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Proposing a Strategic Framework for Distributed Manufacturing Execution System Using Cloud Computing

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Abstract

This paper introduces a strategic framework that uses service-oriented architecture to design distributed MES[1] over cloud. In this study, the main structure of framework is defined in terms of a series of modules that communicate with each other by use of a design pattern, called mediator. Framework focus is on the main module, which handles distributed orders with other ones and finally suggests the benefit of using cloud in comparison with previous architectures. The main structure of framework (mediator) and the benefit of focusing on the main module by using cloud, should be pointed more, also the aim and the results of comparing this method with previous architecture whether by quality and quantity is not described.

Keywords: Manufacturing execution system, cloud computing, service oriented architecture.

1. Introduction

1.1. Motivation

In recent years, the philosophy of "Design Anywhere, Manufacture Anywhere (DAMA) has emerged [1-3], DAMA approach demands the ability to exchange design and manufacturing data across multiple sites, it also helps establish links between manufacturing resource planning, enterprise resource planning, engineering resource

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[1] Manufacturing execution systems

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planning and customer relationship management [4]. Beside the emergence of this philosophy, wide range of usage for distributed organizations is proposed. Several different factors have forced this configuration for organizations, factors like: volatile market demands, high competitions and great force of technology to get latest progress for more efficiency. In fact, the most important potential of this organization is its ability to put entities together and create a concurrent business model, which is composed of customer customization and organization goals.

The key factor to success of this style of approach is shaping its information system in a way that can integrate distributed entities. The infrastructures, these information systems are deployed for, also play an important role to satisfy these organization requirements. Among distributed information systems, what is discussing in this research, is manufacturing execution systems, which have been created to manage information in factories and in the course of time, their limit has changed. In centralized organizations, MES have its specific style, suggesting specific process and manages production in factories, but distributed structures need their own requirements to be adapted. Recently, internet everywhere and cloud computing are considered as stimulus that have changed organizations and their information systems and it seems they are trying to equip organizations with new technologies to make organizational process more simpler.

The main attribute of cloud computing is making computing services scalable, on-demand and available. To have wide view on this topic, it is time to mention the definition of National Institute of Standards and Technology (NIST) for cloud computing:

"A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing services (e.g., network, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.[6]."

But, what causes cloud computing to be a suitable structure for deploying manufacturing execution systems? The answer is the procedure of making cloud computing as a practical model. Generally, this model shows the convergence of two important procedures. A.

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Performance of information technology: something was caused by scalable hardware and software resources. B. Agile business models: information technology is used as a competition enabler for rapid deployment, parallel batch processing, business analysis that needs high computational dependency and real time applications.

Anything in cloud computing literature is considered as a service, such as application as a service and infrastructure as a service. Considering the philosophy of DAMA, high information exchange among different sites, is needed. So cloud computing has a great impact for accomplishment of this philosophy. In general, there are two types of cloud computing adoptions for manufacturing systems: manufacturing with direct adoption of some cloud technologies and cloud manufacturing, the manufacturing version of cloud computing [4].

In this research, we have tried to propose a suitable framework for different sectors of MES (manufacturing execution system) by using the layered structure of cloud computing model. Suggesting this framework on cloud has encountered with different challenges, but throughout the years, it has been seen that great problems have been disappearing, problems that are highly relevant to cloud infrastructure. In this situation, new approach whose name is "mash up" has been suggested for management. Layered nature of cloud should be considered and it is necessary to design in order to increase the cooperation of services. With this style, service oriented structure leads great results in automation environments that are vital; like, standardization that helps industrial organizations for reaching their strategic goals.

In addition, implicitly, industrial environments have deeply sensed the impact of globalization in different levels. But still, there are some challenges that previous infrastructures cannot solve them, the most important ones are:

- Highly centralized and hierarchical implementation
- Scalability will result in exponential complexity
- Low compatibility of applications in different organizations

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- No standards that are highly approved
- Plant floor systems are still isolated from other levels in production pyramid

Here, it is time to deploy an infrastructure that has the potential of removing these challenges.

1.2. CONTRIBUTION OF THIS RESEARCH

Based on researches done, to improve and develop manufacturing execution systems in real world, some requirements are met with acquiring suggested cloud framework for these systems:

A. Simple programming perspective:

Distributed nature of manufacturing execution systems in network organizations and services in real world, may encounter deployment of business logic with different problems, but deployment of flexible cloud programming platforms like Windows Azure have helped developers to create instances for complex production scenarios rapidly.

