and when one becomes non-responsive, the load balancer stops sending traffic, de-provisions it and provisions a new service component. A load balancer is another key requirement to build dynamic and stable cloud architecture.

- **Virtualization management**

Virtualization refers to abstraction of logical resources from their underlying physical characteristics in order to improve agility, enhance flexibility and reduce cost . Virtualization in the cloud may concern servers, client/desktop/applications, storage (e.g. Storage Area Network), network, and service/ application infrastructure. Quality of virtualization determines the robustness of a cloud infrastructure. Good virtualization can effectively assist sharing of cloud facilities, managing of complex systems, and isolation of data/application.

B. Enterprise Requirements

Enterprises are being constantly reminded about the services they are paying in terms of the service quality, service levels, privacy matters, compliances, data ownership, and data mobility. This section describes some of the cloud deployment requirements for enterprises.

a) Cloud Deployment For Enterprises

There are four types of cloud deployment models, public, private, community and hybrid clouds. These cloud services are ubiquitous as a single point of access. Different types of deployment models suit different situations. Public cloud realizes the key concept of sharing the services and infrastructure provided by an off-site, third-party service provider in a multi-tenant environment . Private cloud entails sharing services and infra-structure provided by an organization or its specified service provider in a single-tenant environment. Enterprises' mission-critical and core-business applications are often kept in a private cloud. Community cloud is shared by several organizations and is supported by a specific community that has shared interests and concerns . Hybrid cloud consists of multiple internal (private) or external (public) clouds. Added complexity of determining how to distribute applications across both private and public clouds can be challenging. Clearly, enterprises need to strategically leverage all four cloud deployment models.

b) Security

The notion of entrusting data to information systems that are managed by external entities on remote servers "in the cloud" causes varying levels of anxiety. This is because corporate information often contains data of customers, consumers and employees, business know-how and intellectual properties. Popo-Vic′ and Hocenski discussed security issues and challenges in detail. The above discussed service models (i.e. SaaS, PaaS and IasS) place different levels of security requirements in the Cloud environment. IaaS is the foundation of all cloud services, with PaaS built upon it and SaaS in turn built upon PaaS. Just as capabilities are inherited, so are the information security issues and risks .

c) Business Process Management (BPM)

Typically, a business process management system provides a business structure, security and consistent rules across businessProcesses, users, organization and territory. Some of the examples of BPM applications include customer relationship management (CRM), workforce performance management (WPM), enterprise resource planning (ERP) and e-commerce portals. Cloud-based BPM (e.g. combining SaaS with a BPM application) enhances flexibility, deploy-ability and affordability for complex enterprise applications.

C. User Requirements

Users' requirements are the third key factor for a willing and successful adoption of any cloud system in an enterprise. For users, trust is often a major concern. Trust-based cloud is therefore an essential and must-have feature. This section describes user consumption-based billing and metering requirements, user-centric privacy requirements, service level agreements and user experience requirements.

a) User Consumption-Based Billing and Metering

When it comes to individual end-users and consumption-based billing and metering in a cloud system, an analogy can be drawn with the consumption measurement and allocation of water, gas or electricity on a consumption unit basis. Cost management is important for making planning and controlling decisions. Cost breakdown analysis, tracing the utilized activity, adaptive cost management, transparency of consumption and billings are also important considerations.

b) User-Centric Privacy

In cloud computing, some of the users' data (regarded as his/ her personal intellectual property) are stored at mega-data centers located in the cyber space. In such an environment, privacy becomes a major issue. There is strong resistance and reluctance of an enterprise storing any sensitive data on the cloud. Thankfully, there are various technologies that can enhance data integrity,confidentiality, and security in the clouds, e.g. data compressing and encrypting at the storage level, virtual LANs and network middle-boxes (e.g., firewalls and packet filters).

c) Service Level Agreements (SLAs)

