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CLOUD COMPUTING CONTRIBUTION TO MANUFACTURING INDUSTRY

Master´s Thesis
In Information Systems Science

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Manufacturing industry has been always facing challenge to improve the production efficiency, product quality, innovation ability and struggling to adopt cost-effective manufacturing system. In recent years cloud computing is emerging as one of the major enablers for the manufacturing industry. Combining the emerged cloud computing and other advanced manufacturing technologies such as Internet of Things, service-oriented architecture (SOA), networked manufacturing (NM) and manufacturing grid (MGrid), with existing manufacturing models and enterprise information technologies, a new paradigm called cloud manufacturing is proposed by the recent literature.

This study presents concepts and ideas of cloud computing and cloud manufacturing. The concept, architecture, core enabling technologies, and typical characteristics of cloud manufacturing are discussed, as well as the difference and relationship between cloud computing and cloud manufacturing.

The research is based on mixed qualitative and quantitative methods, and a case study. The case is a prototype of cloud manufacturing solution, which is software platform cooperated by ATR Soft Oy and SW Company China office. This study tries to understand the practical impacts and challenges that are derived from cloud manufacturing.

The main conclusion of this study is that cloud manufacturing is an approach to achieve the transformation from traditional production-oriented manufacturing to next generation service-oriented manufacturing. Many manufacturing enterprises are already using a form of cloud computing in their existing network infrastructure to increase flexibility of its supply chain, reduce resources consumption, the study finds out the shift from cloud computing to cloud manufacturing is feasible. Meanwhile, the study points out the related theory, methodology and application of cloud manufacturing system are far from maturity, it is still an open field where many new technologies need to be studied.

Keywords: Cloud Computing, Cloud Manufacturing, Manufacturing industry

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1 INTRODUCTION

1.1 Research background

In the twenty-first century, manufacturing industry is faced with challenges unlike any in the past because the world is moving faster and is more connected than ever before. This competitive global environment is refining the ways many manufacturing companies do business (Zhang et al., 2012). In recent years IT has benefited from cloud computing, which allows organizations to save cost from some of their costly IT infrastructure (Tao et al., 2011). As a continuum of this development, cloud manufacturing is emerging as a new paradigm for manufacturing engineering.

Cloud manufacturing was first used by Li et al. (2010). It is a collaborative and distributed system consisting of a collection of interconnected physical and virtualized service pools of manufacturing engineering resources. Xu (2012) clarified two forms of cloud manufacturing: a) the introduction of cloud-computing technologies into the manufacturing environment, and b) cloud manufacturing as a replication of the cloud computing environment using physical manufacturing resources in lieu of computing resources. This thesis paper focuses on the latter form.

Although the cloud manufacturing is still in its infancy (Wu et al., 2013), several companies are already developing platforms for commercial purpose. For examples, MFG.com is a unique and powerful cloud-based sourcing platform for manufacturing industry; main functions of their platform are Supplier Relationship and Purchasing Management. There are over 50,000 buyers regularly using MFG.com to drive their business around the world.

This study is aim to represent the shift from cloud computing to cloud manufacturing. Along this study tries to understand the general motivations and its impacts to apply cloud manufacturing systems and new challenges derived from cloud manufacturing.

1.2 Research motivation

The study was conducted as a part of an international master's program Information Systems Science (at University of Turku) and GITM (Global Information Technology Management at Turku School of Economics).

Being an employee in an IT company ATR Soft Oy, the author of this thesis is involved in 3D model designing software related testing and marketing. The author took this study as opportunity to work in this area of interest, as well as helping ATR Soft Oy to have deeper knowledge of cloud computing and cloud manufacturing. The interest was developed from previous software development project on a prototype cloud manufacturing platform called Application Store for SW Company (ASforSW) in ATR Soft Oy.

The author considers herself familiar with manufacturing modeling software, such as CAD and/or CAM, and marketing. The author has involved in a software project on developing a software platform to distribute Software as a Service (SaaS) applications for SW Company' partners. The opportunity motivated the author to study more on cloud computing technologies to contribute manufacturing industry.

1.3 Research problem

The objective of this study is to produce deeper understanding about how cloud manufacturing technology could be used as the next generation of manufacturing. There are very limited examples of commercially implementation of cloud manufacturing. According to Wu et al. (2013) cloud manufacturing is still in infancy stage. For these reasons, the following two general and main research questions will be addressed in the thesis:

1 What are the motivation and its impact on applying cloud manufacturing application?

2 What are new challenges derived from cloud manufacturing?

By answering these research questions the possible shift from cloud computing to cloud manufacturing in manufacturing business can be represented. Finally, based on this understanding, we will determine the cloud manufacturing's feasibility by evaluating whether a prototype of cloud-based manufacturing services marketplace benefits manufacturing enterprises.

1.4 Structure of the research

The structure of this thesis follows a typical research structure. Chapters 2 and 3 present and discuss the theoretical frame of cloud manufacturing. In Chapter 2, cloud computing's concept, characteristics, service models and deployment models are discussed. The Chapter 3 discusses fundamentals of cloud manufacturing according to the research literatures, which includes introduction of some advanced manufacturing technologies and models, and also cloud manufacturing concept and infrastructure.

Methodological approaches are presented in Chapter 4. Both qualitative and quantitative research approaches are discussed. Also data collection methods, data analysis of the study are presented. Chapter 5 includes discussion part, limitation of the study and future research possibilities. Chapter 6 is the conclusion of the thesis.

2 THEORTICAL BACKGROUND

2.1 Manufacturing engineering and challenges

Chituc et al. (2009) states manufacturing engineering involves designing, analyzing, testing, assembling, production and applying manufacturing methods and processes so that high quality products can be produced at a competitive cost within a planned period of time. Manufacturing enterprises are more globalized along with the factors like Internet technology make manufacturing information flow faster, more available distributed resources, global expansions of the manufacturing industries.

Behind the benefits and opportunities for today's global manufacturing enterprises, they are enforced to endure high costs to adopt the global solutions, insufficient supply chain management, wasted recourses, less integration of manufacturing system between global manufacturing agents (Valilai et al., 2014).

Especially the growth of IT infrastructure and expanded information system among manufacturing enterprises has caused huge cost for setup, maintenances, and scale up or down them according to business needs (Ogunmefun, 2011). In most of case the setup of IT infrastructure includes also software aspects for global manufacturing companies will take months, to first determine how many new servers would be needed for each plant, then purchasing and configuring the software at each of these plants. Time and money are both consumed unpredictable.

Secondly the lack of collaboration between information systems is becoming more and more major problem in the global production processes (Zhang, 2012). The manufacturing agents should have the same understanding of the exchanged product information and to rely on them. However, in realistic a single information system may generate millions of messages and how another information system interact can become heterogeneous.

In addition, according to Cai et al. (2009) the complex supply chain also make manufacturing enterprise facing more challenges. Cost-efficient is one main goal for manufacturing companies, this drives them to relocate or outsource pieces of their supply chain. For example, former Finnish giant telecommunication company Nokia has had factories in Finland, China, Hungary, Germany, Mexico, the U.S., Brazil and South Korea. Manufacturing enterprises are thus faced with the increasing challenges caused by highly depended shared manufacturing resources supply chains became too complicated. One of the main reason behind this scenario is the low efficient and effective discovery of shared resources information.

Cai et al. (2009) also pointed out sharing of resources, not only hardware, but also software in manufacturing industry is inadequacy. There is contradiction on manufacturing resources globally. On the one hand, some especially medium-sized enterprises

(SMEs) are lacking of advanced manufacturing equipment to finish their orders. On the other hand, some companies own these equipment with very little production mission. A huge amount of manufacturing resources are wasted. In a modern manufacturing enterprise use many information system, such as enterprise resource planning (ERP), Manufacturing Execution System (MES), product data management (PDM), customer relationship management (CRM), computer-aided design (CAD) is commonplace. Undoubtedly these system are useful for a manufacturer. However, they are very expensive if a company needs to own all of them.

