# Developing manufacturing execution software as a service for small and medium size enterprise

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***Abstract*-This paper analyzes the needs and challenges faced by the IT infrastructure of Small and Medium Sized enterprises. The findings show that the communication between Enterprise Resource Planning (ERP) and Manufacturing Execution system (MES) is not real time. To cover the gaps presented in this paper, we propose a cloud based Software as a Service for MES (MESSaaS). This MESSaaS supports distributed manufacturing and provides key performance indicator data for production; it also has ability to connect with real time external systems such as ERP. To develop MESSaaS, we introduced a framework based on the Model Driven Architecture (MDA) for designing MESSaaS in the IT infrastructure of SMEs. The MESSaaS is designed for flexible manufacturing system and the schema of implementation of proposed solution was explain.**

***Keyword: ERP; MES; Model Driven Architecture; Software as a Service***

## I. INTRODUCTION

The small-and medium-sized enterprise (SME) is an important part of manufacturing industry. Research shows that there has been noticeable changes in Small and Medium-sized Enterprise as markets demand products with low cost and high quality. SMEs operates in competitive markets, which requires a highly agile, effective, and efficient response to demand [1]. Nowadays the classification of IT in the SMEs are categorized in three levels, which are; Enterprise Resource Planning (ERP), Manufacturing Execution System (MES) and control layer. The Enterprise Resource Planning (ERP) has developed greatly, which has giving birth to an opportunity to manage SMEs within and beyond the organizational and has enabled a high level of integration, and enhances the decision-making process; nevertheless, there are many limitations of ERP. The current ERP has four limitations as highlighted by Akkermans et al [2]; firstly, it lacks flexibility in adapting to the changing need of supply chain. Secondly, it lacks extension of enterprise functionality, thirdly, no open modular system infrastructure. Lastly, it lacks capability for high decision support.

In order to bridge the gap, many concepts has been proposed in the past which highlighted a need to design a system that serve as information link between planning systems and manufacturing shop-floor control systems. Research shows that the use of Manufacturing Execution Systems provides great advantages to SMEs in supporting different types of production and processes, advantages such as reduction in manufacturing cycle time and data entry time [3]. However, existing MES lacks the capability of adaptability, reorganization and configuration. It is unable to adjust its architectures and functionalities following changes in enterprises, businesses and organizations, thus hindering the wide adoption of MES software [4]. Nowadays the real limitation of SMEs in IT is real time communication between ERP with MES, there has to be an easy flow and sharing of data across the systems because ERP gives production orders to MES, quality control and material information has been a problem, thus solution has been based on the off line connection [5]. Largely speaking, there is not real time availability of the picture of the entire shop floor, these has prevented high-level operator of seeing all the entities that exist on the floor and what may hinder delivery to the customers. In addition, weak adjustment to frequent changes in enterprise businesses has become an issue due to the rigidity of the control architectures of most traditional manufacturing systems. Furthermore, other problem is how to integrate all these applications and solution in a single platform in order to bundle all SMEs into one supply chain and manage them centrally for improving collaboration and resource sharing. From this problems stated above, cloud computing [6] is one of the new solution proposed, which helps to store services and information in the cloud that are made available to

the user whenever in need. The shortage of solution to the current ERP can be solved by the use of cloud computing[7]. Many businesses has adopted the use of cloud computing. The major commercial provider of cloud application are constantly improving the relationship between the clouding hosting provider and SaaS based software is promoted [8].

To fill the gap presented in this paper, we propose a cloud based solution software as a service for a MES, we used a framework based on MDA for designing MESSaaS. The remainder of paper is organized as follow; Section one explain the proposed solution for SMEs based on SaaS, Section two explain the method for designing MESSaaS in the cloud environment based on the Model Driven Architecture, Section three explain the case study and design MESSaaS for case study, Section four focus on implementing and discussing the proposed solution, while the last section is the conclusion and future works.

