# Cloud Computing Technology for Networked Enterprises

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**Abstract:** Today manufacturing enterprises have to organize themselves into effective system architectures to match fast changing market demands. These architectures can be realized only by using computer networks in order to co-ordinate the production of the distributed units forming different types of networked enterprises (NE). Cloud Computing (CC) is an important up to date computing technology for Networked Enterprises, as it offers significant financial and technical advantages beside high level collaboration possibilities. The paper introduces the main characteristics of future internet based enterprises and the different CC models. Additionally the advantages and disadvantages of cloud computing have been summarized giving special focus on interoperability challenges.

***Keywords**:* Architectures, enterprise integration, interoperability, manufacturing, networks

## 1. INTRODUCTION

Based on the results of the information and communications technologies (ICTs), a new “digital” economy is arising. This new economy needs a new set of rules and values, which determine the behavior of its actors. Participants in the digital market realize that traditional attitudes and perspectives in doing business need to be redefined. In this dynamic and turbulent environment that requires flexible and fast responses to changing business needs organizations have to respond by adopting decentralized, team-based, and distributed structures variously described in the literature as e.g. virtual-, networked-, cluster- and resilient virtual organizations /enterprises. One main aspect of this approach is that organizations in this environment are networked, i.e. inter-linked on various levels through the use of different networking technologies. The new organizational architectures need new information and communication architectures as well.

The architecture of the organizations is in a recursive connection with the IC systems; the IC technology offers new possibilities for restructuring the organization (and its business processes) itself, in other cases the new demands of a business process force the development of a special IC solution. The final goal of all information systems is to provide data, information, knowledge, or different services for the users (human beings), and for firms, enterprises.

Today Cloud Computing (CC) is a hot topic, and according to Gartner Inc. it is on the first place on the top 10 strategic information technology list for 2010 (Dignan , 2010). Every main player of the IT sector plans to develop its own (different) CC architectures.

Cloud Computing is an important technology for Networked Enterprises, as it offers significant financial advantages (pay only for what you use, less in-house IT staff and costs, etc.) while offering high level collaboration possibilities. In spite of these advantages the spread of CC in the practice seems to be behind the very optimistic forecasts. The main disadvantages lay in privacy and security problems. The IT community tries to find the solution for these problems e.g. with applying different Deployment Models; for the Networked Enterprises the Private Cloud – where the CC architecture is owned or leased by one, or by a closed group of enterprises – can be a solution. Because of these difficulties Gartner estimates cloud computing has still two to five years away from mainstream adoption (O'Gara, 2010).

The paper introduces main characteristics of NE and the different CC models, pointing out why CC can be an excellent solution for NE. The advantages and disadvantages of cloud computing are listed as well giving special focus on interoperability challenges. Finally two CC projects are presented shortly to show the application possibilities of clouds in a production environment.

## 2. MAIN CHARACTERISTICS AND TRENDS OF NETWORKED ENTERPRISES

### *2.1 Characteristics of up to date production systems*

In order to fulfill the market demands the flexible, effective manufacturing system architectures become more and more popular around the world. Manufacturing enterprises have a geographically distributed nature, so computer networks for production management is an important feature of their operation. There are different approaches, different names that basically cover the same idea; a flexible network of co-operating autonomous manufacturing units. Enterprise architectures of this kind are e.g. the collaborative enterprise, digital enterprise, smart organization, extended enterprise, virtual enterprise.

Main characteristic of theses architectures is that organizations in this environment are networked, i.e. inter-linked on various levels through the use of different networking technologies. Besides the Internet new (or pilot phase) solutions are offered; wireless networks (Wi-Fi and mobile), powerline communication (using the electric power grid), the Grid technology and lately the cloud computing.

The main characteristics of the digital economy for market participants are as follows:

- Networking and horizontal communication, including the smart product,
- Networked environment ,
- Knowledge based technologies,
- Simplification and coordination of structure,
- Customer focus and real-time, ubiquitous responsiveness to technical and market trends (what customers want, anytime, anywhere),
- Flexibility, adaptability, agility, mobility,
- Organizational extendibility, virtuality,
- Shared values, trust, confidence, transparency and integrity,
- Ability to operate globally co-operating with local cultures.

