Cloud manufacturing framework based on step-nc machine tool for capturing design and manufacturing data

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Abstract. Globalization and industry 4.0 has changed the norm of the manufacturing process of product life cycle. Manufacturing companies are no longer focuses on selling tangible products but have also started selling manufacturing product related services. Computers and information technologies are deeply entrenched in the modern manufacturing systems, giving rise to Computer Integrated Manufacturing (CIM), Cyber Physical Systems and most recently Cloud Manufacturing. The cloud manufacturing platform proposed in this paper will truly emphasize the concept of design anywhere machine anywhere, where manufacturing and machining data and resources can be shared by anyone regardless of locations and limitations.

1. Introduction
In recent years, cloud computing has been elevated as one of the IT trends, which has proven its high potential in enterprise and manufacturing sectors. Implementation of cloud technology in the world of industrial production has opens an entirely new business environment and opportunities. The use of cloud services in the industrial and manufacturing sector gives vast opportunities in creating new and advanced platforms that are able to provide flexible control for product life cycle in industrial processes [1].

Computers play an essential role in increasing efficiency, capability and adaptability of manufacturing systems. Typical examples of such technologies are Computer Integrated Manufacturing (CIM), Distributed Manufacturing (DM), Agile Manufacturing (AM), Cyber Physical Systems (CPS) and Cloud Manufacturing (CM), to name a few [2]. These technologies have evolved from the existing similar technologies that are currently available.

Industries 4.0 has included cloud computing as part of its elements, besides Internet of Things (IoT), Big Data [3], [4] and many more IT related elements, making it emerged as one of the major enablers for the manufacturing industry, transforming manufacturing business models, helping it align product innovation with business strategy, and creating intelligent factory networks that encourage effective collaboration [5] between various fields. Cloud manufacturing is defined as a new network manufacturing model that integrates two emerging computing paradigms: Cloud computing and the Internet of Things (IoT). Cloud manufacturing is also defined as a new manufacturing paradigm that was developed from existing advanced manufacturing models [6] and enterprise information technologies under the support of Internet of Things (IoT), virtualization, cloud computing, service-oriented technologies, and advanced computing technologies [7]. By virtualizing and deploying on the cloud service platform, heterogeneous manufacturing resources can be shared by different complex collaborative manufacturing demands. IoT is allowing users to have on demand access to the right information at the right time and help them in making the best possible decisions, like a speedometer.
that shows your current driving speed versus your speed from yesterday whereas cloud computing enables companies to extract, filter and analyze information that affects the production line [8].

Although network manufacturing platform has shown success outcome through the years [9], application prototype system [10], manufacturing resource modeling [11], resource scheduling [12], and collaborative product design [13], networked manufacturing resources are not as broadly shared and integrated as expected. The critical challenge lies in the agile and interoperable resource virtualization [14]. Cloud-based manufacturing (CBM) is another rising paradigm that will contribute significantly to the success of Industry 4.0 [15].

The main aim of this paper is to identify the requirements for STEP and STEP-NC that could enhance cloud manufacturing concept, and to investigate how cloud technology can address some of the open challenges regarding manufacturing and machining data life cycle. Moreover, it is also to provide an overview of the current research state, in the field of STEP and STEP-NC in regard to computerized manufacturing and cloud manufacturing in terms of cloud computing technology. In this paper, we set the stage by providing a very brief overview of the cloud computing and cloud manufacturing vision and some of its associated pillars. This paper will then introduce the ideas underlying software-defined systems framework along with a surface basic architecture of software-defined cloud manufacturing. The paper concludes with a discussion of future work and long-term research objectives along with an outline of potential opportunities and challenges associated with cloud manufacturing.