## II. PROPOSED SOLUTION: MES SOFTWARE AS A SERVICE FOR SMES

To cover the gap highlighted in the IT infrastructure of SMEs, a cloud based solution, Software as a Service for Manufacturing Execution System (MESSaaS) is proposed. This solution is based on the Service Oriented Architecture. Figure 1 shows prototyping a solution-MESSaaS, the MESSaaS supports distributed manufacturing and also provides key performance indicator data for production. The MES is web based hence no installation time nor additional cost of installation, it also have the ability to connect with external systems. Lastly, using the MESSaaS will improve the scalability and agility of the system. The MESSaaS is connected to the inside network of different SMEs, these SMEs use the web based MES to define the entities existing in the shop floor and they are charged based on the service used. The MESSaaS is deployed in the cloud environment and can have a real time communication with cloud ERP based on the ability of the cloud.

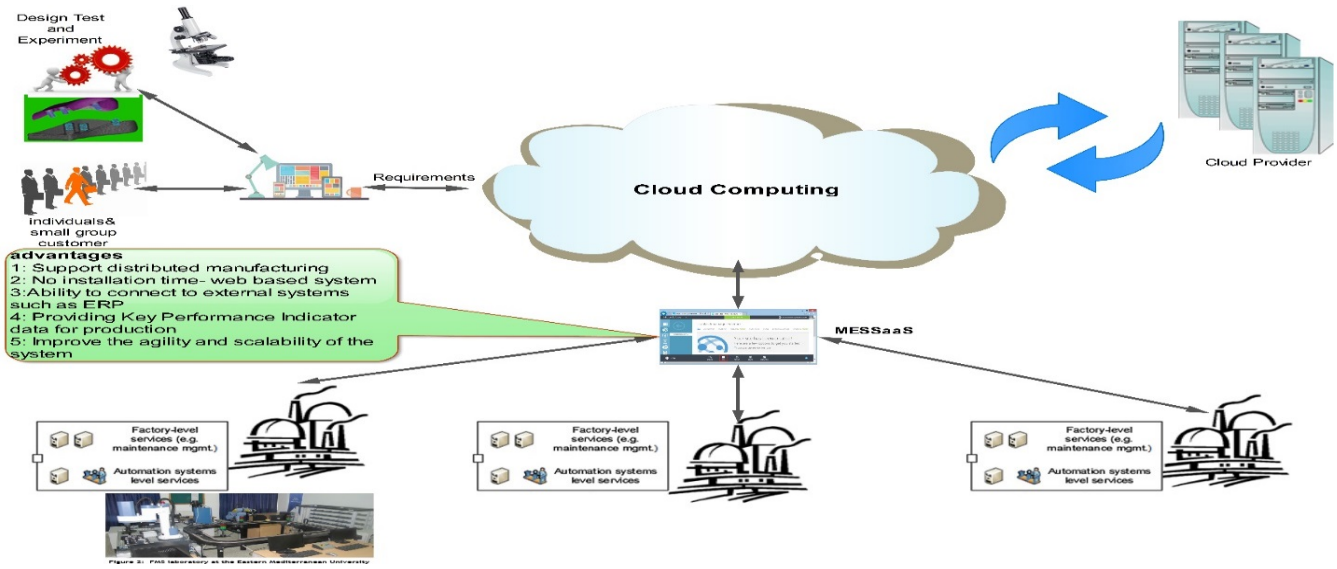


Figure 1: Proposed Solution

The cloud ERP has an online interaction with the MESSaaS for scheduling purpose of the SMEs. This cloud computing is created by the cloud provider, which is responsible for the security of the cloud, fault tolerance, data sharing, maintenance of software etc. costumer such as individual and small group can be connected to the cloud computing via web based application for finding more information about company and ongoing work.

For design MESSaaS we used a framework based on the Model Driven Architecture (MDA). MDA®[9], which is an initiative by OMG®, is an open vendor, neutral approach for enterprise application development. It shifts the focus of software development from the problem domain to solution domain thereby bridging the gap, which exists between domain-specific concepts and the programming technologies used to implement them; and in process enhances the productivity and manageability of software development process. The entire software development process is model-driven with models as the primary artifacts for deployment, design, construction, operation, maintenance and modification of a system. MDA can be combined with Service Orientated Architecture (SOA); this is done by describing each of these services as models and then integrating them to form the complete application. By combining these two technologies, we incorporate platform-independence and interoperability into our application. MDA describes the system at a higher level of abstraction in which

the model forms the primary artifacts. The models are described at different level of abstraction: CIM (Computation Independent Model): describes the basic features of system and produces a structured and coherent document of requirement specification. PIM (Platform independent): describes the behavior and functionality of the system in a generic manner. PSM (Platform Specific Models): describe the system with respect to a specific platform.