Service level agreements are mutual contracts between providers and users for the assurance of a cloud provider to deliver the services that are agreed-upon. Currently, many cloud providers offer SLAs, but they are rather weak on user compensations on outages. Some of the important architectural issues are measurement of service delivery, method of monitoring performance, and amendment of SLA over time.

d) User Experience (UX)

The notion of UX is to provide an insight into the needs and behaviors of an end-user so as to maximize the usability, desirability and productivity of the applications. UX-driven design and deployment is the next logical step in the evolution of Cloud Computing. Cloud-based application/systems should be easy to use, capable of providing faster and reliable services, easily scalable, and customizable to meet the goal of localization and standardization. Human-Computer Interaction, ergonomics and usability engineering are some of the key technologies that can be used for designing UX-based Cloud applications.

III. ACLOUD COMPUTING IN THE CONTEXT OF MANUFACTURING

In recent years, the philosophy of "Design Anywhere, Manu-facture Anywhere (DAMA)" has emerged [17–19]. The DAMAapproach demands the ability to exchange design and manufacturing data across multiple sites. DAMA also helps establish links between manufacturing resource planning, enterprise resource planning, engineering resource planning and customer relation-ship management. It is believed that cloud computing may play a critical role in the realization of DAMA. In general, there are two types of cloud computing adoptions in the manufacturing sector, manufacturing with direct adoption of some cloud computing technologies and cloud manufacturing—the manufacturing ver-sion of cloud computing.

a) Smart manufacturing with cloud computing

Cloud computing is rapidly moving from early adopters to mainstream organizations. It has become one of the top priorities of many CIOs in terms of strategic business considerations. Some manufacturing industry starts reaping the benefits of cloud adoption today, moving into an era of smart manufacturing with the new agile, scalable and efficient business practices, replacing traditional manufacturing business models.

In terms of cloud computing adoption in the manufacturing sector, the key areas are around IT and new business models that the cloud computing can readily support, such as pay-as-you-go, the convenience of scaling up and down per demand, and flexibility in deploying and customizing solutions.

The adoption is typically centered on the BPM applications such as HR, CRM, and ERP functions with Sales force and Model Metrics being two of the popular PaaS providers (refer to Section (b)).

The cost benefit of adopting clouds in a typical manufacturing enterprise can be multiple. The savings obtained from the elimination of some of the functions that were essential in traditional IT can be significant. With cloud-based solutions, some application customizations and tweaks that the company needs at the process level may be dealt with by the company's IT sector along with some of the smart cloud computing technologies. When adifferent way of executing a process is initiated, the IT staff can make the change happen seamlessly and in less time . Elkay Manufacturing Company, a world leader in stainlesssteel sinks, water coolers and kitchen cabinets, is one of the manufacturing companies that have successfully adopted and benefited from cloud computing technologies .

When it comes to supporting smart business processes, cloud computing can be effective in offering Business-to-business (B2B) solutions for commerce transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer. Cloud-based solutions enable better integrated and more efficient processes.

Cloud computing can also be used to enhance many other aspects of manufacturing businesses by moving a traditional process to the cloud for improved operational efficiency. For example, cloud computing can assist the development of an application for customer on-boarding process that is more efficient than the traditional process of company on-boarding customers. The procedure for a company to on-board customers may involve a salesperson visiting a prospective customer, the customer filling in a form, company credit checking etc. A Cloud-based customer on-boarding process may do all of these automatically via cloud resources on the Internet.

Collaboration at scale using cloud technology is an emerging business trend according to McKinsey. Adopting cloud technologies, enterprise collaboration can happen at a much broader scale. Within the organization, demand planning and supply chain organization can be tied into a cloud-based system, allowing different parts of the organization to take a peek into the opportunities that their sales teams are working on. In a more traditional environment, that would involve a few sit-down meetings, several face-to-face discussions, or phone conversations.

The cloud in this case provides a collaborative environment that can give people agility, more transparency, and empowerment through more effective collaborations.