B. Economic benefits:

Other frameworks of manufacturing execution systems have their own solutions to pay for services, but our research is based on cloud and services that uses its specific model. Entities of this framework, similar to the most of cloud information systems, have the attribute of plug and participate, and also use the concept of "pay as you go".

C. Standard services:

Cloud based MES, gradually leads to define standard services and helps to find common services for order module and gather them in service repository for later use.

D. Reducing expense:

MES services will utilize virtualization that causes reduction in capital expenditure.

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E. Service reusability:

Because the base of standardization is service oriented approach, valid services are gathered in a shared repository and with a needed composition of appropriate services; new and efficient services will be available.

F. Creating a new variety of applications:

Cloud computing also introduces a new variety of applications that service in a way that has been seen less before; for example: interactive applications that are responsible for any real time customer and parallel batch processing, what is necessary for distributed manufacturing. It helps to have an accurate analysis by using high processing ability for a great amount of data. New programming models, like Google map-reduce [11], or programming frameworks such as Microsoft Orleans [12], have made parallel processing of applications transparently on many distributed servers.

What is displayed in this research, is based on previous standards like MESA11 [14] and ISA95 [15] that are adaptable with distributed and service oriented environment. What is the main contribution of our research is designing a strategic framework for service oriented computation that is general enough to gather web based protocols and cloud services as separate and distributed entities among different manufacturing sites for service clients and manufacturing sections.

In this framework, each aspect of manufacturing execution systems display its own responsibilities via service oriented perspective, it causes service repository, to be full of standard services (requirement A,C) to reach this aim with available service oriented methodologies like SOMA[16] service oriented analysis should be done with solution pattern suggested in this methodology such as, ESB[17]. So we have tried to reduce the size of main entity and distribute other modules in cloud and finally this solution pattern will result in creating standard interfaces. With new paradigms of programming, developer will be able to create services, will introduce during service oriented analysis.

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Modules will be specified later, will make definition of service level agreements easier and will shape the strategy of service use for clients (requirement B, D).

The rest of paper is organized as follows: section2 discusses related work and background. Section 3 defines the foundation of our service oriented and cloud based framework, considering manufacturing and network requirements; like, information structure. Section 4 describes the main feature of framework and in the next section; cloud based and agent oriented MES are briefly compared. Finally last section included conclusion of this subject.

2. BACKGROUND AND RELATED WORK

In recent years, there was a great effort to prepare cloud for deploying different information systems. For distributed manufacturing information systems, most of the proposed solutions is agent oriented and different agents mange different sections of the producing an order. The range of distributed solutions for industrial automation is different from low to high. Some of them have resulted in full architectures that not only include manufacturing execution systems but also all of the control system and organization in its scope.

PROSA 18] is the most famous architecture that is Holonic, which is an agent oriented approach. It consists of three Holon: product, order and resource. Similar to other distributed architectures, it is needed to have supervision over plant floor activities, so another Holon is used, named with staff Holon. Other similar architectures are Metamorph [19] and consequently Metamorph II. To have good communication between components and other systems, mediators have been used here. Metamorph is multi agent architecture with the aim of increasing efficiency of distributed manufacturing organizations. Finally, PABADIS [20] and PABADIS PROMISE [21] were proposed. This agent oriented architecture covers all the manufacturing pyramid, but its main aim is distributed MES. Beside these frameworks, it is needed to have a quick overview over the main present, cloud platform. In fact, Sales Force is a customer relationship management,

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with special architecture that is responsible for real time customer need. Sales force is the fundamental infrastructure for Force.com, which have been created during 10 years ago and is used by 100,000 businesses, 185,000 applications, and 3 million users [25].

Sales force is multi-tenant and responses to customer need efficiently, uses sandbox environment to be able to have update copy of applications, data and configurations. The structure of this platform is distinct, but it is not platform as a service. It is hard to consider a compiled and static program for this aim, so this program should have dynamic structure. Designing this platform is compromised to use of execution engine that create components from metadata.

3. GENERAL ASPECTS OF FRAMEWORK

One of the main features of proposed framework is a set of modules that services customers who are the users of manufacturing zones. Composition of these services, fulfill the execution of an order. To design these services using cloud computing model, it is needed to consider the main cloud technology to support them. Virtualization is one of the main aspects of cloud computing, that can be responsible for services in different levels, besides it defines right position for each module in framework.