Taking into account the above issues, a manufacturing company in order to remain competitive using its in-house resources and capabilities alone will be very difficult. The general sharing of global manufacturing resources become very critical for an enterprise to grow in a competitive market (Wu et al., 2014).

2.2 Cloud computing

2.2.1 Definition of cloud computing

This chapter provides an overview of current status of cloud computing. First of all, here is existing definitions for cloud computing as follows:

> "Cloud computing is a model for enabling ubiquitous, 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 related with minimal management effort or service provider interaction" (NIST 2011)

The term of cloud computing is often described as the evolution of the Internet and called "the cloud". Cloud computing is changing the way of enterprises doing business since the cloud technology makes business environment became more dynamical and resources are more virtualized. From a technical point of view, cloud computing utilizes a large pool of computing and storage resources via distributed and decentralized client-server architectures and offer advanced services to personal computers with graphical user interfaces and mobility. From a business point of view, cloud computing is a milestone that changed the mode of IT deployment and service pricing strategies.

2.2.2 Characteristics of cloud computing

The advantages of using cloud computing came from its distinct characteristics, which are (NIST, 2011):

1. On-demand self-service. A consumer can access computing capabilities, such as server time and network storage, whenever need without interaction with any service's provider.
2. Broad network access. Consumer can access all kind of network resources via standard mechanisms in different client platform, e.g. mobile phone and laptop, etc.
3. Dynamic resource pooling. By using multi-tenant model, the computing resource are pooled to the multiple users from different service providers.
4. Rapid elasticity. The capabilities can be rapidly and elastically provided. The consumer can access and purchase the capabilities in any quantity at any time.
5. Measured Service. Cloud system transparently control and optimize resource used by consumers, meanwhile monitoring and reporting the usage capacity to both providers and consumers.

According to the International Data Corporation (IDC, 2013), the global market for public cloud service reached 47, 4 billion US dollar in year 2013. And it is expected to be more than 107 billion US dollar in year 2017. Over the 2013 – 2017 forecast period, public cloud services will have an annual growth rate of 23,5% which is five times that of the IT industry as a whole.

2.2.3 Service models of cloud computing

As we can see from Figure 1 below, a cloud computing is composed of three service models (NIST, 2011). They determine how computing resources are being provided and consumed as a utility. From top to down, they are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The infrastructure layer is the lowest, it is representing system elements includes processing, network, storage elements, etc. In realistic they can be servers, storage equipment, switches, routers and other system handles workloads from network. Platform as a Service is the middle layer, it includes more advanced services, for example, to develop, test, deploy, host and maintain software. For example, Google App Engine, Microsoft Azure, IBM Smart Cloud, Amazon EC2 and Salesforce.com can be PaaS service providers. The top layer will delivery direct service to end users by on-demand. A simple example can be Gmail, it is a SaaS where Google is the provider and we are consumers (V.Nandgaonkar et al., 2014).

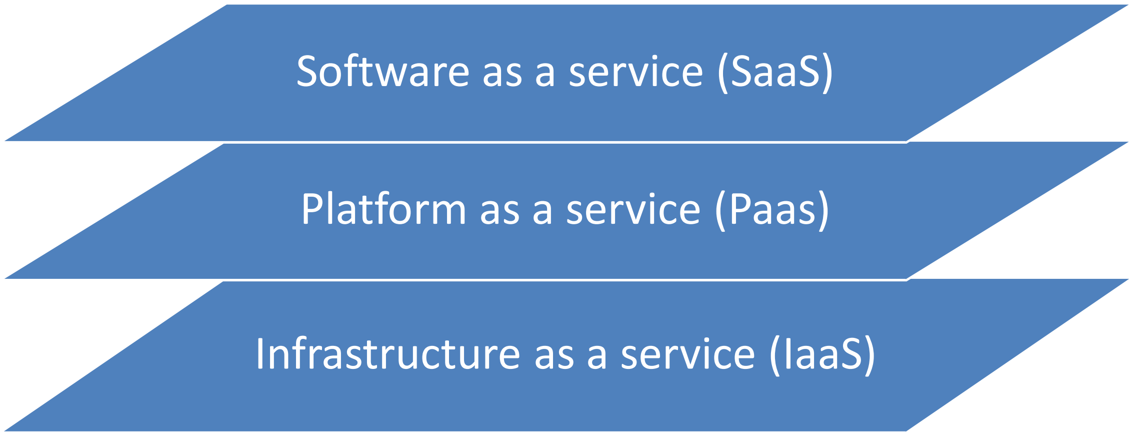


Figure 1 Service model of a cloud computing

2.2.4 Deployment models of cloud computing

It seems that the process of matching operation requirement to the offer of a cloud service is relatively straightforward. The challenge arises when determine the deployment model.

The NIST Definition of cloud computing also described cloud computing has three deployment models: private cloud, public cloud, and hybrid cloud (See Figure 2). According to Mell et al. (2011) the private cloud model has the services and infrastructure maintained on a private network in order to provide the greatest level of security and control, but shortage of this model is that organization must purchase and maintain all the software and equipment, cost saving are reduced and IT management burden remains unchanged. Public cloud model include off-site services and infrastructure over the Internet (Ogunmefun, 2011). This model can provide most efficiency in sharing resources, though less direct control over the shared data. Hybrid cloud is a mix of private and public cloud. In details, a hybrid uses a private cloud combined with the use of public cloud services. Many companies with private clouds will evolve to manage workloads across data centers, private clouds and public clouds (Ogunmefun, 2011). In this way organization can keep each aspect of the business in the most appropriate environment.

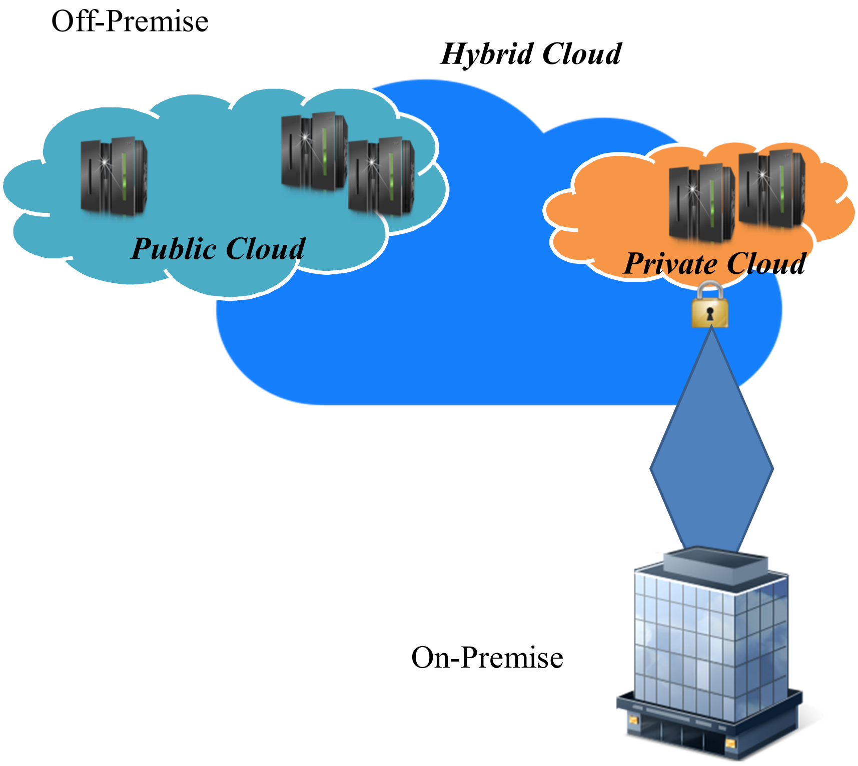


Figure 2 Cloud computing deployment models

3 FUNDAMENTALS OF CLOUD MANUFACTURING

Manufacturing industry has been always facing challenge to improve the production efficiency, product quality, and their innovation ability (Xu, 2012). Since the 1970s, computer technology developed rapidly, all kinds of information means have been implemented in the manufacturing industry. However, the more development of global manufacturing industry the more challenges they are facing, such as the waste of manufacturing resources, the lack of efficient coordination, the complex supply chain and inefficient utilization, etc. (Zhang et al., 2012). In this chapter, first introduction to some advanced manufacturing technology or model is given. Second the potential benefits of utilizing cloud computing technology in manufacturing engineering will be described. Third an ideally infrastructure of cloud manufacturing will be introduced. At the end of the chapter, the relationship between cloud computing and cloud manufacturing, also characteristics and advantages of cloud manufacturing are discussed.