Typically, there are some parts of the manufacturing firm that can quickly and easily adopt cloud-based solutions, whereas other areas are better to remain traditional. Hence, what a cloud-adopting manufacturing enterprise also requires is a smart mechanism to deal with integration. Solutions such as Cast Iron are addressing some aspects of such integration; vendors such as Model Metrics are pitching in as well.

B. Cloud manufacturing

With cloud manufacturing, what comes into one's mind first is the existing networked manufacturing concept, or sometimes called Internet-based manufacturing or distributed manufacturing. However, today's networked manufacturing mainly refers to integration of distributed resources for undertaking a single manufacturing task. What is lacking in this type of manufacturing regime are the centralized operation management of the services, choice of different operation modes and embedded access of manufacturing equipment and resources, without which a seam-less, stable and high quality transaction of manufacturing resource services cannot be guaranteed. In a typical distributed manufacturing environment, the resource service provider and resource service demander have little coordination. Thus, adoption of the networked manufacturing concept has been slow and less effective.

In Cloud manufacturing, distributed resources are encapsulated into cloud services and managed in a centralized way. Clients can use the cloud services according to their requirements. Cloud users can request services ranging from product design, manufacturing, testing, management and all other stages of a product life cycle. A cloud manufacturing service platform performs search, intelligent mapping, recommendation and execution of a service. Fig. 2 illustrates a cloud manufacturing system framework, whichconsists of four layers, manufacturing resource layer, virtual service layer, global service layer and application layer.

a) Manufacturing resource layer

The manufacturing resource layer encompasses the resources that are required during the product development life cycle. These manufacturing resources may take two forms, manufacturing physical resources and manufacturing capabilities. Manufacturing physical resources can exist in thehardware or software form. The former includes equipment, computers, servers, rawmaterials, etc. The latter includes for example simulation soft-ware, analysis tools, "know-hows", data, standards, employees, etc. Manufacturing capabilities are intangible and dynamic recourses representing the capability of an organization under-taking a particular task with competence. These may include product design capability, simulation capability, experimentation, production capability, management capability, and maintenance capability. The types of service delivery models that may exist at this layer are IaaSs and SaaSs.

b) Manufacturing virtual service layer

The key functions of this layer are to (a) identify manufacturing resources, (b) virtualized them, and (c) package them as cloud manufacturing services. Comparing with a typical cloud computing environment, it is much more challenging to realize these functions for a cloud manufacturing application.

A number of technologies can be used for identifying (or tagging) manufacturing resources, e.g. RFID, computational RFID, wireless sensor networks (WSN), Internet of things, Cyber Physical Systems, GPS, sensor data classification, clustering and analysis, and adapter technologies.

Manufacturing resource virtualization refers to abstraction of logical resources from their underlying physical resources. Quality ofvirtualization determines the robustness of a cloud infrastructure. Different manufacturing resources are virtualized in different ways. Computational resources and manufacturing knowledge can be virtualized in similar ways as are the general Cloud computing resources. Manufacturing hardware is usually mapped to become virtual machines that are system-independent. Virtualization man-agers (e.g. Virtual Machine Monitor and Virtual Machine Manager (VMM)) are responsible for communicating with the lower level devices, and coordinating and allocating virtual machines.

Agent can be an effective tool for virtualization. Take MTConnect as an example. MTConnect is a standard based on an open protocol for data integration. Although it is for enhancing data acquisition capabilities of machine tools, the use of agent technology provides a plug-and-play environment for manufacturing facilities, which has the potential to support cloud manufacturing. Fig. 3 shows a schematic of a factory system with three machine tools that are virtualized and integrated via MTConnect agents. It needs to be pointed out though that MTConnect mainly supports monitoring processes.