We know that previous frameworks have their own information model; our framework information model should be conformed to service oriented ones and should be capable of deploying needed services. Similar to information model, control structure should also be able to responsible for service communication and it is mostly affected by used solution pattern. In addition, economic aspects of this cloud based framework should also be adapted.

3.1. BASIC STRUCTURE

To understand the framework and its main components, it is necessary to have right view over layered structure of cloud computing.

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Software as a service:

Software as a service that also is called application as service, prepares multi-tenant structure to share common services; here, the most essential aspect is integration with other applications.

Platform as a service:

Platform as a service is a way of creating a platform, composed of systems and environments that manage all of the MES application life cycle.

Virtualization management:

Virtualization in different levels is the base of this framework, and several execution environments are needed. Because success of MES depends on real time data, acquiring dynamic virtual execution environments that produce customized programs for different modules is inevitable. Beside this environment, hardware virtualization (memory, CPU, …) and software one is also applicable.

3.2 Information model

Distribution of different modules, according to order requirement is the main paradigm of this framework. Because communication among different modules to service end users; is challenging subject, mediator as a design pattern, will be helpful. The aim of using mediators to shape information model of this framework, is a set of information management services in different levels. It keeps manufacturing data resources together in service oriented manner, to eliminate one of the main distributed MES challenges, the information gap among modules. Generally, this information model is designed with the aim of representing resources in different levels, by use of different databases.

Small database:

It contains information about services in lowest level, composition rules for workflows, so that it is capable of managing communications between resources and applications.

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Conceptual database:

It manages simple and complex services and composition rules in rational level.

System database:

It contains general information about mediator and also simple and complex services with their composition rules for this level.

3.3. CONTROL MODEL

In this aspect of framework, our aim is composing several services to get value added and create complex services. Interaction between services is usually performed by sequence of procedures owned by different business entities, which need to interact to reach their common goals. Normally, orchestration and choreography is used here; considering the service analysis that will be presented in next section, we realize that the main entity in this framework is order management and other modules are extracted from it, to be provided as a service. For adopting a suitable control approach, order management is organized by orchestration. Similar to orchestration, choreography can be applicable for MES in different abstraction levels. In other words, control pattern can contain internal choreography blocks to have right management over complex situations. Finally, what is expected is choreography among distributed services and orchestration in main module.

3.4. ECONOMIC VIEW

It is obvious that cloud computing and use of it in distributed MES is time consuming but, always there have been stimulus roles for new technologies to be accepted. Multi-tenant concept and web services are two important roles that shape economic view of manufacturing with cloud.

Multi-tenant concept:

It means that one instance of an application can be serve simultaneously to different users and reduces costs; this structure is well applicable for manufacturing environments.

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As for proposed framework that will be explain later, this information system is full of small applications that needs to be executed by several users in this manner , so this concept prepares a desired economic paradigm.

Web services:

A web service as is defined by W3C is "a software system designed to support interoperable machine-to-machine interaction over a network" [29]. But, generally is defined for client- server interaction over network protocols. Its benefit for reducing costs is interface standardization to facilitate application communications.

4. FRAMEWORK DESIGN SPECIFICATION

MES is composed of different sections and functions, with the aim of creating an integrated mechanism for manufacturing with highest efficiency. Because distribution is main attribute of proposed framework, flexibility and interoperability should also be provided. Cloud environment provides these aims naturally, we will identify practical services; in other words, we have service oriented approach for our MES applications. Order entity, as the core of framework, how it proceeds and uses manufacturing resources, gathers information for scheduling and finally how finishes, all of these activities are described here with designing appropriate modules.

4.1. SERVICE ORIENTED ANALYSIS

To have service oriented analysis, it is needed to acquire a service oriented methodology. SOMA [16] methodology is used, which uses different techniques for service identification. First, goal service modeling is done. In fact it maps high level goals to services. Next one is domain decomposition, where MES is reviewed as operational environment and was decomposed to subsystems. It should be mentioned that ISA95 is the used standard in this research and its generic model is the basis of our service oriented analysis.

