Developing Manufacturing Execution Software as a Service for Small and Medium Size Enterprise

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ABSTRACT

Small and Medium Size Enterprises (SMEs) have been considered as the engine of economic growth and for promoting equitable development, many of the Small and Medium-size enterprise are suffering from the lack of the capabilities of research and development. SMEs will have to increase the agility and flexibility of their IT infrastructure, in order not to lose competitiveness and to respond quickly to customer's demand. Also the real time access to information and response to unplanned disruptive events are becoming important issues, due to the rigidity of the IT infrastructure. This research 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 hence it affects the flexibility and agility of the system. To cover the gaps between MES and ERP, a Cloud based Software as a Service for MES (MESaaS) is proposed. This thesis (a) proposed a cloud based MES for SMEs (b) introduces a framework based on the Model Driven Architecture (MDA) for designing the proposed MESaaS.

It is concluded that using the proposed framework, there is a real time operation and the complexity of the IT infrastructure of the SMEs is reduced.

Keywords: Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), Software-as-a-Service (SaaS), Model-driven Architecture (MDA)

ÖZ

Küçük ve Orta Boy İşletmeler (KOBİ), ekonomik büyümenin motoru olarak ve adil kalkınmayı, sağlamak için birçok araştırma ve geliştirme yeteneklerinin eksikliğini gidermek için düşünülmüştür. KOBİ'ler için rekabet etmek ve müşteri talebine hızlı cevap verebilmek için , BT altyapısının çevikliğini ve esnekliğini artırmak zorunda olduğu belidir. Ayrıca bilgi ve plansız olaylara yanıt vermek , gerçek zamanlı erişim sayesinde IT altyapısı sertlik ve önemli konularda haline gelmektedir. Bu araştırma Küçük ve Orta Ölçekli işletmelerin IT altyapısı karşılaştığı ihtiyaçları ve zorlukları inceliyor. Bulgular Kurumsal Kaynak Planlama (KKP) ve Üretim yürütme sistemi (ÜYS) arasındaki iletişim sistemin esneklik ve çeviklik etkiler , dolayısıyla gerçek zamanlı olmadığını gösteriyor. ÜYS ve KKP arasındaki boşlukları doldurmak için, ÜYS (MESaaS) için bir hizmet olarak bulut tabanlı yazılım önerilmektedir. Bu tez, (a), (b) önerilen MESaaS tasarımı için modele güdümlü mimari (MGM) dayalı bir çerçeve sunar KOBİ'ler için bulut tabanlı ÜYS önerdi.

Bu önerilen yaklaşım kullanarak, azalır gerçek zamanlı operasyon ve KOBİ'lerin bilişim altyapısının karmaşıklığı olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Kurumsal Kaynak Planlama (KKP), Üretim Yönetim Sistemi (ÜYS), yazılım olarak servis(YOS), Modele güdümlü Mimari (MGM)

DEDICATION

I dedicate this thesis to God almighty who has made it possible for me to complete this research and also to my parents for their enormous support.

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INTRODUCTION

1.1 Introduction

The small and medium-sized enterprise (SME) is an important part of manufacturing industry, it plays a significant role in the development of gross domestic product, it reduces employment pressure and also optimizes economic structure[1].Many of the Small and Medium-size enterprise are suffering from the lack of the capabilities of research and development, operating management and coordination of the industrial chain. Research shows that there has been noticeable changes in Small and Medium-sized Enterprise as markets demand products with low cost and high quality. The small and medium-sized industry, in order not to lose competitiveness and respond to customer's demand will have to increase their agility and flexibility, while maintaining their productivity and quality[2]. The real time access to information and response to unplanned disruptive events are becoming important issues, due to the rigidity of the control architectures of most traditional manufacturing systems; there has been weak response to unplanned disruptive events.

A survey by the American Society for Quality(ASQ) in December 2013 stated "only 13 percent of the manufacturers surveyed said they use smart manufacturing within their organization", but 82 percent of the organizations that have implemented smart manufacturing have enjoyed increase in efficiency, there has been products defects with 49 percent while 45 percent enjoyed increased in customer satisfaction. An important element of smarter manufacturing is the adoption of the Internet of Things (IoT)[3], though manufacturing companies have been implementing sensors, Programmable Logic Controllers (PLC) and PC-based controllers for decades but they are far below IT and operational system. IoT have been widely studied and applied in many fields, as they can provide a new method for intelligent perception and connection from man-to-man, man-to-machine, and machine-to-machine, which helped with on-demand use and efficient sharing of resources respectively. Many information technologies and theories have been fast developed and widely applied. At the same time, the growth of competitive market globalization and customer demand diversification have led to the increasing demand of agility, networking, service and socialization of manufacturing[4]. To realize some certain goals, which include fastest time-to-market, highest quality, lowest cost, cleanest environment, greatest flexibility, and high knowledge, a variety of IT infrastructures have been proposed. Companies have been able to realize a closer integration of their information services (IS) as a result of the advent of internet, many SMEs has adopted a betters means of doing business from the traditional way to e-business due to the development of internet[3]. IT helps to manage information in industrial enterprises; IT makes it easy for enterprise to integrate many decision functions that exist in the subsystems, which are important in manufacturing and distribution of a product. These subsystems are sales, production planning, purchasing, process control, quality control, and supply chain logistics. In manufacturing field, IT infrastructure has developed for about 35years, many technologies and popular manufacturing modes have been proposed. In the late 1960s to 1970s, Manufacturing Requirements Planning (MRP) was proposed and integrated. Manufacturing resource planning (MRP II) was built on the basic MRP model extended MRP to include capacity planning[5]. Nowadays the classification of IT in the industry are categorized in three levels, which are; ERP, MES and control layer.

There has been great development in ERP, which has giving birth to an opportunity to manage SMEs within and beyond the organizational scope[6]. This supply chain improves communication within internal and external business networks, enables a high level of integration, and enhances the decision-making process. Current ERP solutions has limitations in terms of supporting multiple plants, multiple suppliers, and lack abilities such as inventory control, production order processing and management planning in manufacturing industry. The present ERP technology provides an information-rich environment that is good enough for intelligent planning and execution logic. Theoretically, ERP can solve the strategic problem at the upper level, and mainly handle internal and external relevant resource issues. Nevertheless, there are many limitations of ERP. It is precisely because of integration that the ERP system provides an industry standard for specific types of business. On the other hand, it also limits the flexibility and lowers the competitive advantage of an enterprise particularly in the manufacturing industry. In order to bridge the gap, there is a need to design a system that can provide the detailed and traceable data about production at lower level, such as the shop-floor control, these data are precisely the key cost drivers in manufacturing [7]. Also a system that can serves as information link between planning systems and manufacturing shop-floor control systems, research shows that the use of MES 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; it improves product quality, it optimizes the inventory and warehouse, it empowers the plant operators; it improves customer services and real-time responds to unplanned disruptive events [8]. Therefore researchers propose the use of MES to bridge the gap.

ERP gives production orders to MES and link quality control, scheduling and material information. It also supports the handling of material including serial number generation for products and also the receipt of goods. Statistics reporting and performance dashboards could also be added to provide a complete view of production cells and lines in the system [9]. Multi agent based MES is a new approach in the field; it supports distributed manufacturing and increases autonomy because tasks should be performed by agents without the help of humans and have a control over their own actions and also be able to interact with humans and other software agents. They also have high and timely response to change occurring in their environment and modify their behavior over time in response to changing environmental conditions [10-12]. Mobility is also an important characteristic of a multi agent MES because it changes its location to improve its problem-solving ability [13].

However, existing MES lacks adaptability, reorganization and configuration. It is unable to adjust its architectures an d functionalities following changes in enterprises, businesses and organizations, thus hindering the wide adoption of MES software [14]. From this problems stated above, several system solution were proposed such as Agile manufacturing (AM)[14], networked manufacturing (NM) [15], Virtual Manufacturing (VM), Smart manufacturing(SM), grid manufacturing (GM), Cloud Manufacturing (CM), Service Oriented manufacturing and so on. The process of modern manufacturing nowadays is becoming most complex living human system, and the system's adaptability is becoming complex. SMEs have a business environment that undergoes rapid changes and also frequent changes in the IT/IS systems; hence there is a need to propose a new solution that will support distributed manufacturing.

Cloud computing 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[16]. Third party operation like professional computer and network company provides cloud computing. Cloud computing may be referred to as the continuation of grid computing and virtualization. However, cloud computing has a peculiar difference as it introduces a change in the service mode[17].In the cloud architecture, cloud computing run on a Software as a Service (SaaS) layer. Metered time and duration of use are the bases for charging the user of cloud. Cloud computing is faster, cheaper and simpler to use and it provides a set of functionality that is richer than in house counterparts, it offers business users chance to immediately implement services with usage-based billing that are tailored to their requirements. The shortage of solution to the current ERP can be solved by the use of cloud computing. Many businesses have adopted the use of cloud computing. The major commercial providers of cloud application are constantly improving the relationship between the clouding hosting provider and SaaS based. Figure 1 shows a cloud environment connecting all entities in different enterprise together.

Figure 1. Cloud computing

In 2011, Moad stated that cloud based application is new in manufacturing industry, however, the use of cloud in terms of performance and the security of the public network is no more a concern, the concern remains how cloud commercial providers will enhance cloud's functionality such as business intelligence and individual capability of each enterprise. Manufacturing sub-processes across different plants in different areas is been standardized by the use of cloud based MES. Manufacturing assets in different areas is acquired and better internal cooperation within the organization is achieved, which makes the cloud based MES concepts very suitable.

Nevertheless, bringing ERP and MES to cloud has remained a great challenge. MES is more process specific, in other word, it has a highly customized process operating on a specific plants, and a need for a rapid reconfiguration, when there is a change in requirements and processes is needed[6]. Cloud-based solution however, has limitation in customization, and also since cloud-based solution is in early days of implementation, there is a need for standard and more research.

1.2 Research Aims and Objectives

The aim of this research is to investigate the challenges and needs for the management of multi manufacturing in small and medium-size enterprises by proposing a cloud based manufacturing execution system, and the key technologies for implementing the proposed framework in the SMEs will be introduced in details. Data integration inside SMEs network affects the complexity of the IT system and the communication between ERP and MES is not real time, also bringing ERP and MES to cloud has remained a great challenge. To minimize the problem faced by SMEs which is integrating ERP and MES in cloud, this research present a framework based on cloud computing for a centralized ERP and MES that focuses on improving the real time operation and reduce the complexity of the IT infrastructure of SMEs.