In this turbulent environment only those organizations can survive which effectively apply the results of the different disciplines.

### *2.2 Collaboration in Networked Enterprises*

The collaboration and cooperation are main characteristics of networked enterprises, so the contacts among the users, the human beings have outstanding importance. A very important element of this human contact is trust. In a networked organization, trust is the atmosphere, the medium in which actors are moving. Trust is the base of cooperation, the normal behavior of the human being in the society. As the rate of cooperation is increasing in all fields of life, the importance of trust is evolving even faster.

Himmelman developed a hierarchy of partnerships (Himmelman, 1997). The levels of this hierarchy are distinguished from each other by the amount of trust, time, and risk needed to establish and maintain the partnership. In Himmelman's framework, networking, coordinating, cooperating, and collaborating mean different concepts and are built on each other. Collaboration means **e**xchanging information, altering activities, sharing resources, and *enhancing the capacity of another* individual or organization for mutual benefit and to achieve a common purpose.

A new approach, the collaborative network paradigm has been developed and described in (Camarinha-Matos and Afsarmanesh, 2005) that covers the main characteristic of all different networked units providing a framework to describe these organizations. A collaborative network (CN) is a network consisting of different entities (e.g. organization units and humans) that are autonomous, geographically distributed, and heterogeneous considering their operating goals, environment, social capital and culture. The collaboration is supported by computer network and makes possible to achieve common or compatible goals easier, thus generating joint value.

Most forms of collaborative networks can be connected to an organization that covers the activities of its units, giving rules for the participants. These organizations can be called as collaborative networked organizations (CNOs). The key concept related to CNOs is described in (Camarinha-Matos, Afsarmanesh, Galeano and Molina, 2009) parallel providing a high level classification of collaborative networks, and introducing some application cases in the manufacturing industry.

### *2.3 Trends in Networked Enterprises*

Forecasts and reports on the future of manufacturing and the connected organizations (factories, enterprises) are regularly published by different institutes, committees to appoint the research directions, themes in this field. The Industrial Advisory Group working for Unit G2 issued a report with the title “Factories of the Future PPP - Strategic Multi-annual Roadmap” (Industrial Advisory Group, 2010)

In this study it has been stated that the successful development of high added value technology should consider the following strategic sub-domains:

- Sustainable manufacturing
- CT-enabled intelligent manufacturing
- High performance manufacturing
- Exploiting new materials through manufacturing

The further integration of any newly developed ICT into the production and the industrial environments requires complementary research and innovation efforts. These integration aspects will play a key role for generating and using smart production systems for factories in different industrial sectors. According to the study ICT is a key enabler for improving manufacturing systems at three levels:

- Agile manufacturing and customization involving process automation control, planning, simulation and optimization technologies, robotics (smart factories);
- Value creation from global networked operations involving global supply chain management, product-service connection and management of distributed manufacturing units (virtual factories);
- Better understanding and design of production and manufacturing systems for better product life cycle management involving simulation, modeling and knowledge management from the product

conception level down to manufacturing, (digital factories).

The main research areas related to ICT-enabled intelligent manufacturing should include in the virtual factories: *"Product/service systems: Supporting the manufacturing industry in its transition towards providing customer value via product-linked services and solutions based on integrated product/service systems and the co-creation of value"*.

The European Technology Platform Manu*future* is to propose, develop and implement a strategy based on Research and Innovation. A fundamental concept of the Manu*future* vision is that of 'innovating production', which embraces new business models, new modes of 'manufacturing engineering' and an ability to profit from ground-breaking manufacturing sciences and technologies. The 'virtual factory' of the future will manufacture in adaptable networks linking medium- and large-sized OEMs (original equipment manufacturers) with value-chain partners and suppliers of factory equipment/services selected according to needs at a given time. Its composition will not be limited by the presumption of physical co-location, nor by a need to maintain rigid long-term relationships. (Strategic Research Agenda, 2006).