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4.2. MODULE WORKFLOW REALIZATION

According to service oriented stack, business logic is composed of orchestration and choreography that second one is naturally distributed, while orchestration is centralized. The main module is order management, which has the role of bus that other modules mostly interact with it, in fact; it is orchestrated while others are based on choreography. There are three main approaches to utilize distributed execution engine for MES, enactment, adaptability and fragmentation. Because modules should be responsible for real time situations, it is necessary for modules to be reconfigurable; so adaptability approach is suitable. Because workflows will be capsulated as services during execution, it is needed to fragment workflows (fragmentation approach), while as for use of mediator, enactment approach is inevitable. Decentralization process should be configured in a way that fragments can be easily adapted, during execution. For example, if several business processes are highly depended, they can be executed with each other. This will causes message reduction, and also in different situations, available execution engines can be extended or centralized.

5. MAIN MODULES

After service analysis, main scopes was defined, suitable control approach was adapted. Later we will try to describe framework modules in cloud platform.

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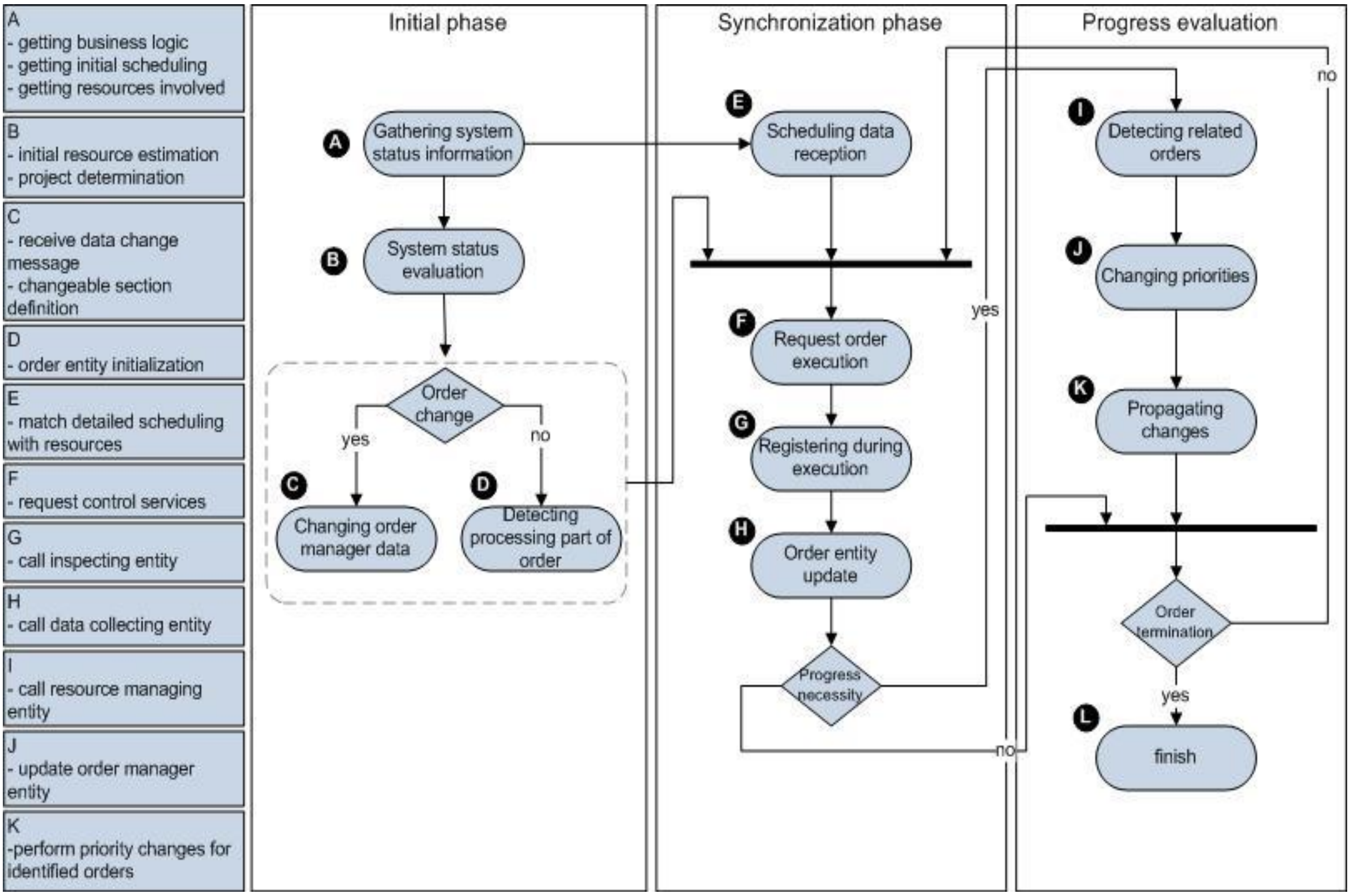