The performance of MDA depends on automating the model-to-model and model-to-code transformations. The process of generating automatically a target model from a source model is known as transformation. Also a set of rules that come together to describe how to transform a model in the source language to a model in the target language is referred to as transformation rule. An MDA based development of cloud SaaS will greatly help to improve the quality of cloud software services and also play a significant role in defining these services in a technology independent manner thereby making them robust, agile and flexible[10].

The proposed framework for developing a MESSaaS for cloud environment based on MDA consists five levels and it is shown in Figure 2. The first level of the framework start by analyzing the requirements with focus on the system's definition. While the second level is the Computational Independent Model (CIM) level of the MDA, in this level, MESSaaS is designed as high-level abstraction with a Use case diagram as cover for the abstraction model. In level three, the high-level abstraction design decomposes the application into several sub software (services) by leveraging Service Oriented Architecture (SOA), each sub software implements a small function of the application.

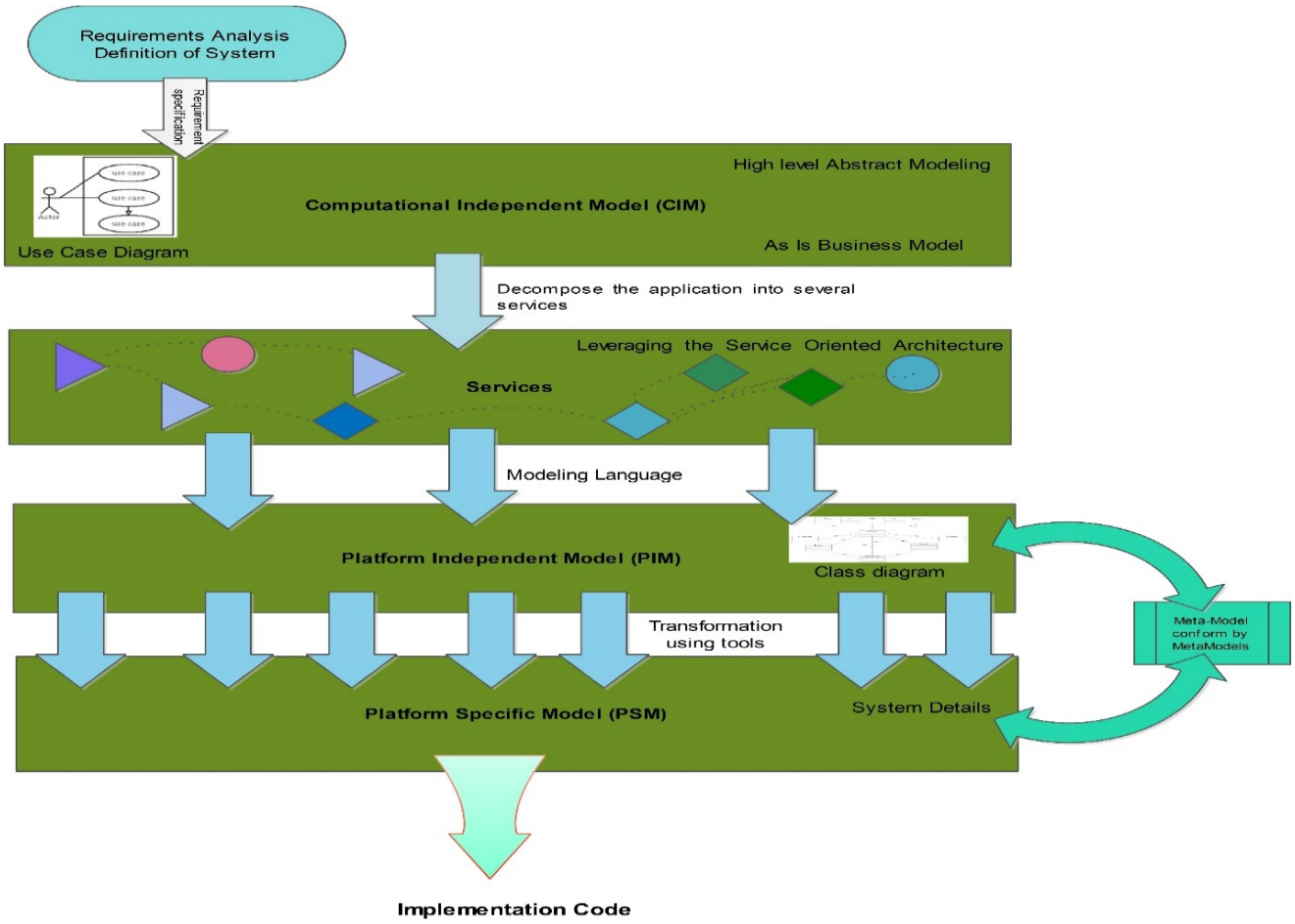


Figure 2 Proposed framework for developing a MESSaaS for cloud environment based on MD

The fourth level is responsible to create a model for each of these services using a model driven approach, this is known as Platform Independent Model (PIM). This model should conform to their meta-models. Level five which is the last level is the Platform Specific Model (PSM), this is responsible for describing the system considering the specific platform on which it would eventually be implemented. A typical example of PSM is Specific relational model. Just like level four, Meta-Model is used for verification of the PSM level.

Meta-model in simple terms are model of a model, they basically constitute the definition of a modeling language, since they provide a way of describing the whole class of models that can be represented by that language [10]. A four-layered architecture of the MDA Meta model is used. The first layer represent the functionality and behavior that should be exhibited by the system, It contains data to be modeled in real world, The second layer contains the models, which explains the real world data present in first layer. Several elements of the modeling language