According to the position paper "Vision: Future Internet based Enterprise Systems 2025" (FInES, 2009) the Future Internet will enable enterprises to interact with other entities within (intra) and outside (inter) the enterprises (e.g. suppliers, business partners, employees, workers, customers) in a seamless way. Interoperability that is basic factor of data exchange must be extended from techniques and tools to all enterprise ICT systems. Cloud Computing Interoperability is a must for effective cooperation of different Internet resources.

It can be stated that according to the trends in future enterprises collaboration, agility, security, privacy and interoperability aspects will play a key role.

## 3. MAIN CHARACTERISTICS OF CLOUD COMPUTING

### *3.1 Definitions of Cloud Computing*

There are three similar computing architectures that can be applied well in networked enterprises. These are the Clusters, Grids, and Clouds. Various definitions and interpretations of "clouds" and / or "cloud computing" exist; two of them are introduced in the followings.

According to (Buyya 2009) "A Cloud is a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers." At a first glance, Clouds appear to be a combination of clusters and Grids, but it is not true. Clouds are next-generation data centers with nodes "*virtualized*" through hypervisor technologies such as VMs.

Mell and Grance from NIST (National Institute of Standardization) gave the following definition (Mell & Grance, 2009): "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". The essential characteristics of cloud computing are:

*On-demand self-service.* A consumer can automatically access computing resources, (server time, storage and network) according its need.

*Broad network access.* Resources can be available over the network through standard mechanisms by different client platforms (e.g., PDAs, mobile phones, and laptops.).

*Resource pooling.* The computing resources of the provider are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.

*Rapid elasticity.* Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in.

*Measured Service.* Cloud systems automatically control, optimize monitor, control, and report resource usage (storage, processing, bandwidth, and active user accounts, etc.) providing transparency for both the provider and consumer of the utilized service.

### *3.2 Cloud models*

Cloud computing, includes many aspects of computing (from hardware to software) so a single solution is not able to provide it all. Clouds can be described by models when their service and deployment characteristics are introduced, they can be classified into three service models, and into five deployment models.

By leveraging different types of services provided by Cloud Computing, it is useful to satisfy the needs of different user types. Service Models can be classified into the following groups:

- Cloud Software as a Service (SaaS). This type of clouds is called also as Service or Application Clouds. The user simply uses the cloud infrastructure or platform, does not manage or control any part of the cloud infrastructure.

- Cloud Platform as a Service (PaaS). The capacity provided to the user is to deploy onto the cloud infrastructure. The consumer has control only over the deployed applications and possibly application hosting environment configurations.

- Cloud Infrastructure as a Service (IaaS). Called also as Resource Clouds. The cloud provides for the consumer provision processing, storage, networks, and other fundamental computing resources via a service interface. The consumer does not manage or control the cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components.

Clouds may be hosted and employed in different styles, depending on the use case, respectively the business model of the provider. Deployment Models are the followings:

- Private cloud. The cloud infrastructure is used typically only by one organization (internal cloud).
- Community cloud. The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations).
- Public cloud. The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.
- Hybrid cloud. The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability.
- Special Purpose Clouds. Special Purpose Clouds are just extensions of "normal" cloud systems to provide additional, dedicated capabilities.

### *3.3 Advantages of Cloud Computing*

Cloud computing has important characteristics that will bring it to the most important IC technologies. In the followings the advantages /disadvantages will be mentioned only in a few fields. The main benefits of this approach are that the users of services do not need to own and manage the capital equipment involved.

General advantages of cloud computing are the massive scale, the homogeneity, the virtualization, resilient computing, low cost software, geographical distribution, service orientation and advanced central security technologies.

Security advantages are that shifting public data to an external cloud reduces the exposure of the internal sensitive data, cloud homogeneity makes security auditing/testing simpler, clouds enable automated security management and redundancy / disaster recovery are simpler.