In achieving this aim, the major objectives of this research can be stated as follow.

- Firstly, a cloud based manufacturing execution software as a service is proposed to bridge the communication gap within the IT infrastructure of SMEs.
- Secondly, a framework based on the Model Driven Architecture (MDA) for designing MESaaS in the IT infrastructure of SMEs is proposed.

1.3 Research Methodology

To solve the software problems faced by IT infrastructure of SMEs, the work done in literature in the field of ERP/MES system was reviewed to highlight the drawbacks, challenges and needs were combined with some requirements of the manufacturing companies operating as SMEs. From the problem statement, a framework named MESSaaS is proposed to cover the gap of data integration between ERP and MES in SMEs. To develop this MES software, a Model Driven Architecture (MDA) is used. MDA is a software design approach for the development of software systems. Figure

2 shows the proposed architecture for integrating ERP and MES in SMEs, the MESSaaS is connected to the inside network of the SMEs for scheduling purpose and have real time information of all entities in the enterprise and connect to the cloud ERP/MES. Customers login to seek information about which SMEs can design a part and the web access has a connection to the cloud ERP/MES to find out which company can carry out the operation, the centralized cloud ERP and MES is connected to the proposed MESSaaS, the MESSaaS has an online connection with the inside network of different SMEs which have their ERP and MES centralized in cloud. This will help to have real time operation and also reduce the complexity of the entire system.

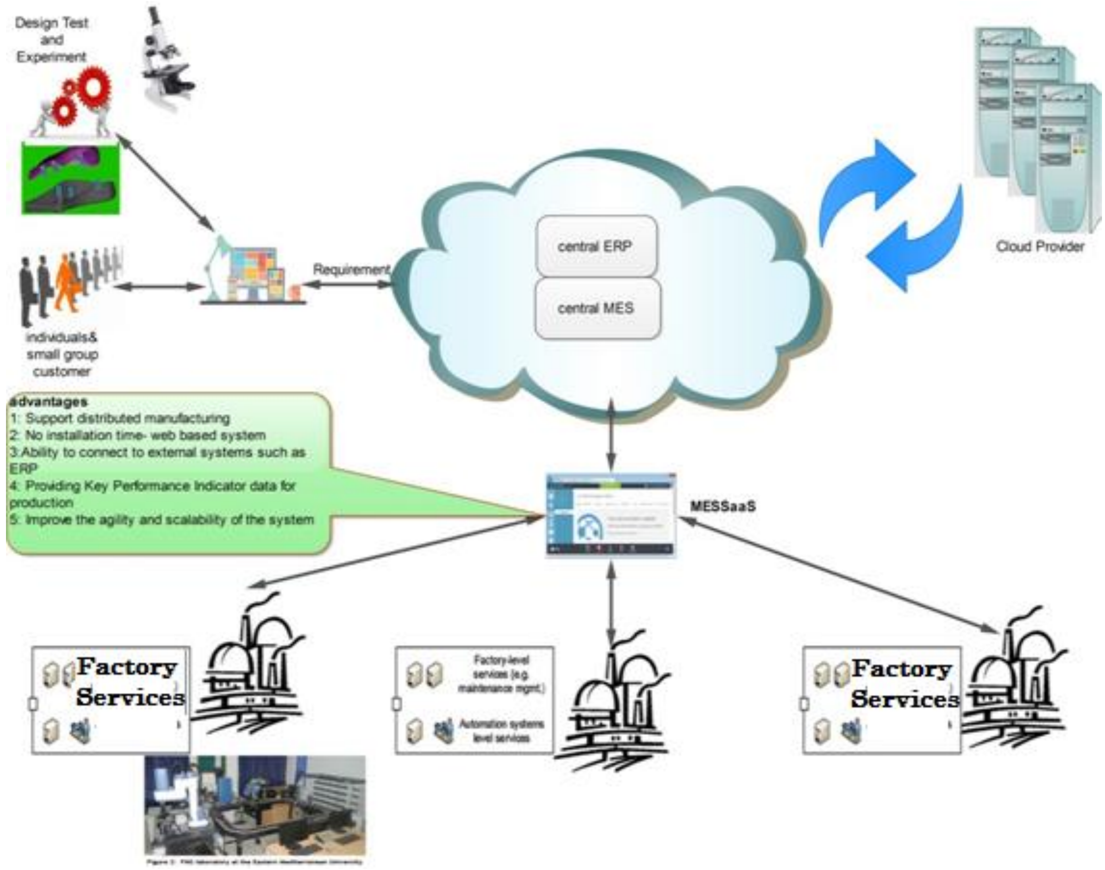

Figure 2. The proposed architecture for integrating MES and ERP system

1.4 Structure of thesis

The remainder of this thesis consists of four (4) chapters. In chapter two, the review of the previous work done in the area of Cloud ERP/MES is presented; the merits and benefits as well as shortcomings of the current solution will be explained. Moreover, the effect of the frequent changes that occur in shop floor of SMEs will be clarified. Since the aim of this thesis is developing a cloud based manufacturing execution system based on Software as a Service; the approach and tools for modeling this architecture will be introduced in chapter three. In chapter four, the implementation and a real case study is presented. Chapter five is the conclusion of this research and some endorsements for future works on this context.

Chapter 2

LITERATURE REVIEW

2.1 Overview of Cloud Computing

In an article from 1990, the future implementation of Computer integrated manufacturing (CIM) was discussed by Goldhar and Jelinek [18]. The gradual change of factory from mechanical operation to information technology operation was highlighted by these authors; they also highlighted the usefulness of CIM for mass customization. The future predicted by Goldhar and Jelinek goes in accordance with the vision of CIM, which includes the ability to give intelligence to the factory shop floor, and the ability to complete any task regardless of the size of the job. Though, Goldhar and Jelinek for saw the "smart" factory, both authors couldn't envisioned the benefit of networking different factories together into a "smart" enterprise. Reasons could have been that internet was not prominent as at the time the document was written in the year 1990. The importance of internet for rapid manufacturing technologies and design was published in 1998 by Rajagopalan et al [19], a connection between manufacturing services and designers by an internet infrastructure was discussed by these authors. They also described the presence of manufacturing services, design clients and process broker which are the intermediaries, just like many other recent papers described it. The stated purpose for such an infrastructure is to allow for the separation of design and manufacturing – both in a geographic and organizational manner. In their work, the design client uses software that augments traditional Computer Aided Design programs and allows connection with the process broker to communicate design requirements to the manufacturing services providers. This work is very clearly applicable to the vision of Computer Integrated Manufacturing presented in this report and represents a significant advancement toward under-standing the possible capabilities and advantages of a Computer Integrated Manufacturing style environment. The DLA Piper legal group explains that internet enabled manufacturing, crowd funding, and advertising through social media represent a revolutionary method of value production in today's marketplace[20]. Clearly, manufacturing business is being transformed from physical product-based business to service-oriented business[20]. Traditionally, manufacturing industry is featured as a type of heavy capital investment business because of the upfront investment on manufacturing assets (e.g. CAX software and CNC machines), which unfortunately does not provide the much needed agility for today's business.

Nowadays, a manufacturing enterprise would not survive without computer-aided applications (CAX) technologies. Deploying CAX software on the Cloud improves the performance in terms of flexibility, extendibility, integrity and easy/unlimited data storage. With a Cloud structure, software is easily maintained and utilized on a Cloud server. In realizing this, more and more companies have started adopting a service-oriented approach – packaging traditional manufacturing resources as consumable services on a pay-as-you-go basis. Autodesk (a world leader in computer-aided design software) has introduced a set of cloud-based tools for simulation and engineering processes - Autodesk 360 Cloud Services. It brings mechanical, fluid flow and thermal simulations all to the cloud, and is typically based on a pay-as-you-go model that allows users to access the software without the need to make heavy investments in licensing fees, installation, or software updates and upgrades. NetSuite Inc. a leading provider of ERP solutions, unveiled its next-generation ERP solution as budget cloud services. Customers can choose the right software package based on their personalized needs and financial plans. The above endeavors signal a trend of transforming business operating infrastructure to the cloud, which gives manufacturing companies business agility and financial flexibility. This paradigm shift gives rise to a novel manufacturing business model - cloud manufacturing. Cloud manufacturing is a customer-centric manufacturing model enabling ubiquitous, convenient, on-demand access to a shared pool of diversified and distributed manufacturing resources that can be rapidly provisioned as consumable services [1]. These services can range from conception of a product all the way up until its disposal.

2.2 Service Oriented Architecture (SOA)

SOA has become an architectural style that allows the reuse of existing assets within a new pattern that ensures abstraction of underlying logic, loose coupling, discoverability, flexibility and reusability[21]. As the IT industry has found alternatives to the mainframe-computing pattern, the emergence of smaller and more localized computers began to surface. The growth of the infrastructure of smaller and more localized computers has led to the need to make each computer communicate with each other. This quest to make computers communicate with each other has brought about the server/client architecture and later the distributed systems architecture by having some functions and distributed data from 1995 to 2005[22].