2. Manufacturing as a service

Industrial revolution 4.0 will see that manufacturing sector being subjected to a major paradigm shifts and will be facing new opportunities and challenges in the business and technical perspective. Traditionally, manufacturers just focus on selling tangible products, but nowadays manufacturers are also incrementally competing in offering product-related services that occurs throughout the process of a product life cycle. Over the last decade, these manufacturers have continuously increased their revenues from income coming from the service business and have started to expand their business by offering manufacturing design product-related services [16]–[18]. Although organizations in manufacturing struggle to drive profits or income through service, the service business is becoming more and more important, as it generates more steady revenue streams, as compared to the rather cyclical product business [19] not to mentioned that the current industrial design is heading towards service sector.

The concept of manufacturing as a service has been predicted since the 1970s by a Harvard University Sociologist, Professor Daniel Bell, predicting knowledge-based services would overtake manufacturing as the growth engine for western societies, and services in general would swamp manufacturing as a source of employment [20]. The IBM research team together with UC Berkeley also has come out with this model that classifying services as a science, the term is Service Science, Management and Engineering (SSME). Where the application of science, management and engineering discipline complimented each other [21]. “service science” were designed to teach individuals to apply scientific, engineering, and management disciplines that integrate elements of computer science, operations research, industrial engineering, business strategy, management sciences, and social and legal sciences, in order to encourage innovation in how organizations create value for customers and shareholders that could not be achieved through such disciplines working in isolation [22]. The key thing in cloud computing concept is the cloud computing services [23] where it basically offering structural things or architecture as a service.

Cloud manufacturing could enhance the current model of cloud computing by combining Manufacturing as a Service (MaaS) and Hardware as a Service (Haas) to be part of the current cloud computing service model. To further understand the whole service model concept, examples on Software as a service would be Solidworks and any 3D systems that offer software on the creation of product design as well as simulations, and simpler examples would be Google Docs that are very similar to Words documents, Google Sheets for Excel spreadsheets and Google Slides for Power Points Presentations. All these applications are made available on the cloud without the user have the
requirement or needs to install any software in their own personal computers. No cost for installations and software maintenance, as all that is done by the provider through the cloud platform.

The cloud platform for product design and machining data resources through STEP-NC machine tools that is proposed by this paper will follow the same architecture as the mentioned existing platforms.

Salesforce.com, Amazon Web Service (AWS) and Autodesk 360 are some of the cloud computing company that are available in the market that provide Platform as a Service (PaaS) to its customers, meaning that they do not only allow their user to use the software but providing a platform for them to interact with people from various processes. For example, manufacturing platform Autodesk 360 (A360) that have the capabilities to perform product life cycle management, design simulation and direct modelling, provide a platform for its users in product design, engineering, and project that make teams work together more easily in an online workspace where employee can view, search, and share design files from their desktop or mobile device regardless of locations.

After we understand the concept of cloud computing service models, we could define cloud manufacturing as a new manufacturing paradigm that make use of cloud computing, internet of things and all the advanced computing technologies to provide network access to a shared pool of configurable manufacturing resources like manufacturing software especially shared data, manufacturing equipment and manufacturing capabilities. This is important in supporting the current industrial revolution which is the Industry 4.0, where it emphasis on cyber physical system that focus on communication between machines that requires less or no intervention by the human operators.

3. Intelligent factories in the cloud
STEP and STEP-NC has been viewed as having the capabilities of capturing data throughout the whole manufacturing life cycle, from design until the actual product development [24]–[27]. The hierarchy or tree structure of STEP data has enabled it to retain the data relationship in between processes making data maintenance and configuration easier. The extendable characteristics of STEP data has made it possible to connect computerized manufacturing and forward it to the cloud environment.

The current concept of cloud manufacturing mainly involved with making the design data available on the cloud providing simulations to users and potential manufacturers. What the current cloud manufacturing scenario lacked, would be the actual history data that involved with the machining of the product of itself, like the type of tools that could and would be used, the tools rotation involved, is it clock wise or counter clock wise, the federate, coolant information and even the actual position on how the piece should be clamped or clamping position as well as the machining strategy of the machined product. All this information should be made available through computerization instead of totally dependent on the know-how and knowledge of the machining operators or the technician.