3.1 Some advanced manufacturing technologies and models

In the twenty-first century, the manufacturing industry is urgent need to utilize the innovated information technology processes to improve their core competitiveness. In recent years, many advanced IT technologies have been developed to help manufacturing industry to override their challenges, such as Internet of Things (IoT), Service-oriented Applications (SOA), Networked Manufacturing (NM) and Manufacturing Grid (MGrid) (Zhang et al., 2012).

3.1.1 Internet of Things

INFSO (2008) proposed the semantically definition for Internet of Things as "*a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols.*" According to Gubbi et al. (2013) the Internet of things (IoT) is a paradigm utilizing advantage of sensor or wireless networks technology. IoT uses commonly adopted sensors include global positioning system (GPS) sensors, barcode sensors, radio frequency identification (RFID) sensors, wireless sensors, infrared sensors, mobile devices and other information sensing devices according to the agreed protocol, which connected to the Internet to provide data, information or even service order to intelligently identify, locate, track and manage a network.

Bandyopadhyay et al. (2011) epitomized an architecture of Internet of Things according to Atzori et al. (2010)'s research shown in Figure 3.

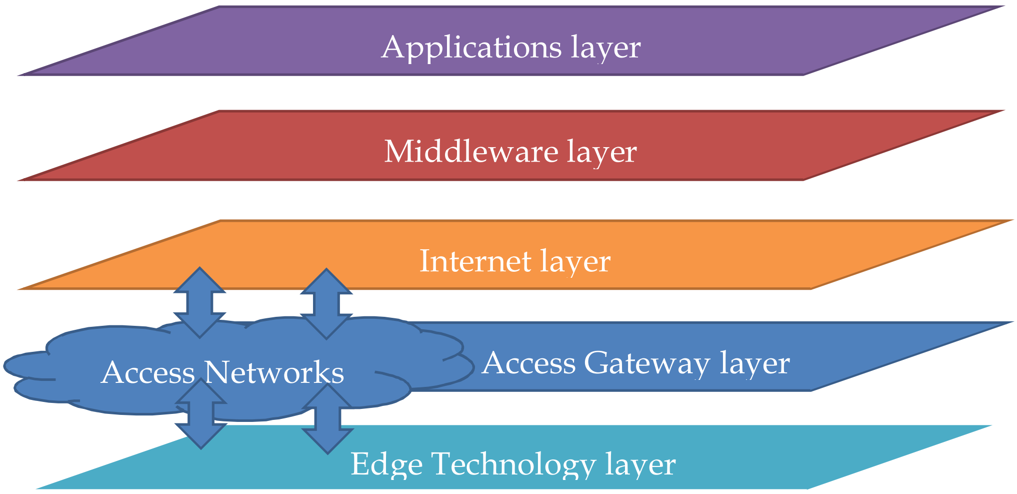


Figure 3 Layered architecture of Internet of Things

1. Edge technology layer is hardware layer consists of RFID tags and readers, sensors, etc. Many of these hardware equipment have the functions of identification and information storage, data collection, data processing, communication, control.
2. Access gateway layer is the layer to processing data and taking care of data transformation, it can be cross platform communication.
3. Internet layer is the computer networks that use the standard Internet protocol suite TCP/IP to link devices.
4. Middleware layer is a software layer acting as an interface between hardware layer and the application layer. Main functions of this layer includes device control, information management, data filtering, semantic analysis, access control, etc.
5. Application layer is on the top of the architecture includes user interfaces to end users to access middleware's functionalities for example using a standard web service.

Gubbi et al. (2013) revealed that IoT technology is widely used in logistic system and improving the automation in manufacturing industry. The result is that IoT technology has dramatically changed the traditional way of handling goods in factory. This is also the reason IoT is considered as Internet of the future.

However, according to Atzori et al. (2010) there are numerous of issues challenging the Internet of Things. Major problems are such as uncompleted standardization among communication between hardware and Internet, security issues (IoT is vulnerable to attacks), and privacy of individuals is seriously threatened in IoT environment.

3.1.2 Service-oriented architecture

Erl's (2004) book defines Service-oriented architecture (SOA) as "*a design model with a deeply rooted concept of encapsulating application logic within services that interact via a common communications protocol.*" Another description of SOA is: "*In essence, it is a way of designing a software system to provide services to either end-user applications or other services through published and discoverable interface. Brown et al.* (2002)." A service is a unit of work done by a service provider to achieve desire results for a service consumer.

According to Li et al. (2010), SOA is not new notion and it has been around us everywhere for a long time. For instance, in a manufacturing industry example a consumer has bought a piece of design work for a mobile phone holder. S/he want to print it with a 3D printer. There are two printing factories can print the phone holder, one can print black-white 3D model and another one can print colorful 3D model. Both factories offer printing service and consumer can print not only the phone holder but also many customized stuffs, in another hand these two factories offer the same service with different quality. Another example as the commercial cloud marketplace offers a wide range of cloud computing services, like cloud storage service is the ability to safely store a file in the cloud.

In most of case SOA is implemented through the common Web Services (Raines, 2009). According to Raines (2009) SOA offers positive benefits such as 1) usage of unified eXtensible Markup Language, the programming language neutrality is key for offering and invoke services through a common mechanism; 2) multiple components can be reused and combined to create greater capabilities; 3) efficiency in organizational agility via dividing enterprise IT system to smaller service level then rapidly recombine their capabilities according demand from organizations; 4) leveraging existing IT systems by defining existing IT system's functions and offering them to the enterprise in a standard way.

3.1.3 Networked Manufacturing

Networked Manufacturing (NM) is proposed based on Internet and aims to cover a set of manufacturing activities including market control, product design, material management, manufacturing process also manufacturing technologies, and manufacturing system (Zhang et al., 2012). According to Fan et al. (2005) networked manufacturing reflect to the whole product lifecycle and enables resource sharing between geographically distributed manufacturers, in this way to ensure manufacturing companies to respond to the market quickly. Networked manufacturing platforms attempt to enable the collaboration between those enterprises with different location of the world. It emphasizes resource sharing and helps to manage remote resources and processes easily through Internet.

Fan et al. (2005) has pointed out networked manufacturing's main layers as following Figure 4. The core level includes basic elements of networked manufacturing such as related structure standards, specifications, etc. On the second layer of software and enabling tools, it includes all relevant software such as PLM (Product Lifecycle Management), PDM (Product Data Management), ERP (Enterprise Resource Planning), CAX (Computer-aided technologies, like CAD, CAE, etc.), CRM (Customer Relationship Management) and enabling tools such as modelling, equipment interlink tools, etc. As well resource libraries like product resources libraries, manufacturing resource libraries and basic data libraries are existing in the second layer. The third layer is application service layer which cover most product life cycle functions of networked manufacturing, such as co-operative design, co-operative manufacturing, co-operative supply chain, etc. At the above user level, it includes all kind of interfaces of various applications with the support of the network manufacturing to users such as Internet, Intranet and Extranet.