From the viewpoint of business and technology, Markes and Bell[23] defined SOA as a conceptual business architecture where business functionality or application logic is made available to SOA users, or consumers, as shared, reusable services on an IT network, also SOA is defined as a framework of technology that enables all systems, both inside and outside of an enterprise, to access well-defined services, and information attached to those services, that may further include composite applications and process layers for developing a solution. In other word, SOA ensures that an architecture is agile, which allows us to deal with changes in system by using a configuration layer rather than having to redevelop these systems intermittently. SOA provides detailed guidelines and specifications to explain how services can be described, discovered and/or used. In SOA, developers organize and package different software applications as services. Each service includes an interface which specifies the operations available and types of messages it can handle. In industrial systems, SOA has been widely adopted and applied to transportation systems, manufacturing execution system, healthcare medical system, electronic power application system, electronics production systems, factory ordering systems[23]. Due to its strong support for both autonomy and interoperability, SOA approaches have the capabilities to implement communication and data exchange between embedded systems/devices and various applications. Figure 3 shows the component of a Service-oriented architecture, the corporate network is connected to the enterprise service bus and software development

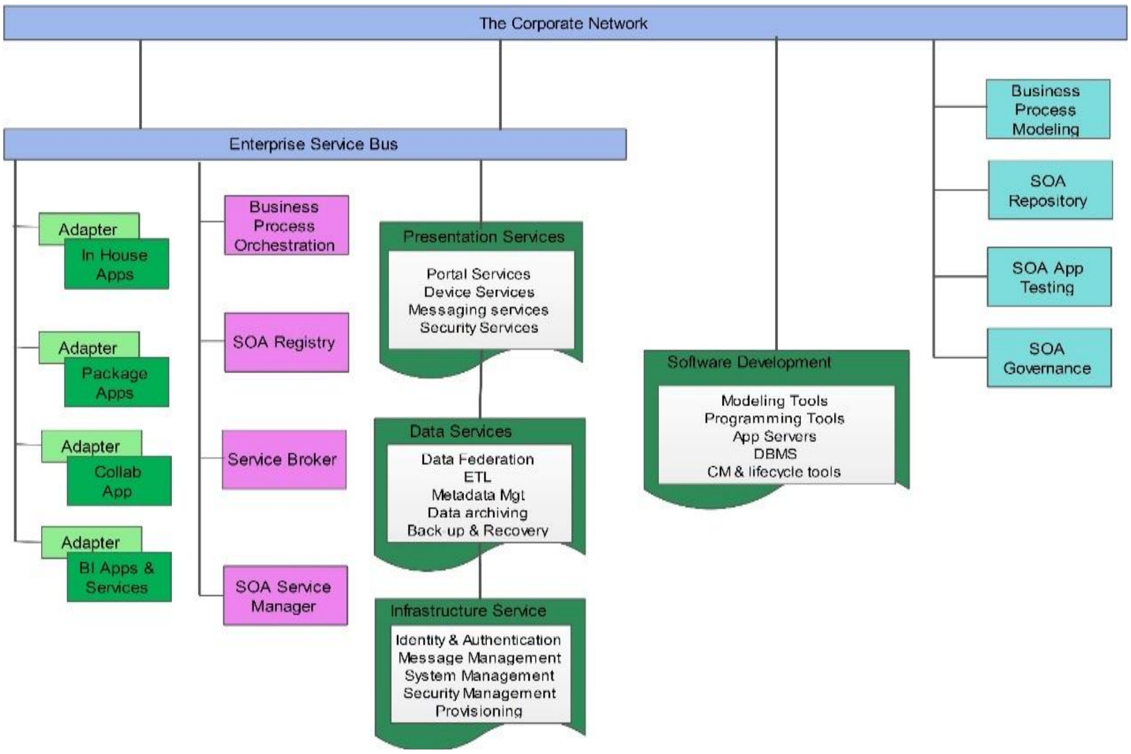

Figure 3. The flowchart of service-oriented architecture components

The architecture allows for the creation of composite business applications from independent, self-describing, and interchangeable code modules called services. These services are available for use on a services bus and can be arranged together, into a business process, or composite application, using process choreography. So, the major components of SOA are:

- Services are the core building block within an SOA. They are repeatable business task, Independent, self-describing, module of code, discoverable resource that executes a repeatable task, and they are reusable.

* Services Bus: An Enterprise Service Bus (ESB) is a flexible connectivity infrastructure for integrating applications and services. A picture of Enterprise Service Bus and its function is shown in Figure 4. One of the objectives of an ESB is to reduce the number, size, and complexity of interfaces in a SOA.

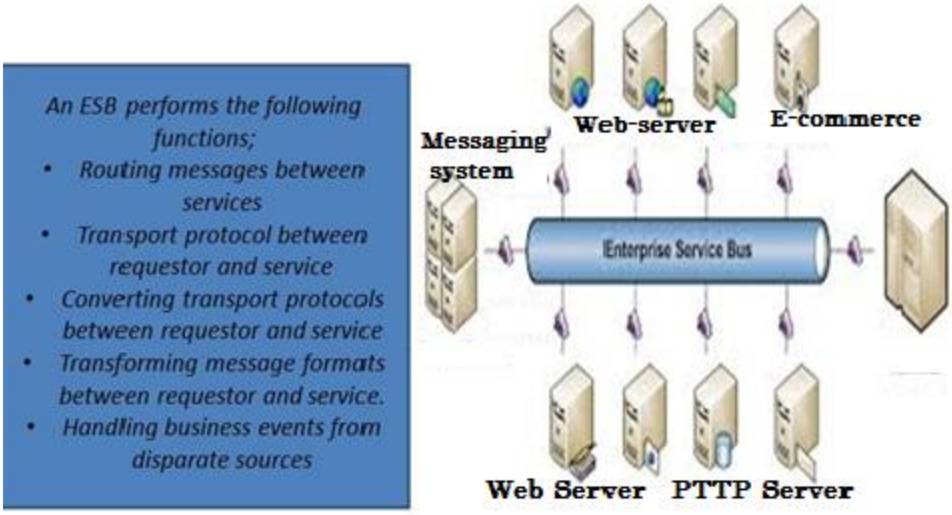

Figure 4. An Enterprise Service Bus[24]

* Process choreography: composite applications within an SOA, process choreography are realized via Business Process Execution Language (BPEL). In general, BPEL is a standard eXtensible Markup Language (XML) based which, when compiled into executable code, allows one to compose business processes out of available services. An example of a business process triggered in a manufacturing area would be a work in process (WIP) tracking process. In an automotive example, when a vehicle enters an assembly area work station, an event triggers a business process that run services like:
    • Update vehicle location in the MES application
    • Update vehicle history record in the MES application
    • Obtain vehicle options from the vehicle order information

• Broadcast vehicle options to future assembly work station programmable logic controls (PLCs)

- Services Registry: can be used to find, publish, manage and subscribe to services. A registry may also be used to store metadata, such as:

  • Service provider

  • Availability

  • Affectivity dates

  • Performance characteristics / KPIs

2.2.1 Benefits of SOA

Yoon and Carter (2007) investigate the benefits that drive an organization's interest in adopting SOA. Their case studies reveal that SOA can facilitate integration of systems, improve data flow and customer service as well as reduce IT cost. In addition, SOA can lead to quicker IT responses to market change or customer demand and to reuse of already existing implemented functionality. Baskerville et al. (2005) emphasize theoretically the high potential of reuse of an SOA, even though they could only partly show positive effects of reuse (such as lower development costs or responding quicker to changing customer demands) in their two case studies, as existing services needed to be adapted to reuse existing functionality. SOA is a key competitive edge that allows an increase in market share; create better products and lastly living up to the goals of the organization. The full benefit of SOA is highlighted in details[25];

1. Reuse of services and behaviors, or the ability to leverage application behavior from application to application without a significant amount of recoding or integration. T-Mobile is employing SOA for both internal integration Sand reuse, as well as the external, partner- and revenue-

generating elements. This approach enables T-Mobile to work effectively with third-party content providers such as Time Warner and the Bertelsmann Group to deliver services to customers.

2. Agility, or the ability to change business processes on top of existing services and information flows, quickly and as needed, to support a changing business. Motorola has introduced 180 services through its SOA framework and business activity monitoring projects (monitoring the linkages between enterprise software apps), and has an average of 50 rules, covering everything from credit card transactions to warranty services.
3. To increase speed to market: Owens & Minor, a distributor of medical and surgical supplies, has embarked on a four-year SOA initiative, and forecasts annual savings of $650,000, half attributable to better inventory accuracy and half to productivity savings and improved cash flow. The company can now automate processes in a few weeks that once would have taken as much as nine months.
4. Monitoring is the ability to monitor points of information and points of service, in real time, to determine the well-being of an enterprise or trading community. Moreover, SOA provides the ability to change and adjust processes for the benefit of the organization in real time.
5. Extended reach or the ability to expose certain enterprises processes to other external entities for the purpose of inter-enterprise collaboration or shared processes. This is, in essence, next-generation supply chain integration.
6. Cost reduction: Verizon Communications claims it averages about 2.5 million to three million Web services transactions a day through a "home-grown" SOA. The system went operational in 2004 and Verizon says it has slashed its

IT budget by 50% by eliminating redundant systems inherited from the merger of Bell Atlantic and GTE. The SOA also helped integrate the operations of some 7,000 developers.

2.3 Cloud Computing

Cloud computing is an idea of providing service which is stored in the cloud to the user. This concept is provided by professional computer and Network Company which is known as a third party operation. Cloud computing may be regarded as a continuation of grid computing, howbeit, the peculiarity of cloud computing is the introduction of changes in the service mode. Computing resource becomes a high technical service and users access it in a more informational way in cloud computing. Cloud computing represents a combination of various IT technologies: hardware virtualization, distributed computing (grid computing, utility computing), internet technology (service oriented architecture, web services, Web 2.0, broad-band networks), system management (service level agreements, data center automation) and open source software[16, 26, 27]. The relationship between cloud computing and SOA is that cloud computing provides IT resources it can leverage on demand, including resources that host data, services, and processes. Thus, While many believe they can simply create quick and dirty links between core enterprise information systems and cloud computing resources, the fact is that you really need an architecture inside of the enterprise, such as SOA, to make the most of cloud computing. Cloud computing focuses on enterprise applications, these made it unique from grip computing method, scientific and engineering applications has been the major focus of such computing method.

Cloud Computing has many problems in security, because this technology is new and we can see that many problems will appear in its feature. Data availability or business continuity[28] is one of the most important problems in Cloud Computing environment. Cloud computing also makes use of concentrated of resources in a single domain which has different data centers. The idea of cloud computing covers companies with different management, sizes and different number of users, there are different service delivery types of cloud

- Private cloud: These involve a sort of infrastructure that is been operated completely by an enterprise, it may either be controlled by a third party or the enterprise.
- Community cloud: Many enterprises share this type of infrastructure and support a specific community that exhibits the same mission and policy, it also can be managed by a third party or by the enterprises and the infrastructure may exist within the community or outside.
- Public Cloud: This is a business oriented type of infrastructure made available to the public or very large organizations usually provided by commercial cloud service provider.
- Hybrid Cloud: it comprises of more than one cloud(community, private or public) which are joined together by a technology that is standardized which allows application and data portability, and they all exhibit a unique entities. A hybrid cloud represents a composition of two or more clouds mentioned above that are connected together but remain relatively independent.

Generally, cloud services can be divided into three service delivery models. the three delivery models in which cloud computing can be subdivided: Software as a Service

(SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). It is important to also have an understanding of the underlying service delivery models in order to fully understand the cloud concept.