are used in these models and to create these models, any modeling language can be used. The third layer describes the user models in the second layer. Meta models describe various elements and syntactic details used in the user-defined models; hence, they are essential in model driven development. Models in second layer are instances of these Meta models. The last layer represents Meta Object Facility (MOF), it is a standard that provides Meta Object Language (MOL) for the standardized description of the Meta models present in various modelling languages in third layer. This helps to bring together different models specified in various modelling languages into one framework and carry out various model transformations.

## III. CASE STUDY MESSAAS

MESSaaS is designed for flexible manufacturing system which is located in a laboratory in EMU. The lab consists of three stations namely; ASRS station, machining station (CNC machine) and assembly station. The control MES system of this lab uses multi agent control system, which was proposed and implemented by some of authors at this paper [11, 12], and it follow the standard ISA-95.3. The users of the MESSaaS can be classified in two groups: Cell level, this level consist of group of stations such as Machine and Robot. They can connection to internet via PC and sub software of each station installed to this PC. The other group is the MES level, which is in charge of scheduling and controlling cell level. Modeling the system involve three steps. (1) Firstly, we model the system at highest level of abstraction known as CIM, The use case diagram for MESSaaS is shown in Figure 3. Cell level logs in using its username and password, the user then inputs the information of cell level and data base of user updated after which the software then displays a list of scheduling for cell level. The production execution is sent to cell level after selecting a schedule. (2) Second step is decomposing software to services. The important services consist of; data based service, scheduling service, production execution service, status monitoring service, communication service. Figure 4 illustrates some of the service that created by decomposing application in the several services. The third step of our framework is PIM is represented using UML language. It is modeled as classes. The relationship between classes represents the association between them, an object of one class can refer to one or more objects of a related class. The PIM of MESSaaS is shown in figure 5