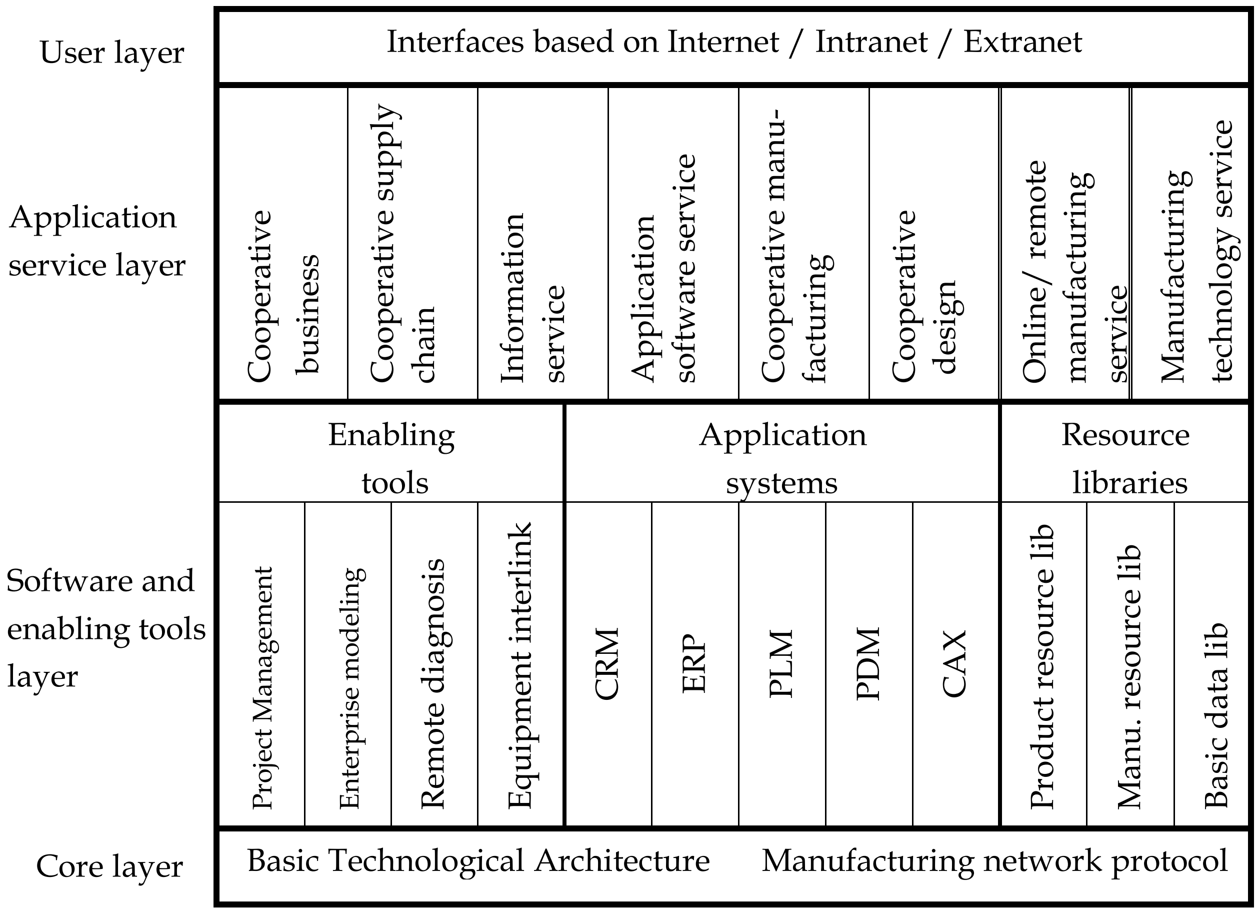


Figure 4 The architecture of Networked Manufacturing

Zhang et al. (2012) revealed a few issues which hinder the networked manufacturing from widely usage, they are: 1) lacking of centralized management and operation service between many different manufacturing resources sharing, as a consequence few resource service providers are willing to share their high-quality manufacturing service and resources; 2) relatively fixed match between business process and shared resources, as the development of service-oriented architecture (SOA) the dynamic and intelligent publish, search and map resources are required more and more by resource service provider and demanders; 3) limited shared resources are used on-demand; 4) lacking of reliable security solution on networked manufacturing and trust between resource providers and demanders.

3.1.4 Manufacturing Grid

Manufacturing Grid (MGrid) is to apply grid computing to produce design, manufacturing resource integration and allocation, enterprise information management, and scheduling. The key concepts of grid are resource sharing and coordinated work according to Tao et al. (2012). One of the main differences between MGrid and networked manufacturing is that MGrid has the support of unified technologies such as Web service, grid service, unified platform such as Globus Toolkit (is an open source software toolkit used for building grids), and unified standards and protocols such as OGSA (the Open Grid Service Architecture), WSRF (the Web Service Resource Framework), while NM does not have such support (Tao et al., 2011).

Tao et al. (2012) pointed out the aim of Manufacturing Grid is to effectively organize all kinds of resources separated in different countries or regions, enterprises, and individuals. Through the services provided by MGrid, users can obtain various manufacturing services as conveniently as obtain information data from the Internet today. Internet is the physical network of MGrid. The construction and operation mode of MGrid is similar to Internet. MGrid provides manufacturing enterprises and individuals with manufacturing services in the similar way that Internet provides information services according to Tao et al. (2012) see Figure 5.