2.3.1 Types of Service delivery models

1. Software as a service (SaaS): is a software licensing and delivery model in which software is licensed on a subscription basis and is centrally hosted. It is sometimes referred to as "on-demand software [29]. SaaS provides the right to access application provided by the service provider in a cloud system. Different clients use this application through an easy way such as web browser. Network, storage, operation systems and servers are part of the cloud infrastructure which cannot be controlled by the user.
2. Platform as a service (PaaS): provides the ability to use applications created or acquired by consumer by using programming languages and tools allowed by the service provider. Just as in SaaS, Network, storage, operation systems and servers are part of the cloud infrastructure which cannot be controlled by the user, however the consumer has control over the applications and over the configuration of the hosting environment
3. Infrastructure as a service (IaaS): is the ability to access the networks, storage, operation systems, deployed applications and other computing resources, however the user cannot manage the underlying cloud infrastructure. It has a minimal control over some networking components. Operating systems, load balancing, internet access, virtual instances, brandwidth provisioning, web servers and computing hardware are services offered by this delivery model.

Among them, SaaS is regarded as a potential segment and the utilization of SaaS solutions can lead to many benefits for enterprise users with profound consequences in improving IT performance [29]. Service providers can greatly simplify software installation and maintenance and centralizes the control of versioning. End users on the other hand can access the service “anytime, anywhere,” share data and collaborate with partners readily, while keeping their data stored safely in the infrastructure. As a result, an enterprise customer does not have to acquire the whole enterprise software suite, and yet is able to choose each module from different vendors, creating a unique, cost-efficient and customized enterprise solution [30]. By definition, Software as a Service or SaaS is a delivery model that enables application software for use by end-user organizations „on tap‟ or „on demand‟ or “as and when required‟ using Internet based Service. Figure 5 shows the three delivery model which is Software-as-a-Service, Platform-as-a-Service, Infrastructure-as-a-Service and a little inside features of each services is shown.

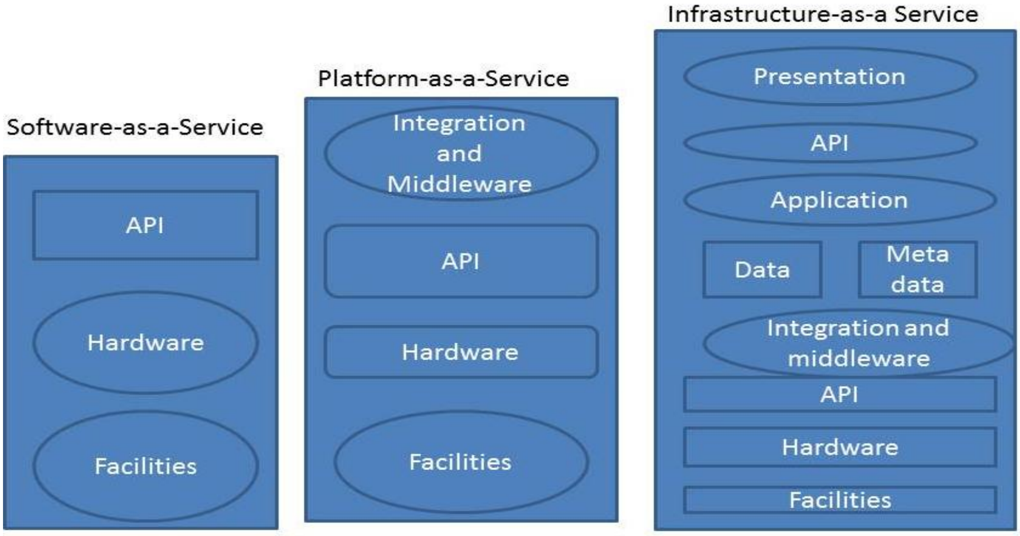

Figure 5. The three delivery model

2.4 Cloud ERP/MES

Cloud computing enables many applications of Web services and rekindles the interest of providing Enterprise Resource Planning (ERP) services via the Internet. It has the potentials to reshape the way IT services are consumed. Recent research indicates that ERP/MES delivered through SaaS will outperform the traditional IT offers[31], the need of ERP and MES based SaaS solution is closely associated with attempts to improve the business value of IT investments, whereas an ERP solution seeks to integrate and streamline business processes and their associated. Within the hype of cloud services, ERP and MES systems delivered as Software as a Service (SaaS) is receiving more focus from ERP vendors. ERP vendors have for many years developed and sold ERP as 'standard software' that fits the needs of many firms, and now SaaS as a new approach to deliver software has emerged.

In India, SMBs companies are always willing to implement ERP Application to automate their Business Processes. However, they are unable to do the same due to huge costs & risks associated with any ERP Implementation (SAP, Oracle etc). Now, full-fledged ERP and MES on SaaS Model is viable option for these organizations where they need not to invest huge amount and minimized their risks with option to withdraw from using ERP on SaaS Model at any moment of time.

In traditional ERP, organizations need extra costs for servers, network, backup systems and other IT infrastructures, otherwise, for implementing such system in Cloud ERP, all this infrastructures will be provided by Cloud Providers and these providers , provide these services with lower cost than implementing these infrastructures inside an Enterprise. Therefore, with Cloud Computing technology, the implementation costs will be reduced. These services will be managed and supported by expert system manager inside the Cloud providers and you will pay per usage and not for hardware's failures, so traditional ERP has relatively high and Cloud ERP has low ongoing costs[1]. Nevertheless, because of the management of these services by Cloud provider, the control over ERP in Cloud ERP is relatively tough. The Cloud ERP providers support customization, integration and module updates so customers can customize their own ERP system and update module they need easily. Customers need internet connections and web browsers to connect to Cloud ERP and this is an extra costs. Traditional ERP obviously wasn't developed with the cloud in mind, however, bringing cloud to ERP and MES is our aim. As mentioned earlier, Cloud ERP/MES solutions are delivered via the Software as a Service model. Although most Cloud ERP providers claim better innovation as one of benefits of Cloud ERP systems, Hoffman 2010 argues that cloud can actually impair the ability of enterprises to innovate. He claims that in order to innovate, enterprises must tailor ERP systems according to their unique needs. In the end, you achieve a competitive advantage by being different and better than your competitors, and not by conforming to same workflow. Saeed et al 2012 [32] argue customization to be difficult in Cloud ERP systems, and consider it a technical barrier to Cloud ERP adoption.

However due to the management these services by Cloud provider, there has been tough control over ERP/MES in Cloud ERP/MES. Customization, integration and module updates are supported by Cloud ERP/MES provider, these phenomenon allows easy way for customers to customize their own ERP system and also easily update modules [33]. The importance and performance of Cloud ERP/MES over traditional ERP can be shown by factors in Table 1 below.

Table 1. Traditional ERP/MES and cloud ERP/MES comparison

Factor	**Traditional ERP/MES**	**Cloud ERP/MES**
Deployment	Local Server	Cloud Server
Control over ERP/MES	Easily controllable	Tough to control
Response to changes	Very quickly	Not real time
Integration centrally	Dependent on vendor	Can be supported
ERP/MES module update	Costly	Low cost
Internet needed	No	Yes

On the other hand, the application of Cloud Computing is limited by some factors, security and privacy issues have been a major concern. So it’s gainful to focus on the advantages of cloud computing while considering its limitations and suggest a better way for companies and enterprises to implement this new technology. Security problem is a major concern in Cloud computing. Problems like data availability or business continuity is also a major concern in cloud computing environment[34]. In table 2, some comparisons between problem facing traditional ERP/MES and Cloud ERP/MES are mentioned.

Table 2. Risk factor between Traditional ERP/MES and Cloud ERP/MES

Risk Factor	Traditional ERP/MES	Cloud ERP/MES
Data Availability (Business continuity)	Low	High
Data confidentiality	Low	High
Web security issues	Low	High
Privacy	Low	High
Privileged user access	Low	High
Data locations and sanctions	Low	High
Recovery	High	Low
Long term viability	High	Low
Unknown risk profile	Low	High

2.5 Existing cloud solution in industries and Academia

2.5.1 Academia

This section reviews current and recent research initiatives pertaining to Cloud Solution. The first cloud manufacturing project was funded by China's National High-Tech Research and Development Program and National Basic Research Program. The goal of the project was to "realize the general sharing of global manufacturing resources, reduce time-to-market, improve quality of service, as well as reduce manufacturing costs." The cloud manufacturing concept proposed by Li et al. refers to a service-oriented, knowledge-based smart manufacturing system which encompasses the entire product development lifecycle from market analysis to design, manufacturing, production, testing, and maintenance. Meanwhile, the goal of the ManuCloud project (2010), launched by the European Commission's Seventh Framework Programme (EC FP7) with € 5 million ($6,700,000), is to "develop a service-oriented IT environment as basis for the next level of manufacturing networks by enabling production related inter-enterprise integration down to shop floor level." Recently, the Engineering and Physical Science Research Council (EPSRC) in the United Kingdom funded a project, titled "Cloud Manufacturing – Towards a Resilient and Scalable High Value Manufacturing" with £2.4 million ($4,050,000). The objective of this research is to "develop a holistic framework and understand its role within global manufacturing networks through: seeking the appropriate products, sectors, scales and volumes; identifying the impacted lifecycle stages from design to manufacture, maintenance and re-cycling; understanding how new product design and manufacturing will be influenced by lifecycle data; and finally analyzing how future products will be influenced by cloud manufacturing enabling local on-demand supply of components and services."

Wu et al. 2011 propose a Cloud Based Design and Manufacturing (CBDM) model composed of a cloud consumer, cloud provider, cloud broker, and cloud carriers[35]. The cloud consumers serve the obvious role of utilizing the cloud's services, while the provider shaves the equally obvious role of providing services in the cloud. The cloud broker is an intermediate party between the consumers and providers, and manages the use, performance, and delivery of services. Finally, the cloud carriers enable the exchange of services between providers and consumers through the provisioning of transport networks. Carlos Oberdan Rolim et al proposed a cloud computing solution for Patient's Data Collection in Health Care Institutions, he highlighted that processes for collecting patient's data are usually slow, error prone and require a great deal of labor work to collect, input and analyze the information. These would bring a latency that prevents real-time data accessibility. He proposed a solution that delivers an integrated telemedicine service that automates the process from data collecting to information deliver as a computing utility. Tao et al 2012 propose a four-stage CM model where manufacturing resources are controlled through the internet via intelligent monitoring systems. These resources are virtualized and encapsulated into Manufacturing Cloud Services (MCSs). These MCSs, in contrast to the actual physical resources they represent, can be accessed and invoked in the cloud. After creation of many different MCSs based upon the manufacturing resources available, the MCSs are categorized and organized into manufacturing clouds of similar services.