Fig.1. Order life cycle management

5.1. ORDER LIFE CYCLE MANAGEMENT

The core of MES is described, here; which its main role is calling and requesting other modules. As it is explained in figure 1, orders are completed virtually, by calling needed components, which compiled before and are adapted during execution time. Product life cycle management, are done with two aims; first, for beginning and executing new orders and second, changing an order, while it is executing. For both of them, main bus requests components for getting information about orders. Responses are gathered by calling data

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management module, next data is analyzed and an “order manager”, which is composed of different sections, is prepared.

Order manager is considered as a profile that contains all data before execution time and final data, after delivery, all of them are registered, in this profile. Besides, if a section of an order should change in this phase, it will be done here. Right execution of this entity, has an important effect for making distributed MES successful. More, order life cycle begins a new phase to coordinate different processes. Scheduling is the first module is requested that is executed in small intervals. Data collecting and indexing is another one that is called at the end of scheduling module. Next, it is analyzed if continuance of order is vital or not. In the next phase, related data for order manager is gathered, order priorities will change and changes will propagate to related entities. Finally, if order has not finished, it returns to synchronization phase.

5.2. MANGING RESOURCES

The orders are controlled during execution, to have supervision over resource usage efficiently. With every execution of synchronization phase, data related to resources changes and consequently, data for each resource is registered in order manager profile. Before resources are changed, to have right appropriation, it is essential that requests are analyzed. Scheduling is the closest module to resource manager, which means detailed scheduling with very small time slots without any time gap between plant floor practical scheduling and desired one.

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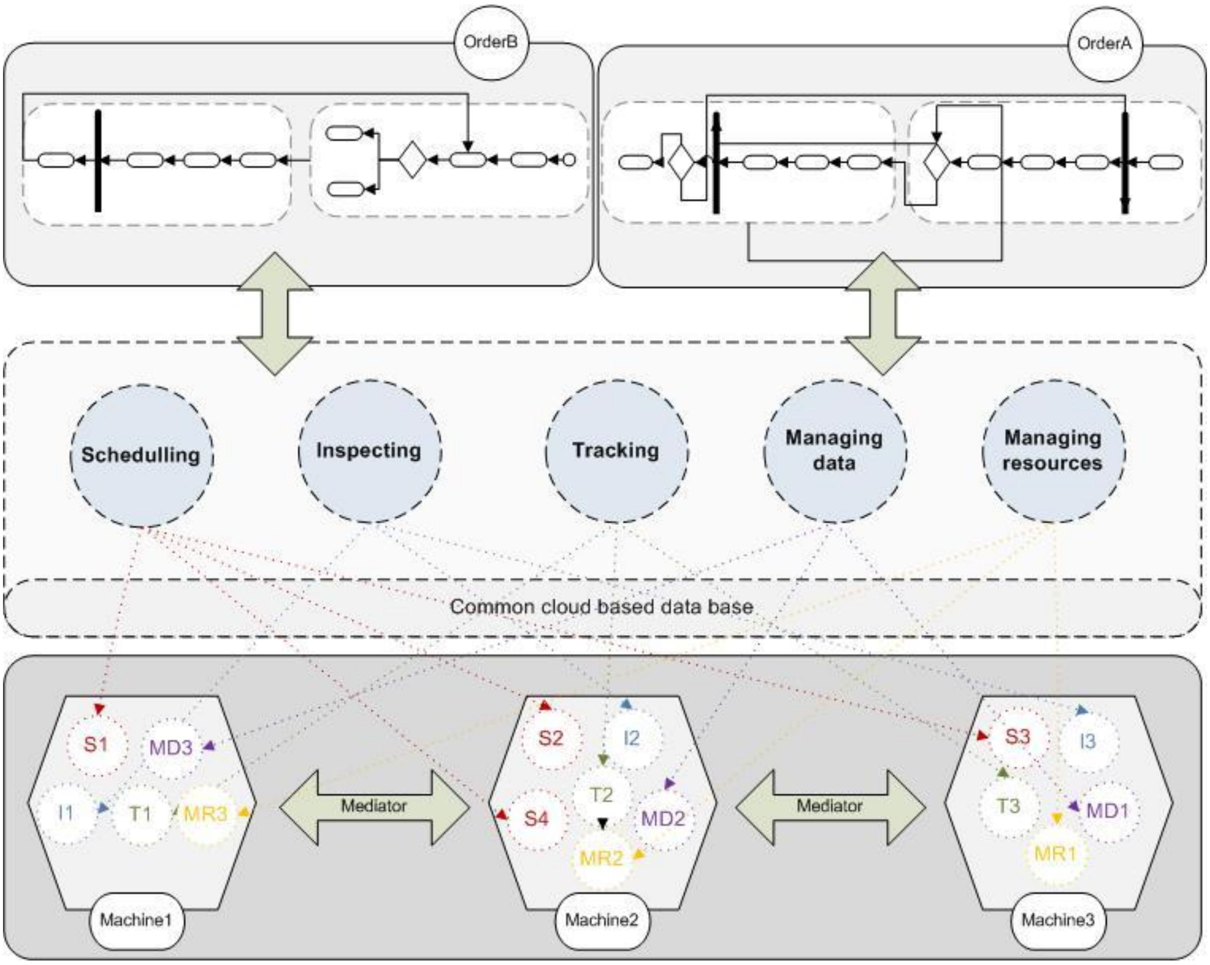