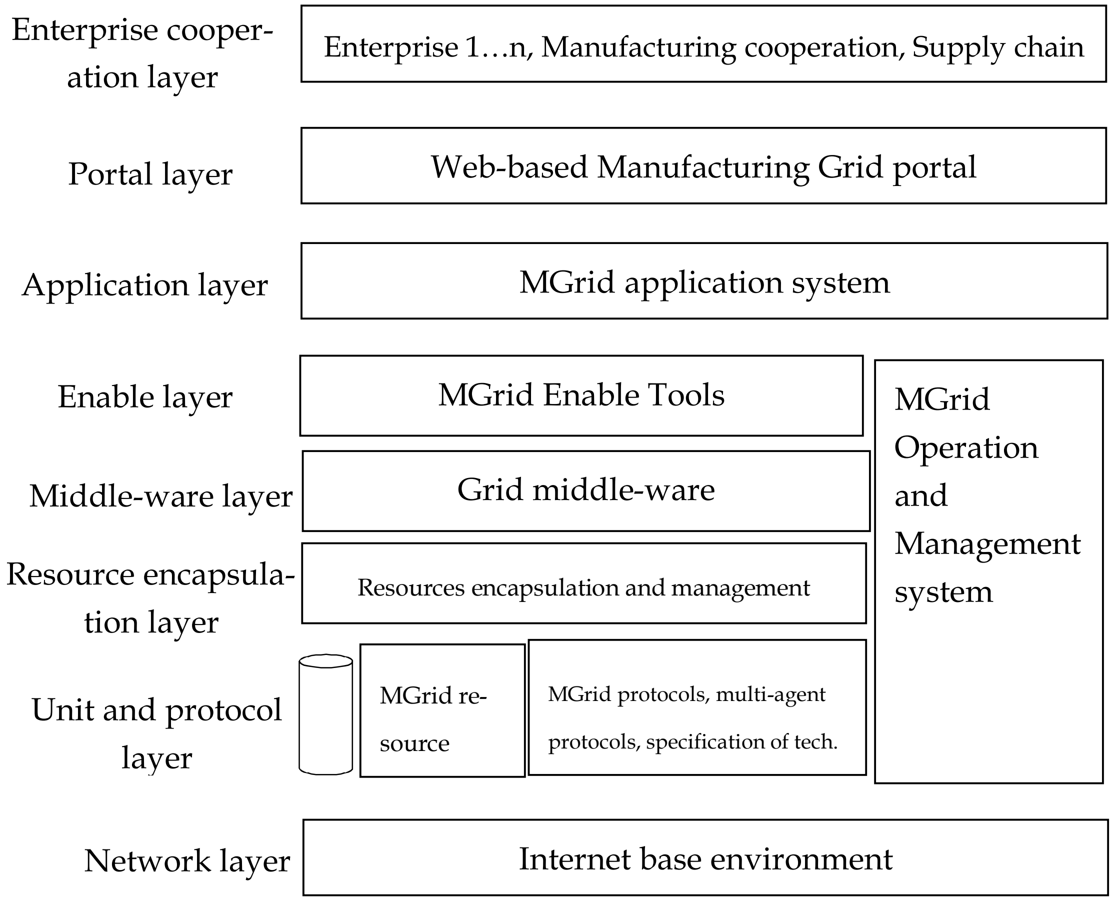


Figure 5 The architecture of Manufacturing Grid system

In Tao et al. (2012)'s book, it stated that same as networked manufacturing although many researchers have endeavored to make practical application of MGrid, and some companies have used grid technologies in their manufacturing activities and the product design, but there is no commercial entities have taken the role in developing the MGrid platform and the manufacturing services are not well collated and operated as products.

Above technologies or models have played very important roles in manufacturing engineering fields, and have made great contributions to the development of modern manufacturing. Each of these advanced manufacturing technology has its own emphasis and advantages. However, lacking in the centralized operation management in the services, equipment and resources is one of the main bottleneck for them to be applied more widely (Zhang et al., 2012).

3.2 Cloud computing is game-changing technology for manufacturers

Since 2008 cloud computing is merging as a new paradigm for those manufacturing enterprises are embracing new IT technologies. All the computing of more than one computer via a network or the service gained from the host computer via a network is considered cloud computing. Through different types of devices such as laptops and smart phones users can access to services and computing resources in clouds. According to a study executed by Tata Consultancy Service group (TCS, 2012), from year 2008 to 2012 the heaviest users of cloud applications are from manufacturing industry, especially those manufacture the technology hardware, e.g. computers, electronics and telecom equipment, etc. As can be noticed from Figure 6 below, the same trend we can see from the adoption rate of cloud computing technologies by major manufacturing industries.

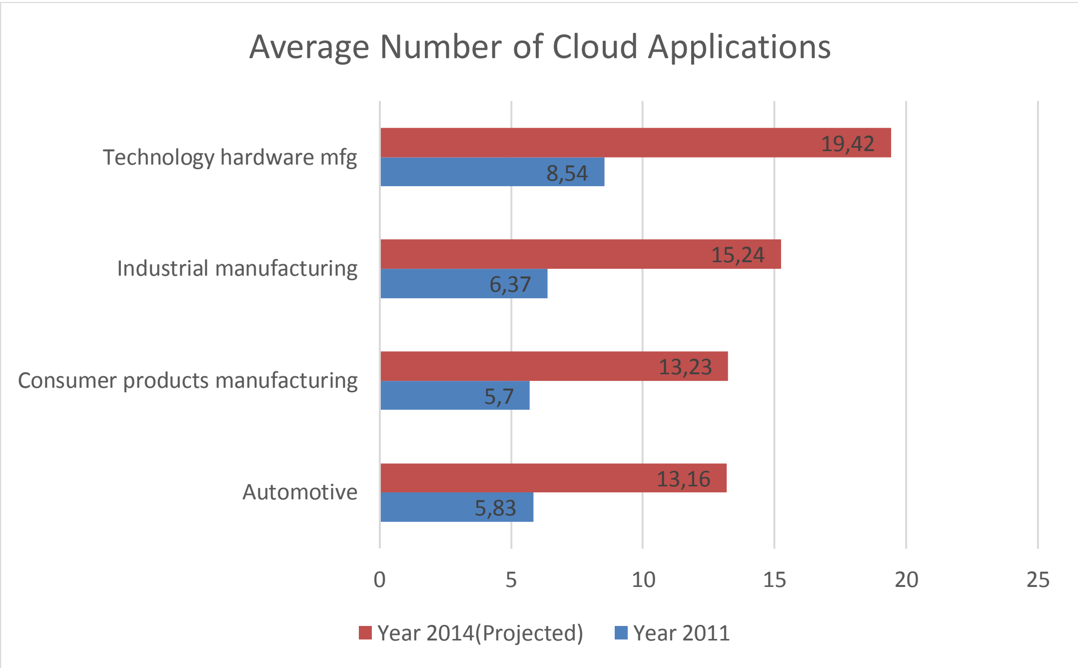


Figure 6 Comparing industries by average number of cloud application per industry

According to Ren et al. (2014) cloud computing represents a merging of two major trends in manufacturing industry. The cost-efficient policy refers to using resources more efficiently through highly scalable hardware and software resources. Obviously, reduced hardware infrastructure, less power consumption, no maintenances fee for servers, and much lower IT department expenditure as well pay-as-you-go price model has removed the huge cost from manufacturing companies. Furthermore, TCS (2012) also revealed the same trend of business agility drives manufacturing enterprise to adopt ubiquitous and cost efficiency cloud computing in response to changes in their business environment.

Columbus (2013) has published an article on Forbes to review the reasons why manufacturing enterprises are embracing cloud computing technology and what aspects has fulfilled their requirements based on Columbus' visits with manufacturers. Columbus pointed out 10 aspects to utilize cloud computing such as 1) implementing cloud-based business tools to mobility support the analysis and reporting, also 2) deliver real-time order status and forecasts, and 3) create multiple access entry points.

These business tools can 4) support different business purposes customer management, 5) sales management, 6) product management, 7) supply chain management, 8) ERP, 9) HRM etc. 10) Using cloud computing platform can streamline key phases of manufacturing and product management, which is strategy that many manufacturers are pursing today.

From only IT point of view, cloud computing is a solution can meet various need and budget because cloud computing is available in many deployment shapes, size and pricing levels. From costly private cloud to the public pay-as-you-go cloud solution. This has helped companies to run upgraded and standard IT solution that can improve their productivity at a smaller cost. According to Ogunmefun (2011) cloud computing also provide a way to better resource utilization. In a traditional in-house IT environment, servers are often underutilized and storage amounts excess capacity. Cloud computing deliver services on demand. Besides cost saving, flexibility, cloud computing benefits includes as well quicker deployment and ease of use.

3.3 Cloud manufacturing

3.3.1 Definition

In order to achieve manufacture industry competitive vision, a new manufacturing business model is urgent needed. Li et al. (2010) first address cloud manufacturing as *"a service-oriented, knowledge-based smart manufacturing system with high efficiency and low energy consumption"*. Xu (2012) provides a definition of cloud manufacturing as "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., manufacturing software tools, manufacturing equipment, and manufacturing capabilities) that can be rapidly provisioned and released with minimal management effort or service provider interaction."* According to Zhang et al. (2012), cloud manufacturing is considered as a new paradigm for manufacturing industry. It compared to conventional networked manufacturing, the cloud manufacturing has more rapid scalability, resource pooling, and ubiquitous data access.

Cloud manufacturing is a group innovated advanced manufacturing models. Cloud manufacturing consists various resources, services and solutions for addressing a manufacturing task. Any manufacturing enterprise can use these resources, abilities and knowledge to carry out its manufacturing actions. Within a cloud manufacturing landscape, a manufacturing enterprise does not need to possess the entire manufacturing environment, such as machines, IT infrastructure and personnel or even software involved in manufacturing actions, such as design, production, management and logistic applications. A manufacturing company can require the resources and services in the cloud manufacturing platform along with pay-as-you-go pricing policy.