Katzel 2009 presents that the manufacturing sector in defined by computing needs which vary significantly with the product life-cycle phase. Cloud computing, as stated by Katzel 2009, can be thought of as a utility service, which can be accessed on-demand without owning the enabling technologies. According to Katzel, cloud computing can aid manufacturing and engineering by providing data storage, software services, and computational power. Edstrom 2011 presents that typical server usage lingers at roughly 8–15% of total capacity. The need to oversize computing resources based upon peak usage rates, in addition to the cost of maintaining these technologies, makes a usage based pay on-demand system truly beneficial and cost effective. Schultz 2007 presents that despite its clear benefits, data storage in the cloud has been slow to gain popularity because of concerns over data security, meeting regulatory compliance requirements, and cloud performance.

2.5.2 In industries

In addition to research projects being conducted in academia, several companies implement cloud solution for manufacturing, based on a particular case in the Elkay Manufacturing Company, which adopts a cloud-based solution, an average IT person's workload has shifted to higher level functions, and his or her skill set and knowledge base have evolved significantly in the process. Several companies are developing and testing similar commercial systems, most notably in the consumer product industry with rapid prototyping manufacturing resources. These companies utilize cloud-based services as a technology enabling their ventures and connecting designers with manufacturing resources over the Internet. Quirky offers users with access to a complete product creation enterprise [Quirky, 2014, available from https://www.quirky.com/.]. The business model of Quirky incorporates the originating designers into the wealth-sharing model and provides them with a portion of the profits that their products yield. The economist also discusses Shape ways, a company offering 3D printing services over the Internet. In contrast to the vetting process used in the Quirky business model, Shape ways provides user's immediate access to 3D printers to build any object that they want. Another successful project on Cloud conducted in the U.S. is part of the Manufacturing Experimentation and Outreach (MENTOR) program of DARPA[35]. The MENTOR effort is part of the Adaptive Vehicle Make (AVM) program portfolio. Several teams were awarded contracts for the MENTOR program, including Georgia Tech. The vision for the MENTOR program was to "develop an integrated, distributed design and manufacturing infrastructure that can support a progressive set of prize challenge competitions through integrated CAD, CAE, and CAM tools." The goal of this project, led by Georgia Tech, was to "engage students from these participating high schools in a series of collaborative design and distributed manufacturing experiments." The developed prototype system, Design and Manufacturing Cloud was built upon an integrated distributed manufacturing infrastructure with tools such as CNC machine tools, additive manufacturing machines (i.e.,3D printers) through a network of high schools dispersed across the U.S.

Chapter 3

METHODOLOGY

3.1 Cloud based Software-as-a-Service

To solve the problem of communication between ERP and MES in the IT infrastructure of SMEs, and also to have a real time operation and scheduling process, a cloud based manufacturing execution system is proposed based on Software-as-a-Service which is shown in figure 6. The proposed architecture is called MESaaS, The proposed solution consist of:

- Cloud provider for providing cloud environment, and it is responsible for flout tolerance, security, maintains of software etc.
- User 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.
- MESaaS
- Consumer: the SMEs that uses the proposed framework

The MESaaS supports distributed manufacturing and provides key performance indicator data for production, it also improve the agility and scalability to the system hence it provides real time operation to the IT infrastructure. The MESaaS is connected to the inside network of the SMEs for scheduling purpose and have real time information of the enterprise and connect to the centralized cloud ERP/MES. Individuals login to order a product or find out about an ongoing work via the web, and the web make a connection to the cloud environment to find out which company can carry out the operation, the MESaaS has an online connection with the inside network of different SMEs, which have their ERP and MES centralized in cloud. The IT infrastructure of each SMEs implement their existing network to connect with each entity in the shop floor, the MESaaS is connected to the upper level(Centralized network) of the IT infrastructure of each SMEs, this is done online to have real time operation and also reduce the complexity of the entire system. Furthermore advantages of this solution can be highlighted as follows:

1) It support distributed manufacturing
2) No installation time
3) It has an ability to connect to external system
4) It provides key Performance indicator data for production
5) It improves the agility and scalability of the system.
6) It reduces cost of IT architecture (pay as used).
7) It has no maintenance to worry about.
8) Less risky investment, no huge license fees to pay up front.

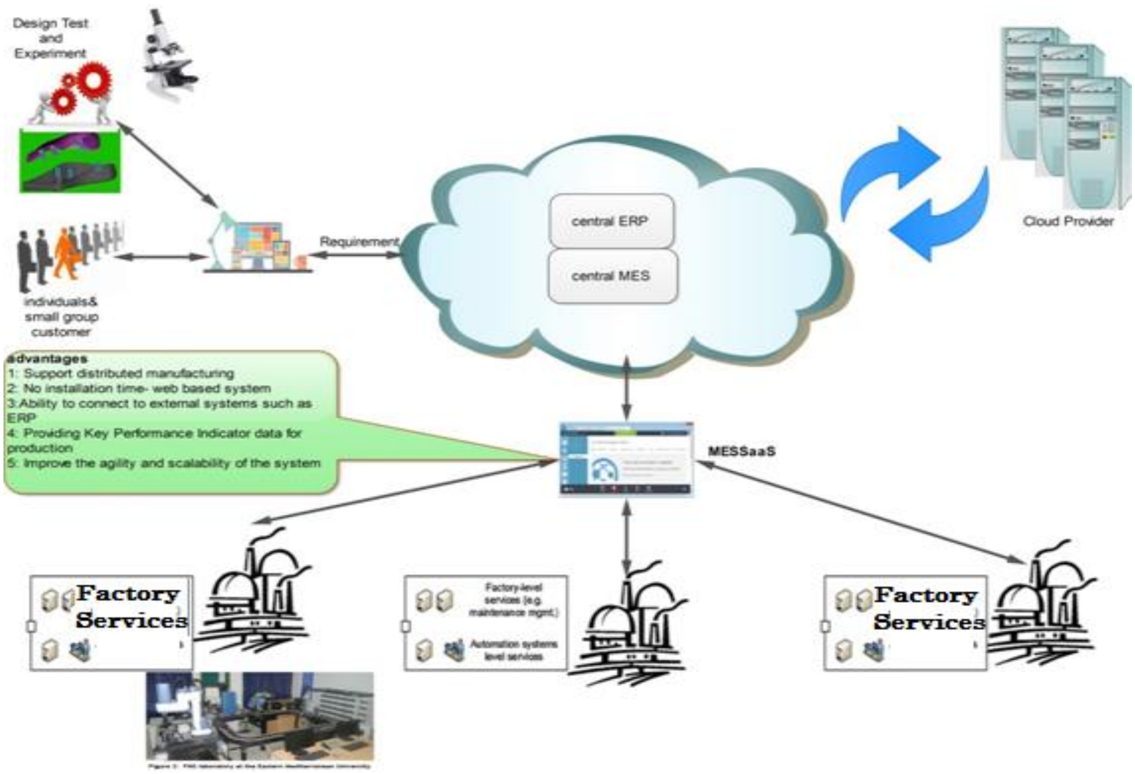

Figure 6. The proposed architecture for integrating MES and ERP system

MES based on software as a service is proposed to fill the gap presented in this research. To design the proposed MESaaS, a framework based on the Model Driven Architecture (MDA) is used to design it.

3.2 Designing MESaaS for SMEs based on MDA

To develop the software in cloud, the proposed MESaaS was designed based on a Model Driven Architecture. Model Driven Architecture (MDA) is the software design approach for the development of the software systems. MDA provides a set of guideline for the development of software systems and also provides a set of guidelines for the structuring of specifications, which are expressed as models. Model-driven architecture is a kind of domain engineering, and supports model-driven engineering of software systems. It was launched by the Object Management Group (OMG) in 2001. MDA 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. Model Driven Architecture (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, platform-independence and interoperability is incorporated into the application. Figure 7 is a snapshot of an MDA, it shows that MDA support various aspect such as Manufacturing, Healthcare, transportation, finance etc. MDA describes the system at a higher level of abstraction in which the model forms the primary artifacts.

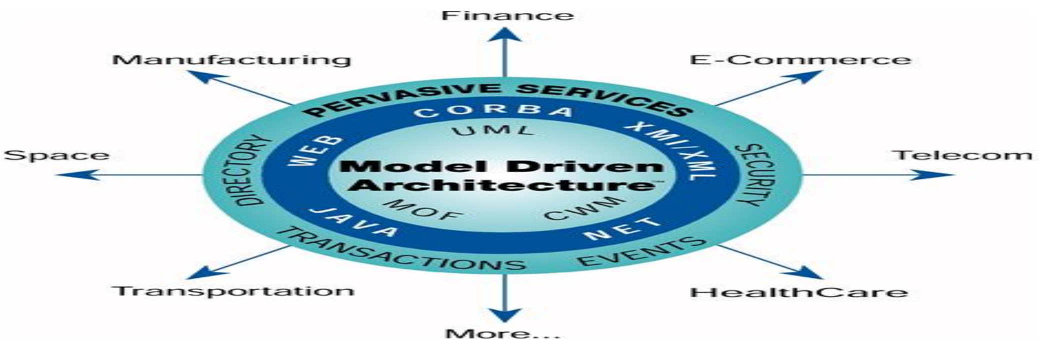

Figure 7. A snapshot of MDA[35]

3.3 Different level of abstraction of the models

MDA can be divided into three levels, the models are described at different level of abstraction which are:

1. Computation Independent Model (CIM): describes the basic features of system and produces a structured and coherent document of requirement specification. It is also often referred to as a business or domain model because it uses a

vocabulary that is familiar to the practitioners of the system's domain It presents exactly what the system is expected to do, but hides all information technology related specifications to remain independent of how that system will be (or currently is) implemented.

2. Platform independent Model (PIM): describes the behavior and functionality of the system in a generic manner. A platform independent model is a view of a system from the platform independent viewpoint. PIM describes the system, but does not show details of its use of its platform. Figure 8 shows PIM communication with different platform, which is supported by COBRA, JAVA and other models.

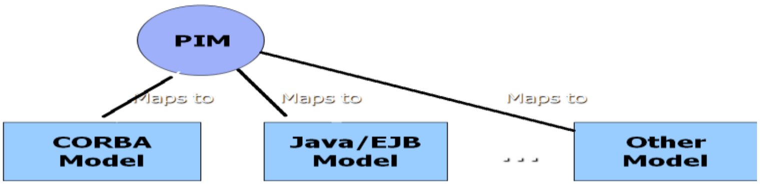

Figure 8. A snapshot of PIM[35]

Platform Specific Models (PSM): describe the system with respect to a specific platform. A PSM combines the specifications in the PIM with the details required to stipulate how a system uses a particular type of platform. If the PSM does not include all of the details necessary to produce an implementation of that platform it is considered abstract (meaning that it relies on other explicit or implicit models which do contain the necessary details) An MDA based development of cloud SaaS will greatly help to improve the quality of cloud independent manner thereby making them robust, agile and flexible.