Fig.2. Module distribution over cloud

5.3. SCHEDULING

Scheduling and resource managing modules communicate dynamically and real time. This module is composed of small operating sections, the most important one, is defining possible scheduling, which requests and finds appropriate services from data manager, next; related resource manager will be defined. Finally involved processes will be temporarily stopped to update related processes.

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5.4. INSPECTING

This module is a set of control services that inspects how resources are accessed at the beginning and during execution time. This inspection can be right initialization of resources or internal and external system status for taking over resources. It is also responsible for error control and unexpected events.

5.5. TRACKING

One of the main goals of managers to acquire MES is tracking and tracing orders. It requires keeping data related to history of orders, during execution and keeps services to retrieve them. In fact, it has the role of gathering report from scheduling and resource managing modules.

5.6. MANAGING DATA

All information systems need to store data in different levels, as it is mentioned before, mediator is considered as a solution to keep right data among different framework modules. This module manages process data initialization, data integrity system data analysis, order change conformation and order rejects.

6. COMPARISON OF CLOUD BASED AND AGENT ORIENTED MES

The environment, which a framework is designed for, is the main factor forces some rules and constraints. As it is mentioned before, agent oriented applications are applied too much. So a general comparison is done between cloud based and agent oriented MES based on three indexes. These indexes as it will be described later are compound of other factors.

- Breadth: In fact, this index is a weighted combination of variables, such as: ability of deployment and implementation in different sites, financial stability and

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implementation costs. Whatever this quantity is higher it means that it has the flexibility for implementation in small to larger environments.

- Functionality: Whatever a framework supports more modules, it has higher functionality. This index is based on the common MES modules, such as scheduling, managing resources, tracking and dispatching. Here access to real time information, which is the main challenge of the proposed framework, is considered.
- Dependability: One of the main features of this analysis is dependability. In fact, it is a composition of variables, like, security of framework for external attacks, safety of system itself and being dependable for common uses.

For reaching the aim of this comparison, a general interview and questionnaire is done in Jamsaz [2]Company, and finally the results are presented in a clustered column chart. The grades for each index are the average of answer s to related questions. The respondents in manufacturing section of Jamsaz are supposed to answer each question with grades between 0 and 10. The average of them is considered as final grade.

Table1. Result of questionnaire

Breadth				
	Implementation for different sites	Financial stability	Implementation costs	
Agent oriented	8.14	4.92	6.09	
Cloud based	8.32	8.78	8.12	
Functionality				
	Scheduling	Tracking and tracing	Managing resources	Dispatching
Agent	4.53	6.32	6.12	5.04

[2]Jamsaz is a company, manufacture different lightening systems for conventional automobiles in Iran that has distributed structure with different nodes in different locations.