3.3.2 Ideally infrastructure of the cloud manufacturing

In some studies like Wu et al. (2014) cloud manufacturing is considered as the manufacturing version of cloud computing. Then a cloud manufacturing layered architecture can be addressed based on cloud computing layered architecture, and the additional layer would be Manufacturing as a Service (MFGaaS*)*. See Figure 4. A similar layer architecture is also introduced by another relevant model of cloud manufacturing is Cloud-Base Design and Manufacturing (CBDM), instead of MFGaaS layer in CBDM the additional layer is Hardware as a Service (Haas) see Figure 7.

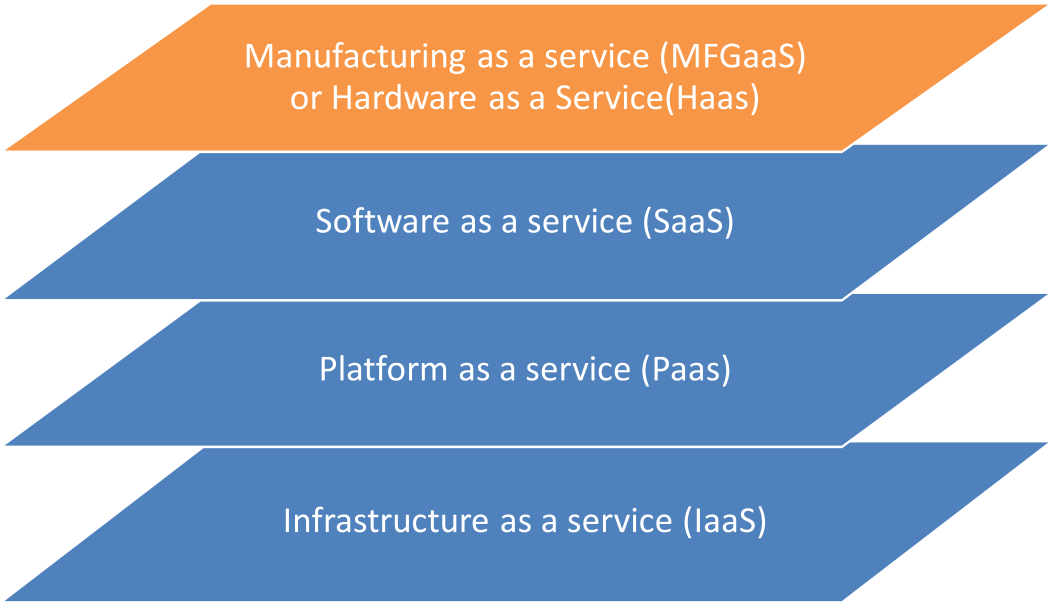


Figure 7 A general layered architecture of cloud manufacturing

In CBDM model, HaaS service model simply provides consumers with access to manufacturing hardware, for example, CNC machine tools, 3D printers, etc. HaaS allows service consumers to rent hardware from providers as pay-on-use.

Wu et al. (2014) indicates in next few years the following example service providers in Table 1 and their services could build up the cloud manufacturing arena particularly in designing and manufacturing field. The listed enterprises are considered as currently major cloud manufacturing service providers for SaaS, HaaS, Paas and IaaS.

Table 1 Service providers and their services

	Provider	*Service*
SaaS	Autodesk 360 platform Dassault Systems SOLID-WORKS TeamPlatform	CAD file editing, mobile viewing, cloud rendering 3D modeling Desiging, sharing and viewing CAD files, design optimization, simulation Project Management, 3D scanning and printing, product design
HaaS	Shapeways Cubify.com MFG.com	3D printing 3D scanner, printing Supplier search engine, cloud-based resourcing, purchase management
PaaS	Microsoft windows azure Amazon relational database service Salesforce	Developing and hosting web application Database query system for analysis of massively large datasets Workflow automation, custom websites, sales teams, enterprise analytics
IaaS	Rackspace Amazon elastic compute cloud Microsoft OneDrive, Dropbox	Internet hosting Virtual machines Online storage, file syncing

However, according to Ren et al. (2014) in cloud manufacturing model the MFGaaS will cover all services of a product life cycle see Figure 8. In details, they are Design as a service (DaaS), Production as a service (PRDaaS), Simulation as a service (SIMaas), Assembly as a service (AssS), Test as a service (TaaS), Logistics as a service (LaaS), Management as a service (MaaS), and Integration as a service (INTaaS), etc. Ren et al. (2014) also points out that in realistic these XaaS services can be clarified into two type, they are OnCloud or OffCloud services. In details, OnCloud service are operating on "the cloud", vice versa, OffCloud services need additional operations by an operator outside "the cloud". In most of case, the OnCloud and OffCloud service will be used by an enterprise side by side.

Figure 8 Capability services for whole life cycle of a product

Tao et al. (2011) propose a ten layer architecture for cloud manufacturing system, which is shown in Figure 9. In brief, the manufacturing resources and abilities at the lowest level. These resources are then virtualized and managed in a cloud environment, and then made available to consumers through an application layer. The seven functional layers are facilitated by the three layers of knowledge, cloud security, and a network such as the Internet.