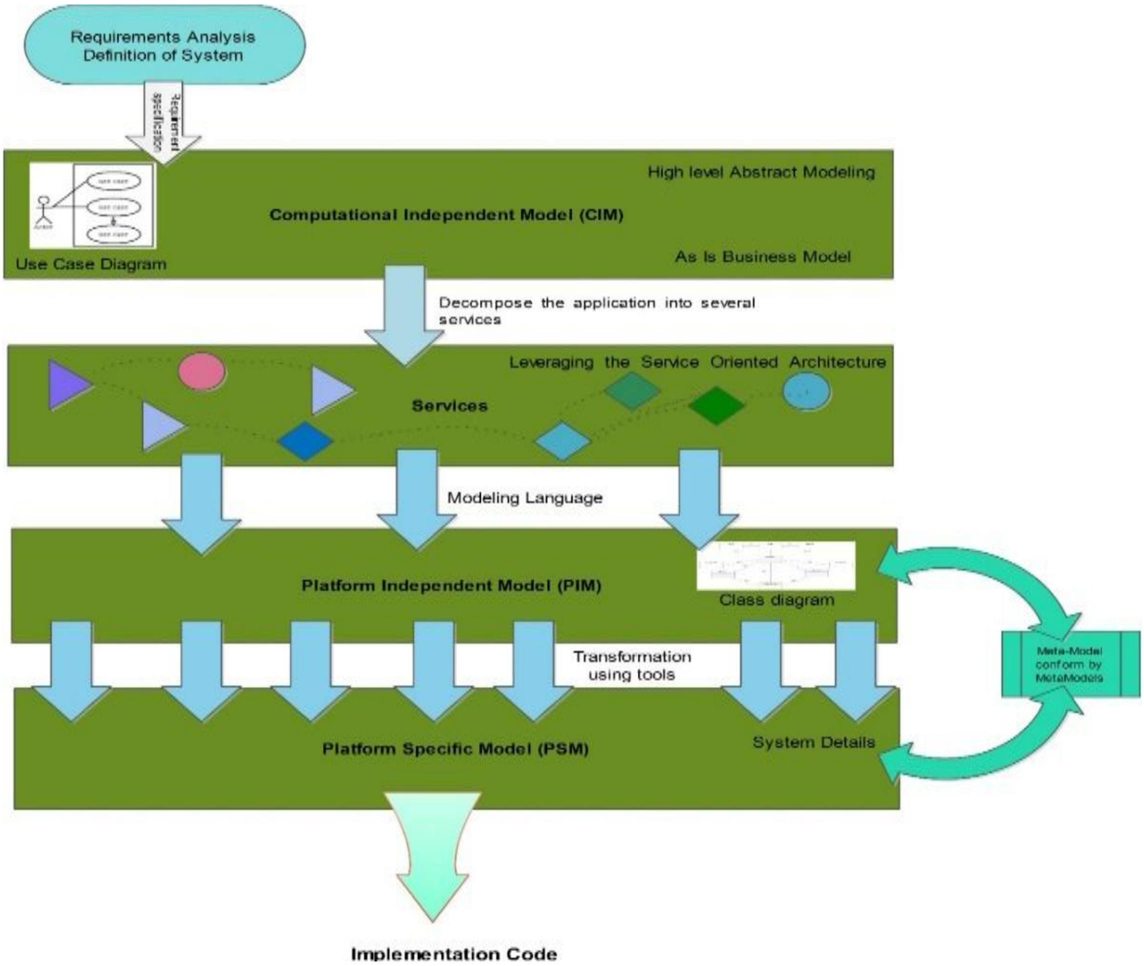

Figure 9. Designing the MESaaS based on MDA

Encapsulating business logic in a manner that is independent of the technical mechanisms will enable them to be reused in a variety of contexts and also satisfy the essence of the applications. The proposed framework for developing a MESaaS for cloud environment based on MDA is shown in figure 9. This framework consists of five levels. The first level of the framework starts by analyzing the requirements with focus on the system's definition. While the second level is the CIM level of the MDA, in this level, MESaaS 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 SOA, each sub software implements a small function of the application. 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. Figure 10 shows four layered architecture of MDA metamodel.

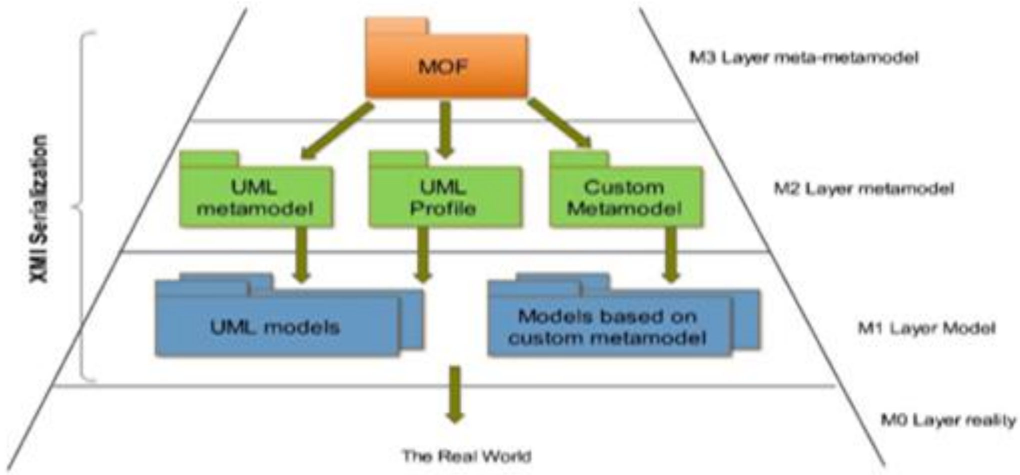

Figure 10. Four Layered Architecture of MDA metamodel

1. The first layer (M0) represents the functionality and behavior that should be exhibited by the system. It contains data to be modeled in real world.
2. The second layer (M1) contains the model which explains the real world data present in M0 layer. Several elements of the modeling language are used in these models and to create these models, any modeling language can be used.

3. The third layer is the M2 layer, it describe the user models in M1 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 M1 layer are instances of these metamodels. Transformation tools uses metamodels to determine how each construct in the source model is transformed to the target model.
4. The Meta Object Facility (MOF) is represented by the M3 layer,its function is to defines metadata and metadata services. It is also a standard that provides Meta Object Language (MOL) for the standardized description of the metamodels present in various modeling languages in M2 layer. This helps to bring together different models specified in various modeling languages into one framework and carry out various model transformations.

Different modeling languages are supported by four-layer architecture to create the models and their metamodels. Thus, it increases flexibility in the application development process. To create PIM, any modeling language can be used, however the most commonly used language is Unified Modeling Language (UML). Object Process Model (OPM) is another self-expressive language that can be used; it models the systems as objects and processes and establishes the relationship as processes acting on objects. They do not have separate metamodels and the elements of the models describe itself, hence they are regarded as self-expressive. The platform specific Model(PSM) is generated once the PIM is developed. By using transformation tools, PSM is generated from PIM. These tools are also useful for model-model, model-code transformations. The transformation tools contain transformation definition, which are specified by transformation rules. These rules also describes the semantics of how a construct in source language is interpreted in target language, they are also represented as models. Each service model in PIM is mapped individually to target environment during the mapping of PIM to PSM. These models are eventually integrated to form a complete PSM. The Quality of Service (QoS) is measured after each transformation; this is to ensure that the model conforms to the requirements. By using different transformational tools, various number of PSM can be generated from the PIM and the implementation code is generated from PSM. The code templates is automatically generated by the tools from the models, however, to have a complete code, additional information should be entered by the user.

3.4 Case study

MESaaS is proposed based on the designed framework of the Flexible Manufacturing System (FMS) which is located in Eastern Mediterranean University (EMU). The FMS lab in EMU consists of three stations namely; Automatic Storage Retrieval System (ASRS) station, machining station (CNC machine) and assembly station. The control MES system of this lab which is shown in figure 11 uses multi agent control system, which was proposed and implemented by some previous authors; it follows the standard ISA-95.3.

Figure 11. FMS Laboratory at the Eastern Mediterranean University

The user of MESaaS can be classified in two groups: Cell level of the factory and MES.

1. Cell level: consist of group of machine which use to production product. They can connection to internet via PC and sub software of each machine installed to this PC.
2. Manufacturing execution system: is software packet for controlling and scheduling of cell level. This software package communication with sub software of each PC and can be control and reschedule of cell level.

The various steps involved in MESaaS are as follows:

1. Cell level logs in using its username and password
2. The user then inputs the information of cell level and data base of user updated
3. The software then displays a list of scheduling for cell level
4. After selecting a schedule the production execution is send to cell level
5. Real time status monitoring exist for MES

3.5 Three Steps to Model the MeSaaS

1. Firstly the system is modeled at highest level of abstraction known as CIM in the second level of framework. The use case diagram for MESaaS is shown in figure 12 which explain the interaction between the cell level and the MES level

Figure 12. Use Case Diagram for MESaaS

After establishing Use case diagram, we published activity diagram. Figure 13 illustrates how proposed system works when new order comes from customers. The customers login to web site and send related information regarding a product. This information send request to ERP, three type of evaluation is created.