The next step is to package the virtualized manufacturing resources to become cloud manufacturing services. To do this, resource description protocols and service description languages can be used. The latter may include different kinds of ontology languages,In a STEP-enabled, networked manufacturing process planning environment, a STEP resource locator (STRL for short) represents a simplest form of cloud manufacturing service. STRL consists of a URL, an Action and a Query (Fig. 4). STRL is similar to the concept of giving a URL address through the Web. The URL gives the name (location) of the system and data identification. It can therefore be used as a link to a particular manufacturing resource, e.g. a data file, working step (machining step), program, etc. For example, if an STRL as shown in Fig. 4 is activated, we will know that the client has requested the job (as described by file manifold.238) to be machined (run) from the first line until the end for all the three working steps.

To describe manufacturing capability, Zhang et al. used a four-dimension array: (Task, Resource, Participator, Knowledge). Task denotes a manufacturing job; Resource denotes the manufacturing resources that are needed to do the task; Participator represents human resources needed for the job; and Knowledge represents all the knowledge required to do the job.

c) Encapsulating Manufacturing Resources With Mapping

The one-to-many mapping concerns with a single resource that appears to a client as a multiple resource. The client interfaces with the virtualized resources as though he/she is the only consumer. In fact, the client is sharing the resource with other users. For example, ANSYS software can provide structure analysis, thermal analysis, magnetic analysis, and computational fluid dynamics analysis. Therefore, ANSYS software can be encapsulated by many different services.

d) Enterprise requirements—Global Service Layer

The Global Service Layer relies on a suite of cloud deployment technologies (i.e. PaaS). Internet of things has advanced to a new level with RFID, intelligent sensors, and Nano-technology as the supporting technologies. Interconnections between physical devices or products are made easier because of Internet of things. Having said this, a centralized and effective management regime needs to be in place to provide manufacturing enterprises with agile and dynamic cloud services. Based on the nature of the provided cloud resources and the user's specific requirements, two types of cloud manufacturing operation modes can take place at the Global Service Layer, complete service mode and partial service mode.

In a complete service mode, the Global Service Layer takes full responsibility of the entire cloud operational activities. The type of cloud service that suits this mode is virtualized computing resources, e.g. CPU, RAM, and network. These cloud services can be dynamically monitored, managed and load-balanced with ease. Application software is also suitable for the complete service mode in that running and execution of software can take place in a distributed computing environment taking advantage of grid computing and parallel computing. Knowledge, human resources, and manufacturing capabilities may also be managed at the Global Service Layer in a complete service mode.

It is possible and sometimes necessary to partially hand over an activity to the cloud manufacturing service a partial service mode. In such a mode, the service provider provides additional input and operational activities. Typically, manufacturing hardware (e.g. machine tools and experiment devices) is this type of cloud services. The Global Service Layer is mainly responsible for locating, allocating, fee-calculating and remote monitoring the manufacturing resources. The hardware providers are still responsible for executing the manufacturing tasks and ensuring the quality of the manufacturing job.

In order to meet the above enterprise requirements, some critical technologies are needed. For example, optimal resource selection and allocation methods are needed to guarantee an effective cloud manufacturing service. Theories such as Intuitionistic Fuzzy Set, Partial Swarm Optimization, and Quantum Multi-agent Evolutionary Algorithm can be handy when developing an enabling technology. Evaluation and management of QoS is another important exercise at this layer.

IV. RESEARCH CONTRIBUTIONS TO THE CONCEPT OF CLOUD MANUFACTURING

Although the concept of cloud manufacturing is new, virtual enterprise and distributed manufacturing concepts have been around for a while and some of the proposed systems and frame-works bear visible traces of cloud manufacturing or make contributions to a cloud manufacturing system. This section discusses some of these research outcomes.