Advantages in data storage are the automated replication, the data fragmentation and dispersal, provision of data zones (e.g., by country), encryption in storage/in transfer and automated data retention.

### *3.4 Problems in Cloud Computing*

*Security and privacy problems*

The most serious drawbacks of cloud are the security issues of the identity of users and the security of data. By the very nature of cloud computing, the data belonging to the organization using a cloud service will be held in a shared environment. A shared environment is implicitly less secure than a non shared one. Furthermore delegating the storage and processing of data does not relieve the organization of its legal and regulatory obligations around this data. Critical points are among others trusting vendor's security model, customer inability to respond to audit findings, indirect administrator accountability, proprietary implementations can't be examined and loss of physical control.

Strongly related to these issues concerning legislation and data distribution is the concern of data protection and other potential security holes arising from the fact that the resources are shared between multiple tenants and the location of the resources being potentially unknown. In particular sensitive data or protected applications are critical for outsourcing issues. Whilst the data should be protected in a form that addresses legislative issues with respect to data location, it should at the same still be manageable by the system.

Because of the many applications of cloud systems and the variety of cloud types imply different security models and requirements by the user. As such, classical authentication models may be insufficient. In particular in cases of aggregation and resale of cloud systems, the mix of security mechanisms may not only lead to problems of compatibility, but may also lead to the user distrusting the model due to lack of insight.

*Data storage problems*

The main problems in the field of data storage are the isolation management/multi-tenancy, the storage controller, single point of failure, exposure of data to third parties.

*Interoperability and Standardization*

Interoperability and standardization have huge impact on the cloud adoption and usage. Standardization will increase and accelerate the adoption of cloud computing as users will have a wider range of choices in cloud without vendor lock-in, portability and ability to use the cloud services provided by multiple vendors. This will also include the ability to use an organization's own existing data center resources seamlessly.

Every new cloud service provider have their own way on how a user or cloud application interacts with their cloud leading to cloud API propagation. There is a need for complex developed business applications on the clouds to be interoperable. Cloud adoption will be hampered if there is not a good way of integrating data and applications across clouds.

There are two basic approaches to solve Interoperability problems in the cloud:

*Unified Cloud Interface/Cloud Broker*

Cloud computing vendors have formed a common platform — Cloud Computing Interoperability Forum (CCIF) — to address the problem of cloud interoperability and standardization. The purpose of CCIF is to discuss and come up with a common cloud computing interface. CCIF is planning to come up with a unified cloud interface (Unified Cloud Interface Project, 2009).

The Cloud Computing Interoperability Forum was formed in order to help organizations to work together for wider industry adoption of cloud computing technology and related services. The main focus is to agree upon framework / ontology that enable the ability of two or more cloud platforms to exchange information in a unified way. CCIF is focusing on building community consensus, exploring emerging trends, and advocating best practices / reference architectures for the purposes of standardized cloud computing (Cloud Computing Interoperability Forum, 2010).

*Enterprise Cloud Orchestration Platform /Orchestration layer*

Every industry, thousands of companies are trying to simplify the speed and adoption of their products and services by transforming them into cloud services. The scenario that is unfolding is that there will not be just one cloud but numerous types -- private clouds and public ones. These will further get divided into general purpose and specialized ones. Similar to the way that internet is a network of networks, InterCloud means a federation of all kinds of clouds. All these clouds will be full of applications and services. It will not be possible to use these without some type of orchestration (CORDYS-Enterprise Cloud Orchestration, 2010).

## 4. APPLICATION OF CLOUD COMPUTING IN PRODUCTION

### *4.1 Cloud platforms and software*

There are many cloud providers, and developers in the market. In the chapter dealing with cloud models description several cloud-types have been mentioned. It is not the goal of this paper to give detailed descriptions on different clouds. A list of the most active 250 firms in the field of cloud systems has been published in January 2010 (Geelan, 2010).