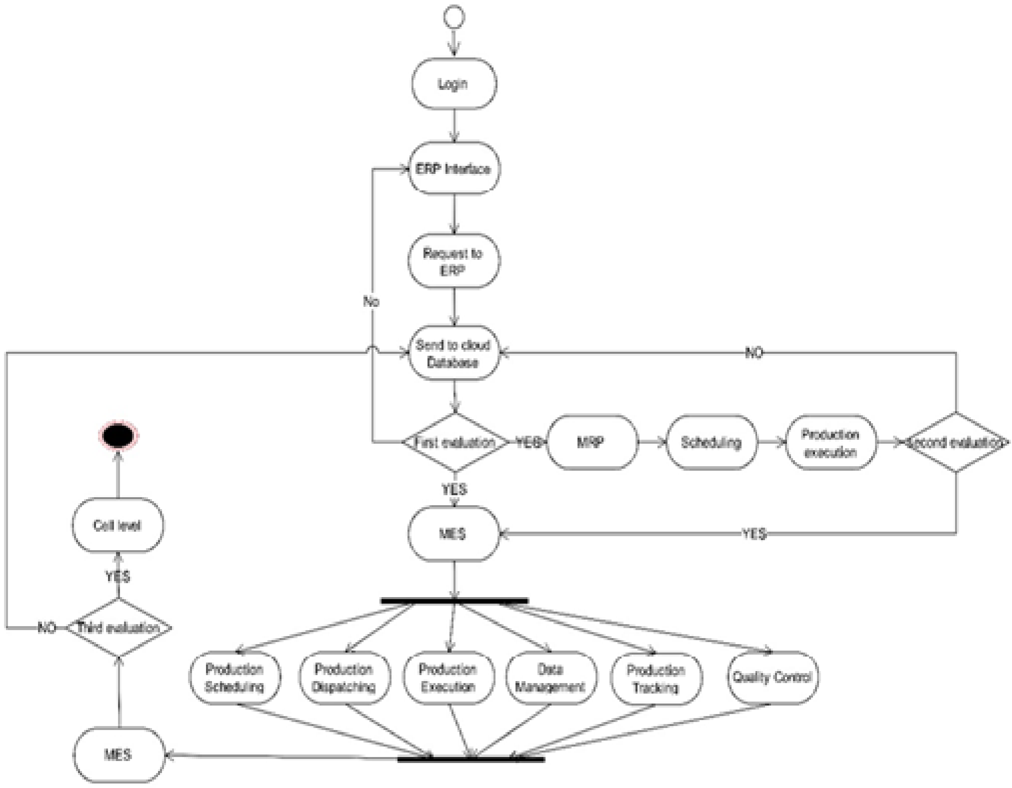

Figure13. User Login Activity Diagram

2. Second step is decomposing software to services which is shown in figure 14. The important services consist of; database service, scheduling service, production execution service, status monitoring service, communication service. Database service is a database that typically runs on a cloud-computing platform.

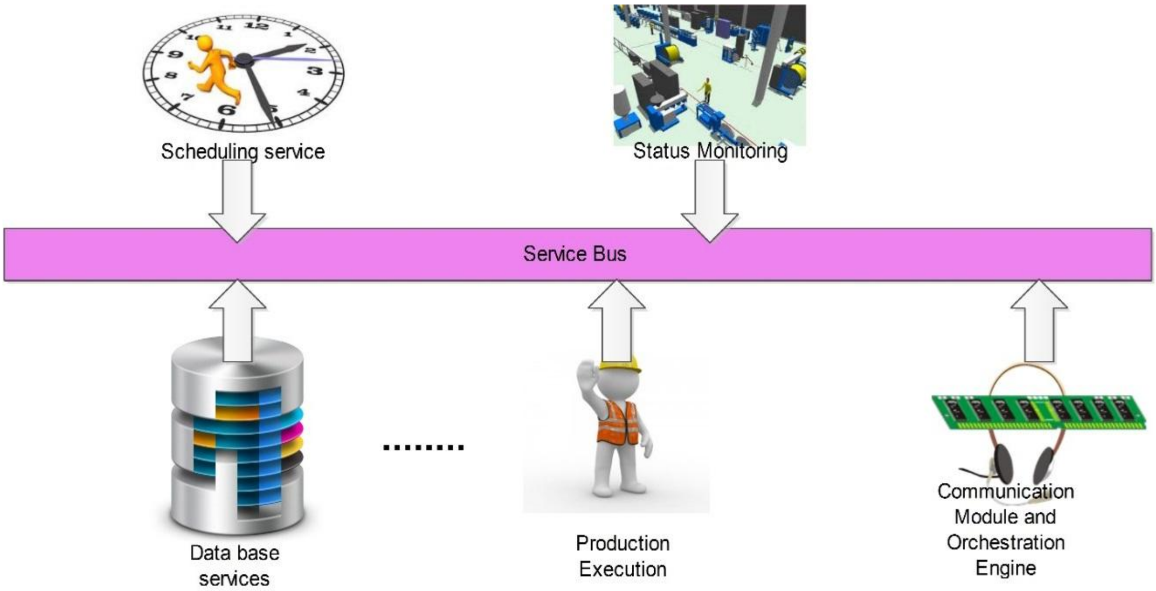

Figure 14. Decomposing software to Services

3. The third step of the framework is Platform Independent Model which is represented using UML language. The PIM of MESSaaS is shown in figure 15, it is modeled as classes and relationship between them. The relationship between classes represents the association between them and object of one class can refer one or more objects of a related class.

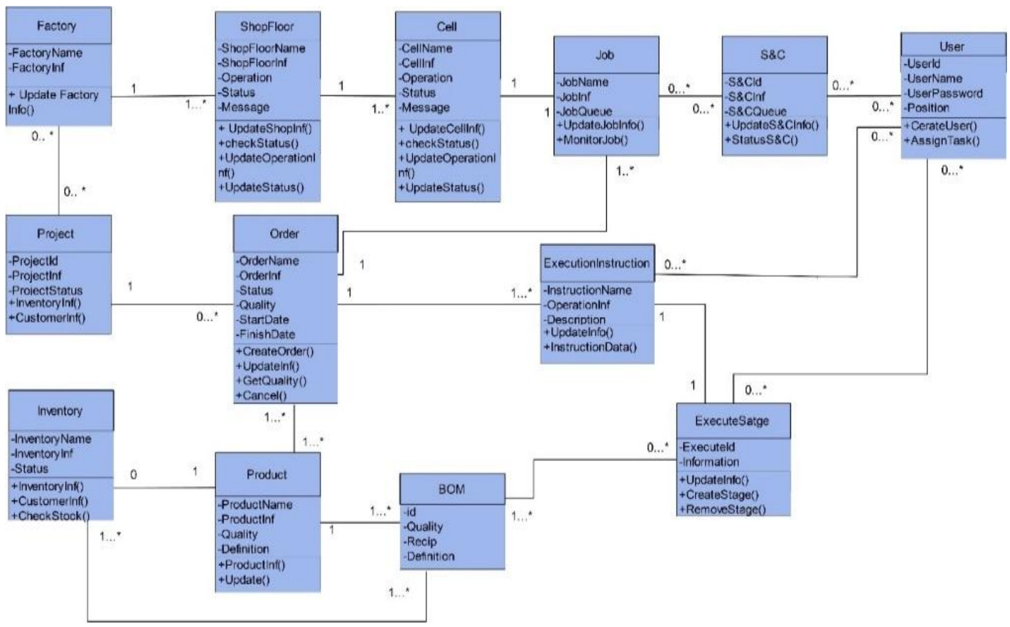

Figure 15. PIM of MESaaS

One of the important classes in the class diagram is scheduling and controlling (S&C). It is responsible to covering scheduling of the system and this class consists of sub classes and methods, for clarification of this class we developed sequence diagram of this class. Figure 16 shows the sequence diagram of this class. The sequence diagram of S&C class consist of ; Production Scheduling, Production Dispatching, Production Execution, Data Management, Production Tracking and Quality Control sub classes and cover the standard ISA-95.

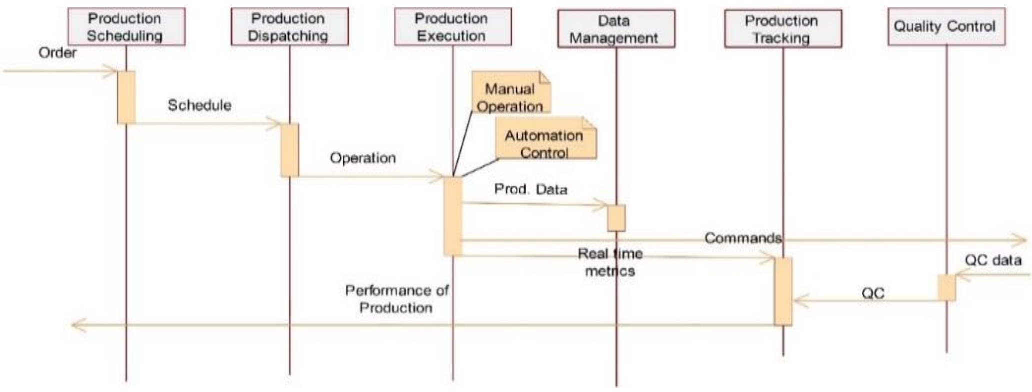

Figure 16. Sequence diagram of the Scheduling and Controlling class

3.6 PIM to PSM (step 3 to step 4)

Transformation tools are used to generate the PSM from PIM. In this research, Java is used as the target language. The data types of attributes are specified in PSM, this attribute differentiate it from PIM. Furthermore, in PSM, functions are specified along with their data types. Whereas these language specific details are not present in PIM model. Implementation code is generated from the model immediately after PSM is generated, this is done by using transformation tools, each constructs in model language is mapped to target language. This leads to a better traceability which can be important for managing the complexity of MDA.

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 exist 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. Finally, Java EE platform is used to create CbMES. The Java Servelt API is used for define HTTP- specific classes. A servlet class extends the capabilities of servers that host applications that are accessed by way of a request-response programming model. A multiple databased is used, single code based for Cloud based MES. A separate database for every client is created. No modification is required to single tenant codebase. Advantages of this method are no codebase modification, easy to ensure client data does not get mixed easily to perform client specific modifications. Oracle Java Cloud Service is used to deploy and manage the MESaaS application in the cloud environment. Oracle Java Cloud Service is part of the platform. The MESaaS system needs to interact online with another service called ERP service, the cloud based MES is shown in Figure 17. This interaction created by data base service between MESaaS and ERP, there will be a real time data sharing between MES and ERP which has covered the existing gaps in this research, this is done by transferring MES to cloud. This gap is automatically covered according to ability of cloud application.

Figure 17. A snapshot of the Cloud based MES

The MESaaS window shown above contains the following elements: Menu Bar, Tool Bar, Viewing area, Device View, Order View etc. the Menu bar constrains four important menus each of which is described in the above three diagram. The Business Process Execution Language (BPEL) diagram for virtualization of MESaaS in the cloud environment is designed based on central BPEL Process

Chapter 4

IMPLEMENTATION

4.1 Schema for implementing MESaaS in the EMU LAB

Computer layout of EMU lab is shown in Figure 18. On the lab exist five computers, each station has its own computer and each computer used industrial network for communication. In the cell level, there exist two computers. The first computer is the cell manager used for MES software, the MESaaS is operating via internet in this computer. Cell manager communicates with other station manager via network and send scheduling to the station level and also concurrently receive monitoring data from station manager. The second computer is a graphical Interface for monitoring purpose, it has some station managers connected with it, these station managers are connected to shop floor entities such as robot, conveyor, AS/RS. The MESaaS has an online interaction with the cloud for scheduling and rescheduling; this will ensure real time operation and communication between ERP and MES. The cloud system is created by the cloud provider; this provider is in charge of the security, data sharing, and maintenance of software.