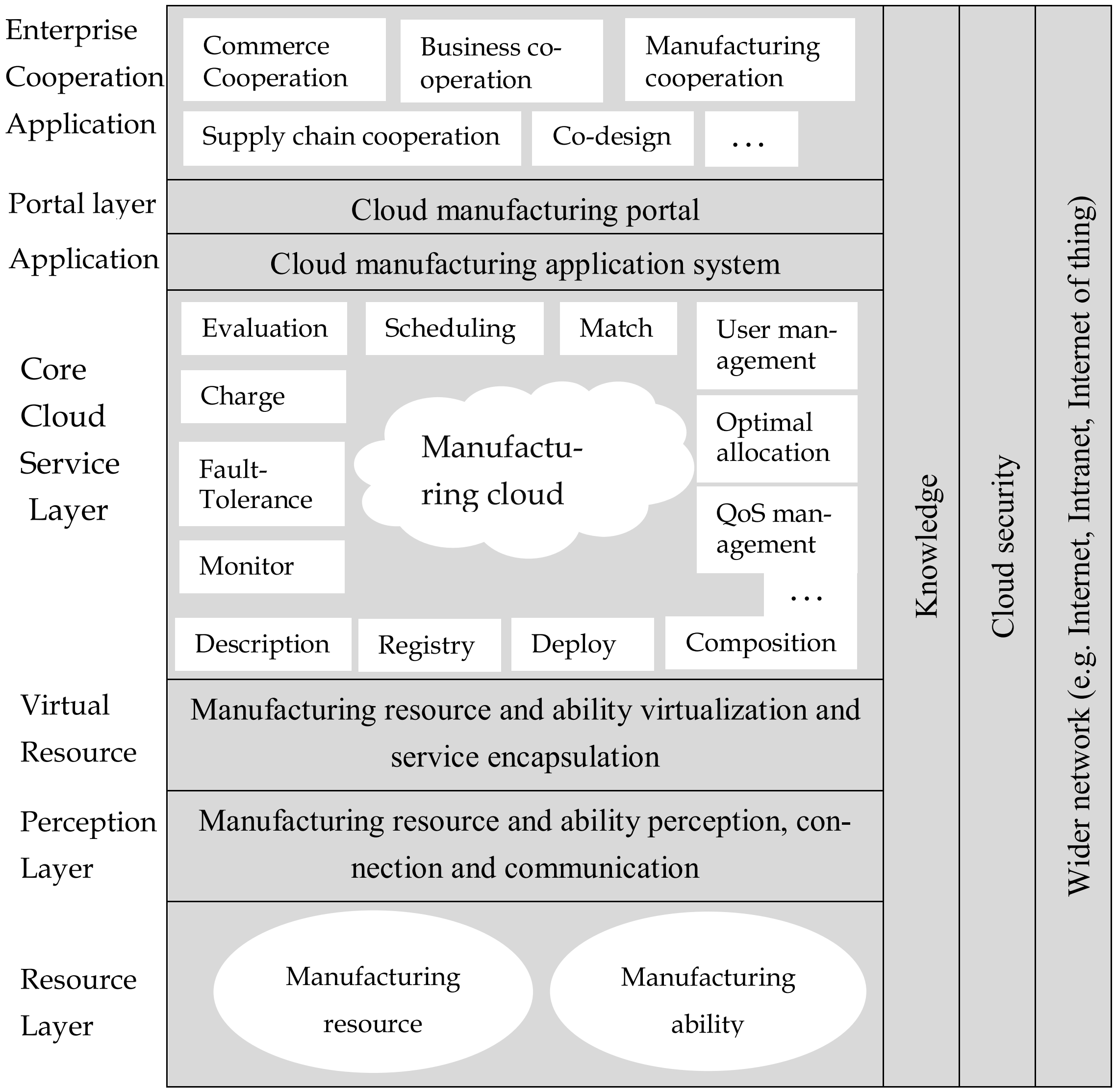


Figure 9 Architecture of cloud manufacturing system

Follow is brief instruction of the ten layers of cloud manufacturing system (Tao et al., 2011):

1. Resource layer provides the basic manufacturing resources and capabilities to cover the whole life cycle of manufacturing. They can be requested by users as a service such as Design as a service (DaaS), Production as a service (PRDaaS), Simulation as a service (SIMaas), Assembly as a service (AssS), Test as a service (TaaS), Logistics as a service (LaaS), Management as a service (MaaS), and Integration as a service (INTaaS).
2. Perception layer is a kind of transformation layer to collect all manufacturing resources' data information then process and send them to network. Internet of

Things (IoT) is the core technology enabling the intelligent perception and connection among different machines.

3. Recourse virtualization layer is aim to virtualize and encapsulate manufacturing resources and abilities into manufacturing cloud service, in which virtualization technology is core enabler.
4. Cloud service layer consist of cloud manufacturing core services can be invoked by service providers, operators and users, such as description, registry, publication, search, charge, evaluation. Service-oriented application (SOA), Web service technology etc. are core enabling technologies.
5. Application layer includes manufacturing application systems such as cooperative supply chain management system, ERP system, etc.
6. Portal layer provides interaction interface for users to access all kind of cloud services.
7. Enterprise cooperation application layer is similar as SaaS layer in cloud computing. It cover core services including collaborative design and manufacturing cooperation, etc.
8. Knowledge layer covers manufacturing domain knowledge, process knowledge, model knowledge, etc.
9. Cloud security layer provides different cloud safety architecture and policy for the whole system.
10. Wider Internet layer is the basic communication environment accessing by all resources, services and users, etc.

3.3.3 Relationship between cloud computing and cloud manufacturing

Tao et al. (2011) use Figure 10 to describe the relationship between cloud computing and cloud manufacturing. In brief cloud manufacturing is merged after cloud computing, and cloud computing is major enabler for cloud manufacturing. The cloud computing related resources are server, storage, network and application etc. However cloud manufacturing includes all manufacturing resources and abilities covered in the whole life cycle of manufacturing, and they are provided to the end users in different cloud service models based on cloud computing architecture such as IaaS, PaaS and SaaS.

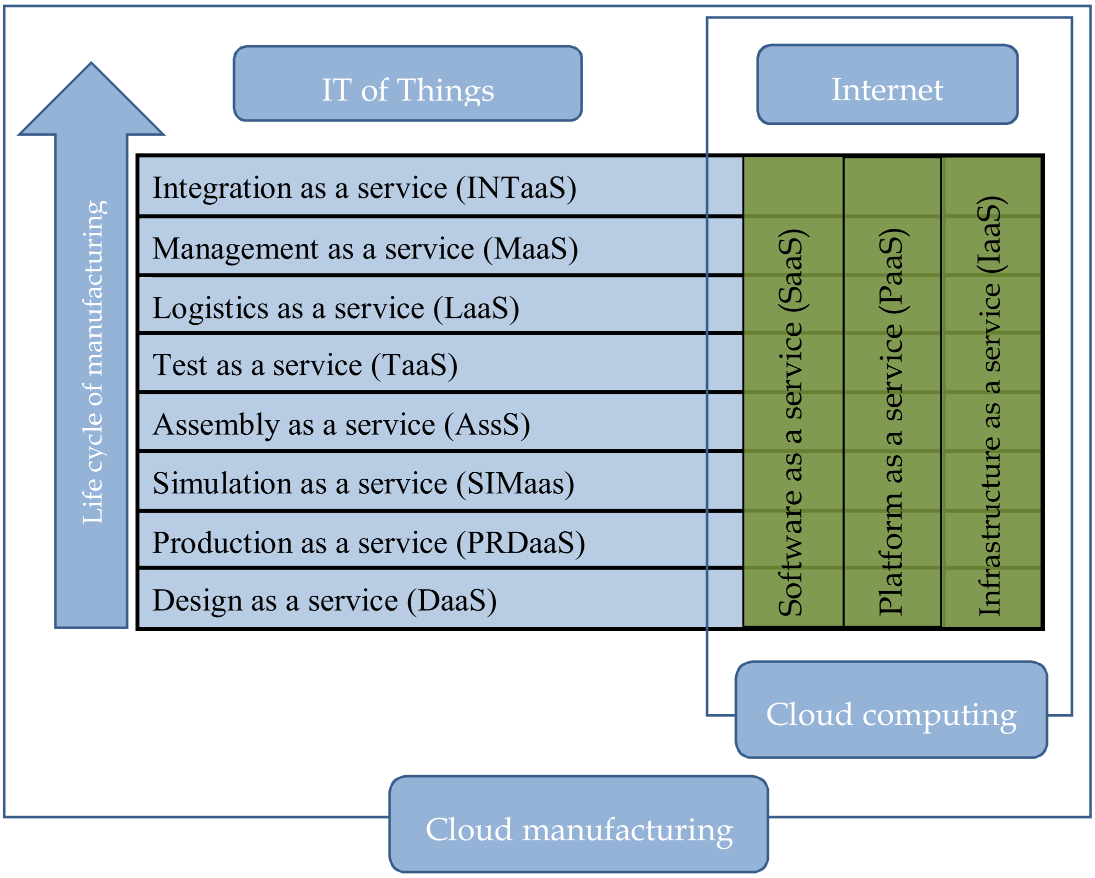


Figure 10 Relationship of Cloud computing and Cloud manufacturing

3.3.4 Characteristics of cloud manufacturing

In Section 2.2, NIST's definition of cloud computing and its essential characteristics were explained. As obvious these features are also detectable in cloud manufacturing. Wu et al. (2012) state the essential characteristics of cloud manufacturing are derived from cloud computing as:

1. On-demand self-service. Manufacturing enterprise can obtain shared manufacturing resources and services by joining the cloud manufacturing platform, vice versa, they can also provide their manufacturing resources and services to meeting others' requirements.
2. Broad network access. Customers, designers and managers are playing important various roles in entire production process and they actively interact to each other, cloud manufacturing can make their access to resources and service more easier by using all kind of tools such as mobile phones, tables, laptops and workstations.