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oriented				
Cloud based	8.07	6.25	8.80	5.03

Dependability			
	Security	Safety	Determinism
Agent oriented	8.03	6.10	5.24
Cloud based	4.94	6.07	6.88

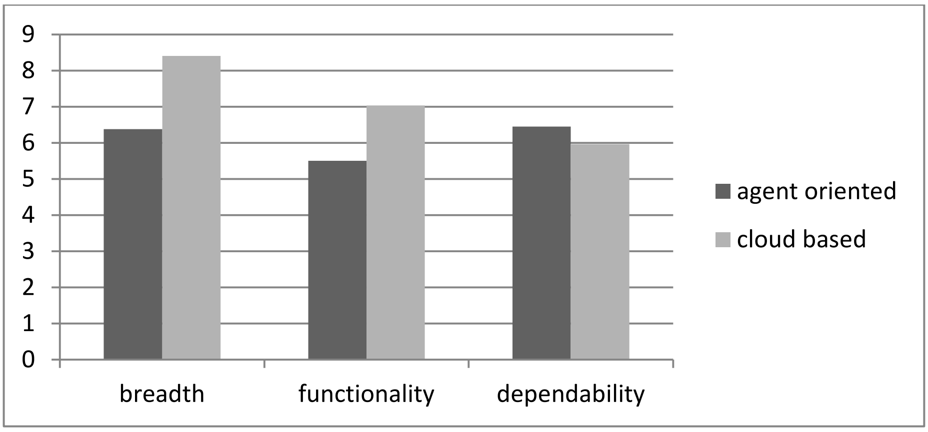

Fig3. Comparison representation

7. CONCLUSION AND FUTURE WORK

Generally, this research shows that the main feature of framework is proposing such information system in cloud. Main modules that usually works centralized, extracted and normal configuration is changed to extract needed ones and distribute them with cloud platform to manage them for working concurrently. Significantly with this structure, flexibility and dynamism is inevitable and the strength of this framework is this ability. In fact, we have tried to propose theoretical basis of this framework and progressively formed its total structure by use of cloud platform.

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7.1. CLOUD BASED MES CHALLENGES

Some of information systems like CRM and HRM naturally can be deployed in cloud environment easier. In comparison with MES, these applications need use data with more time validity and latency will not affect them. So cloud based MES is faced with these challenges:

- Plant floor real time data, need suitable applications to deal with, otherwise the result will not be applicable.

Two policies can be adopted to solve this problem. Cyclic information gathering and event based one. Former makes it easier but, because MES manages unexpected events, so a composite approach is needed.

On the other hand, extra activities is done to support cloud based MES such as, real time operating systems and deploying RFID.

- In most cases, MES is considered as a process specific one, and supporting general- purpose solutions is difficult, so we focus on common processes among different manufacturing environments.

7.2. FUTURE OF CLOUD BASED MES

Taking these challenges, it is obvious that, it is time- consuming to actually have a real cloud- based MES, but its main features like global authentication, unrestricted resources and flexibility has made it as an unavoidable environment, for information systems. So, it is tried to get it by hybrid approach.

These topics are considered as future actions to make this framework as operational plan:

- Service level agreements for MES
- Design and implementation of suitable web services
- Service negotiation for MES modules

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Available online at: http://www.aeuso.org

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References

[1] W. Heinrichs, “Do it anywhere”, IEE Electronics Systems and Software 2005; 3(4):30–3.

[2] S. Venkatesh, D. Odendahl, X u X , M ichaloski J, Proctor F , Kramer T. “Validating portability of S TE P- NC tool center programming”, In: Proceedings o f t he 2005 ASME International design engineering technical conferences and computers and information in engineering conference; September 24–28 2005. p. 285–90.

[3] P. Manenti, “Building the global cars of the future”, Managing Automation 2011;26(1):8–14.

[4] Xu X, “From cloud computing to cloud manufacturing”, Journal of Robotics and Computer-Integrated Manuf acturing, N0.28, 2012, p. 75-86.

[5] H. Kuhnle, “Distributed Manufacturing, paradigms, concepts, solutions and examples”, Edited by Springer, 2010.

[6] P. Mell, Grance T. Perspectives on cloud computing and standards. National Institute of Standards and Technology (NIST). Information Technology Laboratory; 2009.

[7] W. Kim, cloud computing: Today and Tomorrow, Journal of Object Technology 8 (1) (2009) 65 – 72.