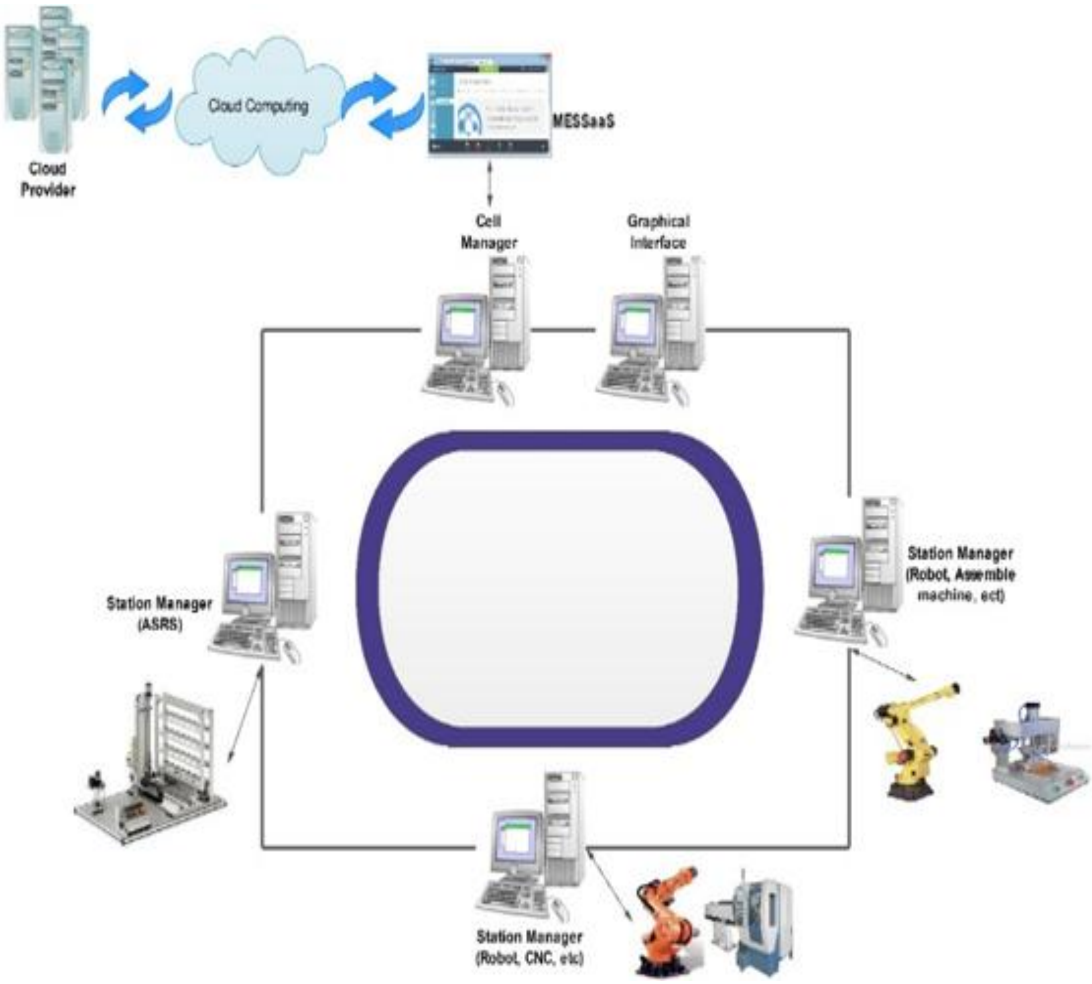

Figure 18. Computer layout and Machine Connection in the EMU lab

4.2 Network Communication in the EMU LAB

Important part of this implementation is the network communication between station and cell manager. I/O, RS232, LAN and internet are used for communication which is shown in figure 19.

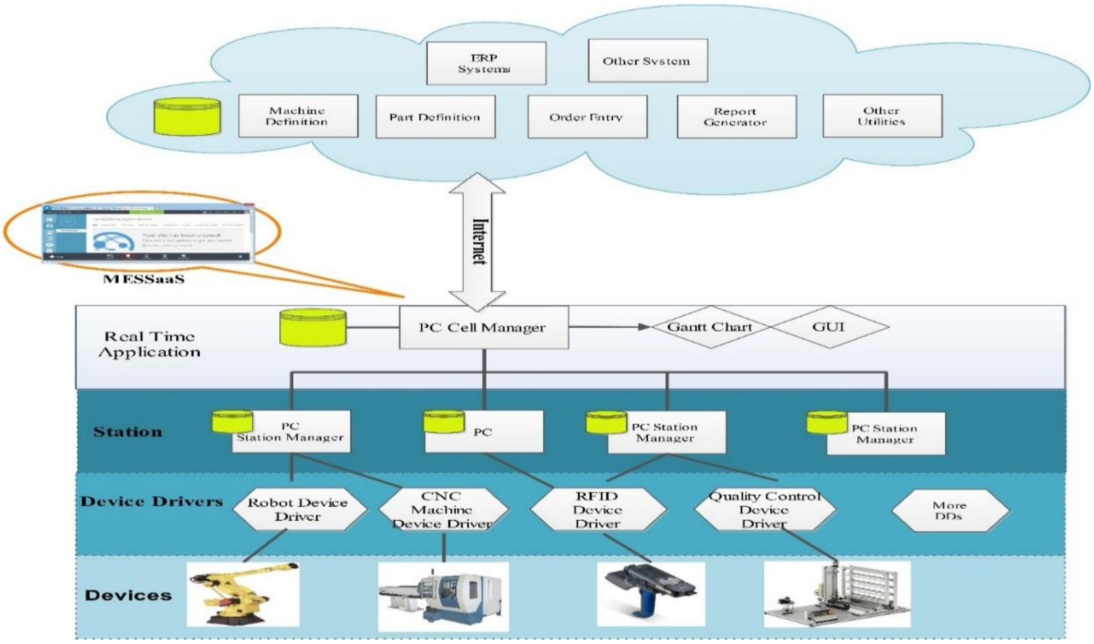

Figure 19. Network Communication in EMU lab

1. Internet: Internet is used for running MESaaS in the Cell manager via web browser. TCP/IPv4 is used for creating this communication between cloud environment and Cell Manager.
2. LAN: The Cell manager (MESaaS) and PC station manager exchange command and status messages via the network. This network is based on the Windows TCP/IP communication protocol. Each module in the TCP/IP protocol has two communication sockets, the server and the client. A socket represents and endpoint for communication between processes across a network. Cell manager uses a Local Area Network 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 them to exchange commands and status information in real-time:
   - The cell Manger software(MESaaS)
   - The device driver software (installed in station manager)
   - The Graphic Tracking PC

- Any PCs running user supplied application that are interfaced to MESaaS

3. RS232: Station Manager PCs use RD232 to
   - Download programs to processing machines
   - Pass MESaaS message to/from an ACL controller
   - Provide a terminal interface for programming ACL controllers
   - Pass MESaaS messages to/from other station devices such as QC systems.

4. Input/Output: I/O connections are 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. The following MESaaS devices use I/O connections:
   - Processing machines(to operate the machine and report its status)
   - Devices attached to an ACL controller's I/O ports(e.g. an automatic screwdriver, a pneumatic gripper for a robot, etc.).

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 MESaaS 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 sample scenario presented below, a cube moves from storage in the ASRS to a CNC station where it is machined into a box. The table 3 below provides a step by step description of the flow of information throughout the MESaaS associated with making a box.

Table 3. Flow of Information throughout the MESaaS

Message source	**Message Destination**	**Message Content**
	ASRS Station	
MESaaS	Station manager	Stop the next empty pallet that arrives at the ASRS station
Station Manager	MESaaS	Empty pallet has arrived at the ASRS station
MESaaS	Robot Controller	Use robot to remove a template with a cube from storage and place it on the pallet.
Robot Controller	MESaaS	Template is in place on pallet
MESaaS	Station Manager	Release this pallet from the ASRS station.
Station Manger	MESaaS	Pallet with cube has send from ASRS
	CNC Station	
MESaaS	Station manager	Stop the next pallet that arrives at the CNC station
Station manager	MESaaS	pallet has arrived at the CNC station
MESaaS	Robot Controller	Use robot to remove template from pallet and place it on buffer of CNC Station.
Robot Controller	MESaaS	Template with part is waiting on buffer of CNC station.
MESaaS	Station manager	Release pallet from CNC station.
MESaaS	Robot Controller	Use robot to place part in CNC machine.
Robot Controller	MESaaS	Part is in CNC machine.
MESaaS	CNC Machine	Use the CNC machine to ream a hole in the cube to form a box.
CNC Machine	MESaaS	Process complete. Box ready.
MESaaS	Robot Controller	Use robot to place box on template in buffer.
MESaaS	Station manager	Stop next empty pallet at CNC station.
Robot Controller	MESaaS	Box is in place on template.

Chapter 5

CONCLUSION

5.1 Summary

Some problems are uncovered gradually, since the manufacturing industry is gradually transferring from traditional product-oriented architecture to service-oriented architecture. The IT infrastructure of SMEs faces several challenges due to the dynamic changes that they undergo. The major problem is the communication between ERP and MES in SMEs, which are not real time. This research analyzes the deficiencies of the current solutions and put forward a proposed framework based on a “cloud”. A cloud-based MES infrastructure has been proposed in order to integrate information exchange between companies and also to support distributed production planning and control. The proposed framework called MESaaS is a centralized system, where SMEs can link each other’s data without high complexity in IT integration. The MESaaS is web based which requires no installation time, it also has the ability to improve the agility and the scalability of a manufacturing system and the ability to connect to external systems such as ERP. The Cloud based MES provides Key Performance Indicator (KPI) data for production. Lastly, the cost of IT infrastructure will be reduced because each SME is charged based on the service used. The proposed framework is designed based on Model-driven Architecture. In a Model driven architecture, 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. It is concluded that there is a real time work monitoring status in MES by implementing the framework.

5.2 Future Works

Implementing the proposed MESaaS with virtual reality software, this will help to validate the work successfully.

Evaluation of the proposed framework in large scale companies by using different type of Service delivery model.

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