### *4.2 Industrial applications of Cloud Computing*

Manufacturing enterprises both SMEs and larger enterprises are trying to find the way how to apply cloud technology. The advantages (agility, easy configuration/reconfiguration of IT system, “pay-as-you-go” model) seem to be really attractive but the drawbacks are stronger at present. According to industrial IT experts e.g. (Holloway, 2010) there are two main areas where CC will become popular for manufacturing companies; inter-factory collaboration and high performance computing.

Cloud solutions are/will be used most frequently for supply chain visibility, transportation management and supplier/contract negotiation. Partners can create cloud computing modules to address other manufacturing issues, e.g. supply chain execution, shop floor planning, demand planning and production scheduling.

The needs for additional computing power, as companies increase the use of digital models to virtually test their products or manufacturing system, to understand their business environment better through business intelligence and decision making. The models used are typically highly parallelizable and fit well for a cloud environment.

The primary disadvantages of CC for the industry are the risks associated with internet reliability, security and access of data (third party), intellectual property rights and the financial stability of the service provider.

In the followings two ongoing projects are introduced to illustrate the industrial application of cloud computing technology.

*The ManuCloud FP7 project*

ManuCloud project intends to implement a cloud-like architecture that will provide users with the ability to utilize the manufacturing capabilities of configurable, virtualized production networks, based on cloud-enabled, federated factories, supported by a set of software-as-a-service applications (Meier et. al., 2010).

ManuCloud has two main R&D focuses; the intra-factory environment and the inter-factory environment. The intra-factory environment involves production-related IT systems within a single factory which function is to connect the factory into the inter-factory environment. The inter-factory environment serves as a market place for virtualized manufacturing services, and supports the dynamic interconnection of multiple factories for specific purposes. The inter-factory environment supports a tightly controlled, on-demand integration of federated production-IT systems of different vendors, supporting joint specification management, shop-floor data transfer and high level of traceability. These services will be based on the ManuCloud Manufacturing as a Service (MaaS) environment.

*Distributed Train Model Rendering: GoFront Group project*

GoFront Group is China’s premier and largest national research and manufacturing group of rail electric traction equipment they produce high speed electric locomotives, metro cars, urban transportation vehicles, and motor train sets. The IT department of the group is responsible for providing the design and prototype of the products. The raw designs of the prototypes are rendered to high quality 3D images using the Autodesk Maya software.

By examining the 3D images, engineers identify problems from the original design and make the appropriate changes of the design for mass production. The rendering of three dimensional models is one of the phases that need a significant amount of time, so the rendering of a complete set of images from one design require three days. So, it has of vital importance for GoFront to reduce the rendering times, in order to be competitive and speed up the design process.

In order to reduce rendering time, a private Aneka Cloud Platform has been set up by using the existing computer resources (desktops, servers) of the IT department of GoFront. The setup contains a classic master slave configuration in which the master node concentrates the scheduling and storage facilities and thirty slave nodes are configured with execution services. A specific software has been implemented that distributes the rendering of frames in the Aneka Cloud and by using this SW the computation is done on the private cloud. Simply using a private cloud infrastructure that worked on demand the spare cycles of 30 desktop machines in the department, the rendering process has been reduced from days to few hours (Vecchiola et.al, 2009).

## 5. CONCLUSIONS

The production and manufacturing systems have to be adapted flexible to the surrounding quickly changing market environment. This adaptation can going on only with added value that is instantiated in software tools. The quick evolution of information technology supports this trend. For connecting the individual production units of the different types of networked enterprises collaboration and interoperability are vital.

Cloud computing technology is under development today, but its basic characteristics look very promising for networked enterprises. The paper presented the different models and advantages/ disadvantages of cloud computing, introduced how they can be applied in production environment with examples. The interoperability in cloud computing has a vital role for networked enterprises, so the possibilities in that field also has been showed. According to the forecasts, trends published by big market analyzer firms cloud computing will be an unavoidable IC technology for networked enterprise in the close future.

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