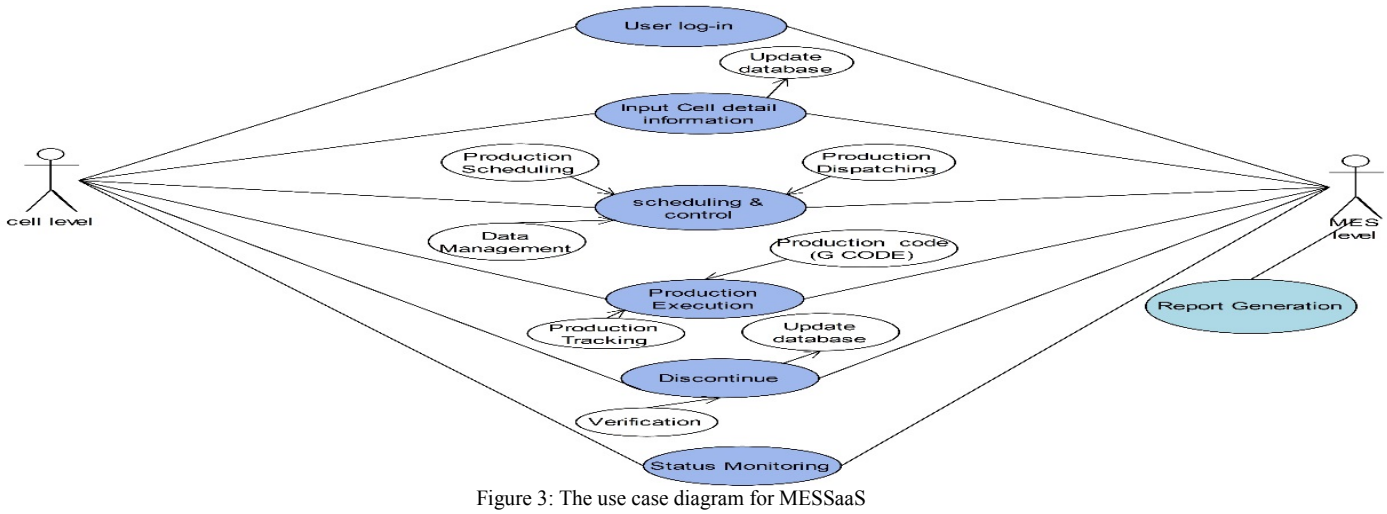


Figure 3: The use case diagram for MESSaaS

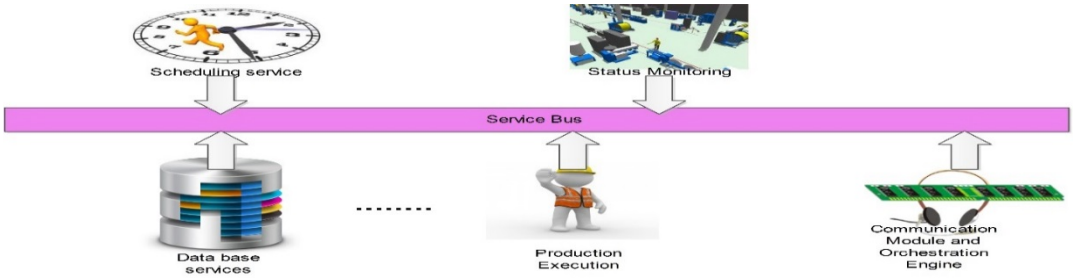


Figure 4: Decomposing software to services

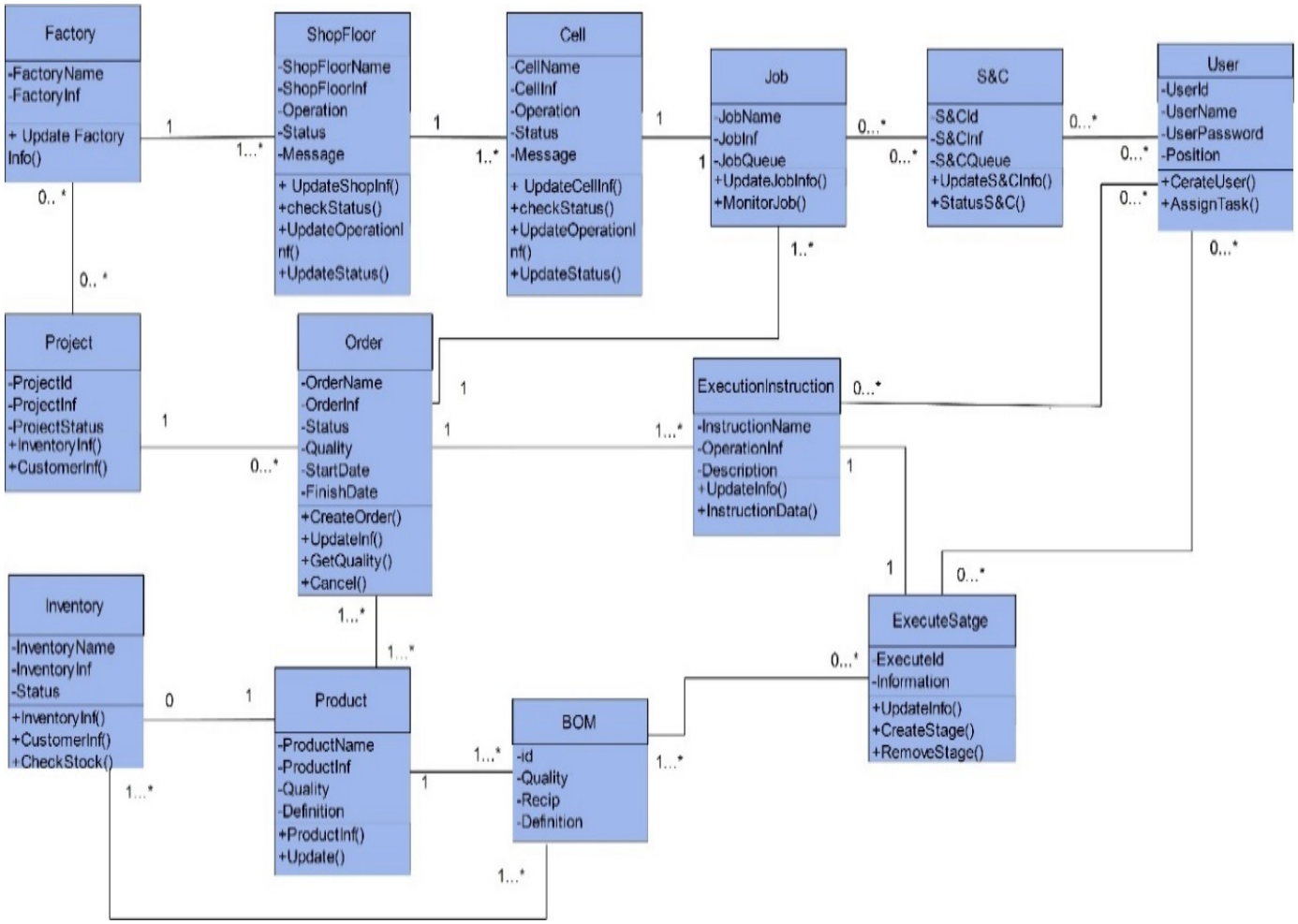


Figure 5: The PIM of MESSaaS

Transformation tools are used to generate PSM from PIM, the transformation rules are highlighted below.

- Each class in the PIM is mapped to its corresponding class in PSM.
- A private attribute exists in the PSM for each public attribute of a class present in the PIM.
- Java language is used to specify different type of attributes.
- There exists two public operations each operation of a class present in the PIM is mapped to a private member function with its return type specified in java language

Implementation code is generated from the model immediately after PSM is generated, this is done by using transformation tools, and each constructs in model language is mapped to target language. Sparx Enterprise Architecture is used to generate code structure from PSM model including Data Model. Finally, the software (code) obtained is deployed in Java platform.

## IV. IMPLEMENTING MESSAAS IN THE EMU LAB

Computer layout and machine connection of EMU lab is shown in Figure 6. On the lab exist five computers, each station has its own computer all computer used industrial network for communication [13]. Cell level has two computers. The first one is Cell Manager used for MES software the MESSaaS is operating via internet in this station manager for monitoring. The second computer is Graphical interface connected to the Cell manager for monitoring purpose. The MESSaaS has an online interaction with the cloud environment for scheduling and rescheduling of station level, which will provide real time communication. Important part of this implementation network communication between station and cell manager I/O, RS232, LAN and internet is used for communication. Figure 7 shows Communication Network Used in EMU lab.