4. STEP based cloud manufacturing
Globalization has made many of the world’s leading industrial nations invested in the initiatives to foster in advanced manufacturing, innovation, and design. Much of this investment was driven by visions such as Industry 4.0, in striving to achieve a future where intelligent factories and smart computerized manufacturing are the norm. Cloud manufacturing as part of cloud computing is one of the element in the industry 4.0 revolution. The cloud manufacturing framework that is proposed in this paper will fully utilized the current capabilities of computing technologies with STEP and STEP-NC as part of its tool that enabled process planning data and machining data to be captured under one system under the cloud platform that can be fully access by various users regardless of location.

Based on figure 1, the proposed system will capture the CNC manufacturing process that start with the design of the part in a CAD system and generates the part programme for a CNC controller using a specific post processor that will be made available on the cloud. During process planning, machining features are extracted from CAD data. Conversion of CAD data to STEP-NC format occurs when machining operations and cutting tools are assigned to extracted features and generic STEP-NC data
are created. During machining, machine-specific STEP-NC data are generated from generic STEP-NC data and machining is performed.

![Current and Proposed Cloud Manufacturing Framework](image)

**Figure 1.** Current and proposed cloud manufacturing framework.

The proposed cloud system will generate tool-path data based on the STEP-NC program. This is done by a tool-path generator that interprets the STEP-NC information to a language that can be understood by local machines. This system is directly integrated to the machine tool, where the manufacturing and machining execution takes place. This is a more straight forward process if a legacy machine tool is being used, which is the case of this research.

5. **Conclusion**

In simpler words cloud computing would be the use of the internet for the tasks that we usually perform on our computer. The truth is, we are on the cloud already. Our daily routines have been influxes with the constant usage of cloud related applications like Turnitin, Instagram, Youtube, Researchgate, LinkedIn, and Facebook. Manufacturing industries have familiarized themselves with the cloud concept and platform through their usage of Amazon Web Service for virtual machines (AWS-E2), Cubify and Shapeways for 3D scanner and printing, MFG.com, a global online manufacturing marketplace that connects buyers of custom manufactured parts with manufacturers and job shops and Autodesk 360, a collaboration workspace for manufacturing storage, design and simulation.

Cloud manufacturing would be the extension of cloud computing through the manufacturing point of view. Cloud manufacturing is being viewed as a new way to run manufacturing businesses. It is a borrowed concept from cloud computing on sharing configurable computing resources that requires minimal management effort from the user and as well as minimal service provider interaction by making those manufacturing related data and services available on the cloud.

Cloud manufacturing has pushed manufacturers to make the shift from production-oriented manufacturing to service-oriented manufacturing. Though the concept is relatively new but it is not foreign as the groundwork for the shift in manufacturing concept has been introduced by STEP for quite a long time, and it create opportunities for more companies especially small and medium enterprise (SME) to be able to take on more complex projects with most manufacturing and machining data being made shareable through resource sharing such as manufacturing software tools, equipment’s and fabrications capabilities.
Cloud computing has changed the way manufacturing enterprises do businesses. The key to the success of cloud manufacturing would be data and data connectivity. STEP and STEP-NC machine tool would be one of the best tool to support cloud manufacturing and would be the tool that will be used in this paper on cloud manufacturing framework development.

Industry 4.0 is the results of globalization where emphasize on data processes, analytics and synthesis has lead towards cyber-physical systems and smart factories. Manufacturing and machining are no longer being linked to physical things only but a concept and visualization that can be shared among manufacturers and users.

6. References

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7. Acknowledgements
This work was supported by University Tun Hussein Onn Malaysia, Research and Development Center (R&D), Office for Research, Innovation, Commercialization, Consultancy Management (ORICC) and Grant TIER1 U927.