[8] I. Corredor, J. Martinez, M. Familiar, “Bringing pervasive embedded networks to the service cloud: A lightweight middleware approach”, Journal of system architecture, pp.916-933,2011

[9] G. Candido, J. Barata, A. Walter Colombo, F. Jammes, “SOA in reconfigurable supply cha ins: A research roadmap”, Journal of Engineering applications of artifitial intelligence, pp.939-949, 2009

[10] S. Marston, S. Bandyopadhyay, J. Zhang, A. Ghalsasi,”Cloud computing - The business perspective”, Journal of Decision support systems, pp. 176-189, 2011.

[11] R. Lammel, "Google’s MapReduce programming model — Revisited",Science of Computer Programming, Vol.70, pp 1-30, 2008.

[12] S. Bykov, A. Geller, G. Kliot, J. Larus, R. Pandy, J. Thelin, "Orleans: A Framework for Cloud Computing".

[13] A. Dubey, D. Wagle, Delivering software as a service, The McKinsey Quarterly (May 2007) 1–12.

[14] “Introduction to manufacturing execution systems”, MES conference and exposition, 2001.

[15] “Enterprise-Control System Integration Part 3: Activity Models of Manufacturing Operations Management”, 2005

[16] A. Arsanjani, S. Ghosh, A. Allam, T. Abdollah, S. Ganapathy, K. Holley, “SOMA: A method for developing service-oriented solutions”, IBM system journal, Vol.47, No.3, pp.377-396, 2008.

[17] T. Dauffenbach, et al.,“IBM and SOA Software ESB Solutions”, 2005.

Vol. 3(8), Jul, 2013, pp 142-161, **ISSN**: 2305-0543
Available online at: http://www.aeuso.org

[18] H. VanBrussel, J. Wyns, P. Valckenaers, L. Bongaerts, P. Peeters,"Reference architecture for holonic manufacturing execution systems:PROSA. ", Journal of computer in industry, Vol.37, pp.255-247, 1998.

[19] W. Shen, D. Xue, D. Norrie, "An agent based manufacturing enterprise infrastructure for distributed integrated intelligent manufacturing system", Proceeding of the international conference on the practical application of intelligent agent and multi agents.

[20] A. Baratoukhine, T. Sauter, J. Peschke, A. Lueder, A. Klostermeyer, "Distributed automation-PABADIS vs. HMS", International conference on industrial informatics, 2003.

[21] A. Luder, J. Peschke, A. Baratukhin, A. Treytl, A. Kalogeras, J. Gialelis, "The PABADIS'PROMISE - Architecture", Proceeding of ANIPLA,2006.

[22] C. Brecher, W. Lohse, M. Vitr. Module-based platform for seamless interoperable CAD-CAM-CNC planning. In: XU XW, NEE AYC, editors. Advanced design and manufacturing based on STEP. London: Springer; 2009.

[23] Van de Velde PJMC. Runtime configurable systems for computational fluid dynamics simulations. PhD thesis. Auckland: Department of Mechanical Engineering, University of Auckland; 2009.

[24] Suh SH, Shin SJ, Yoon JS, Um JM. UbiDM: a new paradigm for product design and manufacturing via ubiquitous computing technology. International Journal of Computer Integrated Manufacturing 2008;21(5):540–9.

[25] http://www.salesforce.com/platform/cloud-infrastructure/, "Force.com cloud computing infrastructure".

[26] The Force.com Multitenant architecture, understanding the design of salesforce.com internet application development platform, whitepaper on salesforce.com

[27] B. Prasad Rimal, A. Jukan, D. Katsaros, Y. Goeleven, "Architectural Requirements for Cloud Computing Systems: An Enterprise Cloud Approach", Journal of greed computing, Vol.9, pp.3-26, 2011.

[28] M. A. Vouk, Cloud computing –issues, research and implementation, journal of computing and information technology, Vol. 16, pp.235-246, 2008.

[29] W3C, Web Services Glossary[cited 2009 April 3]; Available from: http://www.w3.org/TR/ws-gloss

[30] N. C. Dimitris, 2011. Cloud Computing Strategies. CRC Press.

[31] P. Bruni, M. H. S, Caurim, A. Koerner, C. Law, M. Liberman, W. Schuch, E. V. Aerschot, J. Wang, P. Wansch, "Powering SOA with IBM data servers", 2006.

[32] F. Safi Esfahani, M. Azmi Murad, B. Sulaiman, N. Udzir "Adaptable decentralized service oriented architecture", Journal of system and software, Vol 84, pp.1591-1617, 2011.