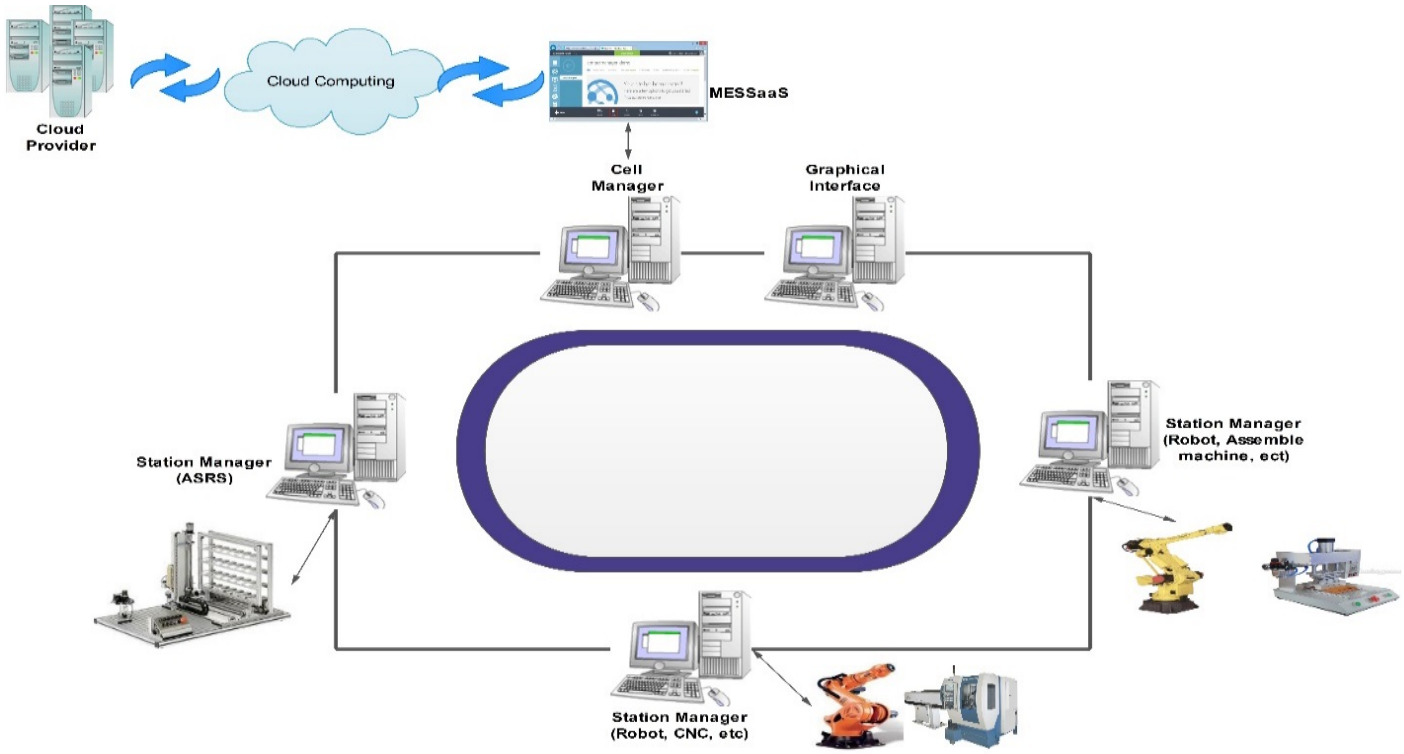


Figure 6: Computer layout with MESSaaS

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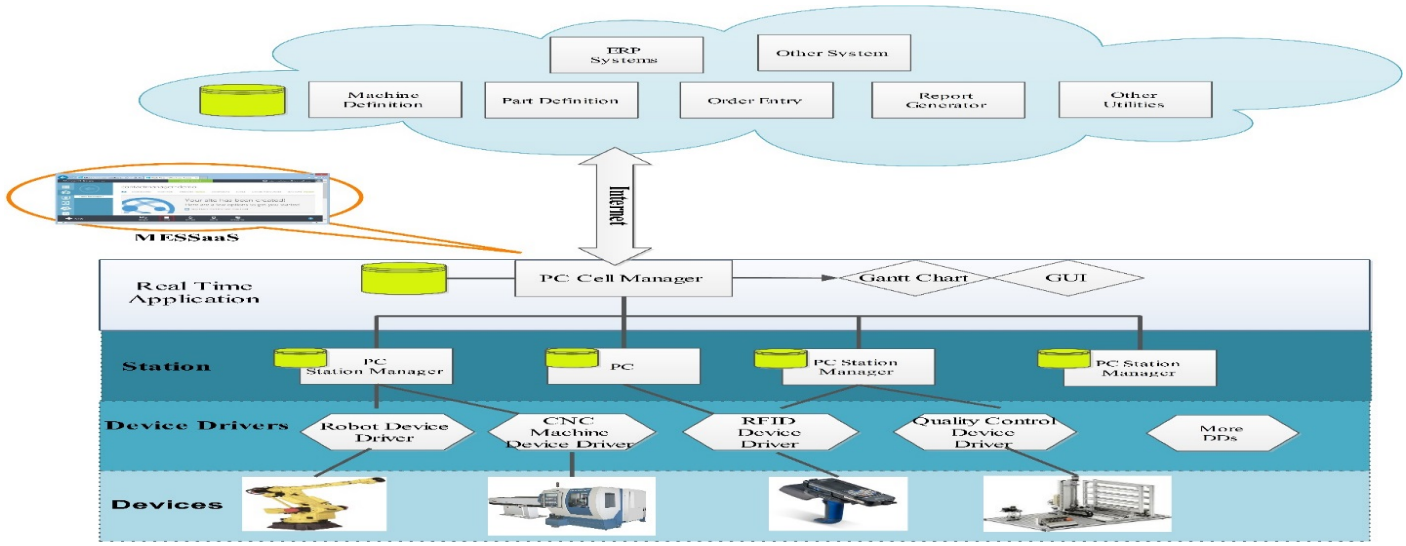