A. Service-Oriented Manufacturing Environment

Brecher, et al. recognized that applications in an information-intensive manufacturing environment can be organized in a service-oriented manner. They proposed a module-based, configurable platform for interoperable CAD-CAM-CNC planning. The goal is to combat the problems of software inhomogeneity along the CAD-CAM-NC chain. The approach is called open Computer-Based Manufacturing (openCBM) in support of co-operative process planning. To implement the architecture and integrate inspection tasks into a sequence of machining operations, STEP standard is utilized to preserve the results of manufacturing processes that are fed back to the process planning stage . The openCBM platform is organized through a service-orientarchitecture providing the abstractions and tools to model the information and connect the models . It is much like the Platform as a Service concept and resembles an Application Layer, where applications are not realized as monolithic programs, but as a set of services that are loosely connected to each other, guaranteeing the modularity and reusability of a system. The module providers as shown in the figure form the Manufacturing Virtual Service Layer and the module database forms a Global Service Layer.

B. SaaS for Engineering Simulations

To achieve a run-time configuration integration environment for engineering simulations, van der Velde reported a plug-and-play framework for the construction of modular simulation software. In this framework the user (at the Application Layer as in a cloud manufacturing system) is allowed to select a target of simulation and assign the performer of the simulation called "component" before running the selected components. These components are effectively software entities (or otherwise known as SaaS as in cloud computing/manufacturing). They are modulated, self-contained, mobile and pluggable. After the simulation, the output is post-processed through the components. In such architecture, software modules are detected, loaded and used at run-time with the framework (i.e. the Global Service Layer) needing no prior knowledge of the type and availability of components, thus providing true plug-and-play capabilities.

V. CONCLUSION

Cloud computing is changing the way industries and enterprises do their businesses. With wider cloud adoption, access to business-critical data and analytics will not just help enterprises Stay ahead, it will also be crucial to their existence. There are three architectural features of cloud computing in terms of the requirements of end-users, enterprises that use the cloud as a platform, and cloud providers themselves. These architectural features play a major role in the adoption of the cloud computing paradigm as a mainstream commodity in the enterprise world.

Cloud computing is emerging as one of the major enablers for the manufacturing industry, transforming its business models, helping it align product innovation with business strategy, and creating intelligent factory networks that encourage effective collaboration. This pay-by-use scenario will revolutionize manufacturing in the same way that the Internet has already revolutionized our everyday and business lives. Manufacturing shops are starting to take advantage of cloud computing because it simply makes good economic sense. Two types of cloud computing adoptions in the manufacturing sector have been suggested, manufacturing with direct adoption of cloud computing technologies and cloud manufacturing—the manufacturing version of cloud computing.

In terms of direct adoption of cloud computing in the manufacturing sector, the key areas are around IT and new business models, e.g. pay-as-you-go, production scaling up and down per demand, and flexibility in deploying and customizing solutions.
The HR, CRM, and ERP functions may benefit from using some emerging PaaS. Cloud computing can be effective in offering Business-to-Business solutions for commerce transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

Moving from production-oriented manufacturing to service-oriented manufacturing, cloud manufacturing seems to offer an attractive and natural solution. In cloud manufacturing, distributed-ted resources are encapsulated into cloud services and managed in a centralized way. Clients can use cloud services according to their requirements. Cloud users can request services ranging from product design, manufacturing, testing, management and all other stages of a product life cycle. The cloud manufacturing service platform performs search, mapping, recommendation, and execution of a service. Two main types of manufacturing resources can be considered at the manufacturing resource layer, manufacturing physical resources, and manufacturing capabilities.
Although the concept of cloud manufacturing is relatively new, virtual enterprise, and distributed manufacturing concepts have been around for a while and some of the proposed systems and frameworks bear the trace of cloud manufacturing, e.g. development of a service-oriented manufacturing environment anddifferent SaaS for engineering applications. There are also some embryonic cloud manufacturing systems developed in the past 2–3 years. In response to concerns about cloud computing adoption for manufacturing businesses, enterprises need to address them in constructive and positive ways. The IT professionals as well as personnel from other manufacturing departments need to work hand in hand to look for solutions to the problems. It can be anticipated that cloud manufacturing will provide effective solutions to the manufacturing industry that is becoming increasingly globalized and distributed. Cloud manufacturing means a new way of conducting manufacturing businesses, that is everything is perceived as a service, be it a service you request or a service you provide.

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