Figure 7: Network communication

- Internet: Internet is used for running MESSaaS in the Cell manager via web browser. TCP/IPv4 is used for creating this communication between cloud environment and Cell Manager.
- LAN: The Cell manager (MESSaaS) and PC station manager exchange command and status messages via the network. MESSaaS(Cell Manager) uses a LAN to exchange information between software modules running on separate computers. When the following software modules are configured to run on separate PCs, the LAN allows to exchange commands and status information in real-time with the Graphic Tracking PC and any PC running supply application that is connected with MESSaaS. RS232: Station Manager PCs used RD232 to download programs to processing machines and pass MESSaaS message to/from an ACL controller, also to provide a terminal interface for programming ACL controllers.
- Inputs/Outputs: I/O connections is used to turn production devices on and off, and to transmit binary information about the status of a device. A separate wire carries each I/O signal. I/O connections use a low voltage DC signal. The exact voltage depends on the specifications of the devices being connected. To operate the processing machines, and the devices attached to an ACL controller such as automatic screwdriver and pneumatic gripper for a robot; The I/O connections is used.

The integration of various systems and devices is described by considering the sequence of events when a part moves from station to station form processing. When the user activates a production order, the MESSaaS builds a production plan. This plan includes the parts to be processed, the stations where they are to be processed, and the production activities they will undergo.In the ASRS station and the CNC station, MESSaaS communicate with the station manager and the Robot controller to do a task and there is a feedback from both the robot controlle. The MESSaaS gives scheduling order to the Robot controller, the communication is real time

## V. Discussion

In this paper, we proposed MESSaaS to solve the real time communication problem between ERP and MES. Our proposed MESSaaS is designed based on Model driven approach. In a Model driven approach, only one platform independent model is created and transformed into several different platform specific model. This prevents re-designing the application for different platforms and increases the lifetime of the application. The system is platform independent, which is created by software development; hence, this feature makes the system though portable but robust. Service Oriented Architecture decomposes the application into services, these services are loosely coupled to each other which enables these services to be reused in different applications. This reduces the time and effort invested in the development process. Each client can customize some parts of the service such as user interface hence multi-tenancy is achieved. Each client's data is stored in a separate directory; this ensures privacy of client's data.

However, this approach also has a few drawbacks: Modeling a large application may result in the creation of several other models and managing these models is complex. The models developed cannot be executed directly; instead, it should be transformed into implementation code. Generation of implementation code from the models is semi-automatic and requires additional information to be provided by the system developer. Lastly, extracting the models from legacy systems incurs additional overhead.

## VI. Conclusion and Future Work

The IT infrastructure of SMEs faces several challenges due to the dynamic changes they undergo, the major problem is the real time communication between ERP and MES in SMEs, this paper put forward a proposed framework based on Cloud. The proposed framework is designed based on Model driven approach. It is concluded that there is a real time work monitoring status in MES by implementing our framework.

Future work includes

- Implementing the proposed MESSaaS with simulation platform.
- Evaluation of the proposed framework in large scale companies by using different type of Service delivery model.

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