3. Resource pooling. Cloud manufacturing consist of a shared pool of configurable and virtualized manufacturing resources and service. Users can conveniently access to the service and use them whenever need.
4. Rapid elasticity. Cloud manufacturing make users respond quickly to the dynamic changing requirements since cloud computing technology allows the cloud manufacturing service consumers to search and fully utilize manufacturing resources. In case there are idle or redundant resources, then these resources can be dynamically used by other enterprise to scale up their capacity.
5. Measured service. Recourse and services which join in this cloud manufacturing platform are monitored, measured and reported to ensure the quality of cloud manufacturing platform.

3.3.5 Advantages of cloud manufacturing

Essential advantages of cloud manufacturing should be addressed out according to Tao et al. (2012):

1. Cloud manufacturing is to increase resources and services utilization and reduce idle capacity. The manufacturing resources and services are provides and shared by many different companies, at same time they are measured on the network all these technologies can improve the utilization.
2. Cloud manufacturing especially can benefit those small and medium enterprise (SMEs) which try to entry competitive manufacturing industry by quickly accessing high-value manufacturing resources and service where normally they are only available to the larger enterprise, in another words upfront investment is lower since infrastructure and administrative costs, energy expenditure, upgrades and maintenance fee are all reduced dramatically compare to conventional manufacturing models.
3. Cloud manufacturing make scalability of production and business more flexible and easier because manufacturing resources and service can be easily obtained so manufacturing enterprise can increase the production capability whenever a new customer requirement arise.
4. Cloud manufacturing optimize the manufacturing distributed resources, and speed up the transformation from production-oriented manufacturing to service-oriented manufacturing for an enterprise. In cloud manufacturing platform, an enterprise does not necessary involve whole lifecycle of manufacturing, such as design, production, testing, integration etc. and the enterprise can emphasize their core business or service.

5. After the cloud computing technology is merged into manufacturing industry, cloud manufacturing make new future manufacturing service possible such as in previous chapter mentioned MFG.com which is cloud marketplace for manufacturing industry.

4 RESEARCH METHODOLOGY

4.1 Research design

The object of the present research is the information systems in manufacturing engineering. This study uses mixed methods research first based on exploratory qualitative method applying a case study. Second in order to form a comprehensive picture and to enhance the understanding impacts of the instance of the case study, quantitative research methods is employed. According to Creswell et al. (2003) the type of mixed methods research used here can be categorized as Sequential Exploratory Design. It is useful to a researcher who think a qualitative data on its own is not sufficient enough, therefore the researcher wants to explore a phenomenon but also wants to expand on the qualitative data by using quantitative data. .

Qualitative research concentrates on describing, interpreting and understanding the research subject, whereas, quantitative research refers to testing and explaining cause-and-effect relationships and forecasting (Creswell et al., 2003). According to Hennink et al. (2011) "qualitative research is an approach that allows you to examine people's experiences in detail, by using a specific set of research methods such as in-depth interviews, observation, content analysis, etc." Qualitative methods are characterized by its aims, which mainly related to understand the experiment. These methods aim to answer questions about the "what", "how" or "why" of a phenomenon rather than "how many" or "how much" (Green et al., 2007). Qualitative methods are approach to research that facilitates exploration of a phenomenon within its context using a variety of data sources (Baxter et al., 2008).

The method selected for the qualitative research is a case study. Case study is empirical forms of inquiry, examining a contemporary phenomenon within its real-life context (Yin 2003). Case study method is a set of processes of information gathering, regarding particular persons, organizations, or events. However, case study research methods is not only about pure data collection, it is also an approach that includes different data collection methods. In details, it can be collection of documents, interviews or observation of participants.

Thus, the case study approach appears to be a suitable research strategy, as the objective of the study was to acknowledge the cloud manufacturing is the evolution for manufacturing industry. Based on literature work, an exploratory case study was carried out in form of evaluation a prototype cloud manufacturing platform for manufacturing enterprises. Qualitative data collected by conducting two informal conversational interviews.

Basing this research only on qualitative approach is not sufficient enough considering the objectives of this research, and another reason behind choosing mixed method research is the limited sources data in this particular study. Quantitative research is concerned with testing and understanding cause-and-effect relationship of certain phenomena, issues or characteristics (Creswell et al., 2003). The quantitative part of this study aims at testing impact of such cloud-based manufacturing platform on primary usage level, which conducted by a web statics analysis.

4.2 Case study

4.2.1 Background information

The case study choose a platform called "Application Store for SW Company" is developed by ATR Soft Oy. The two main criteria for the case selection were the platform should be cloud based and it should be exploited by manufacturing enterprises.

ATR Soft Oy is a steady Turku based software company established in year 2000 with 40 employees having experience with all aspects of the software development process including project management, concept creation, analysis and design, integration, testing etc. For instance, one of the main specialized area for ATR Soft Oy is in data management especially on customization of PDM (Product Data Management) / PLM (Product Life Management) and CAD (Computer Aided Design) system, integration of PLM and ERP (Enterprise Resource Planning) systems.

SW Company is a software that offers mechanical design software solutions. At the moment SW Company has shipped over one million seats of software worldwide and makes it the world's most popular CAD software. SW Company has offices around the globe and sells, distributes and supports its products through a worldwide network of resellers. Its user bases range from individual to large companies.

The project of developing platform "Application Store for SW Company" is a cooperation work between ATR Soft Oy and SW Company China office. SW Company Greater China region includes mainland China, Hong Kong and Taiwan. From 1996, SW Company worked with channel partners to deliver its products into the China market. Over eighteen years SW Company have over 60 value added reseller (VARs) in Greater China region and customers come from different sectors, such as electronics, machine tools, industrial, medical, transportation and automobile, molding/tools, aeronautics and national defense, office equipment, consumer products and power generation. By beginning of 2014, SW Company online community has online registered members 110,000, which is the biggest online community for SW Company worldwide.

4.2.2 Challenges

The manufacturing capacity of China is fast expanding and has earned the name of "The World's Manufacturing Center". Investing in 3D computer aided design (CAD) software can help the Chinese manufacturers efficiently increase designing capabilities, improve product quality, shorten time-to-market, reduce development cost and risk, and help China to realize the transformation from being the current production plant of the world to the design center of the future. In China, more and more manufacturing enterprises are recognizing that designing capabilities has a definite influence on helping them improve their global competitiveness, and optimizing their products through the creation of three-dimensional prototypes that can help improve product quality and speed time-to-market. 3D computer aided design software market has grew extremely fast in last decade in China.

Along with manufacturing enterprises are increasingly dependent on the efficient and effective discovery of shared manufacturing resources and services provided by their partners. 3D CAD software users also realize one big problem on how to gather and access correct design resources and services, not only ready-made modelling resources, design resources, simulation resources, but also optimal add-in software can make the produce development process more automating, and valuable knowledge base service of design certain parts from some experts. However, these resources and services are often located geographically and represented in different formats. SW Company users are no exception faced with these challenges, a cloud-based platform is needed urgently. In the circumstances a request of developing the "Application Store for SW Company" has been sent to ATR Soft Oy.

4.2.3 Application Store for SW Company

The platform called "Application Store for SW Company" (ASforSW), which software development project started in April 2012 and the first version 1.0.3 was launched in China by October 26, 2012. Wu et al. (2014)'s Figure 11 can be an ideal description of services offerings on Application Store for SW Company' platform in which green colored services were partially deployed on the first released platform of ASforSW. There are four type of services to cloud consumers. They are: 1) Hardward-as-a-services (HaaS) delivers hardware sharing services e.g. high quality graphic design computers, CNC machining, 3D printers, hard tooling, machine centers, and manufacturing processes to cloud consumers, 2) Software-as-a-service (SaaS) delivers software applications, such as SW Company software partner's applications regarding CAD/CAM, simulation software and even ERP software to cloud consumers, 3) Infrastructure-as-a-service (IaaS) provides computing resources, such as high performance servers and data pools to consumers and service providers, 4) Platform-as-a-service (PaaS) provides a social media network for consumers and providers to communicate and cooperate.

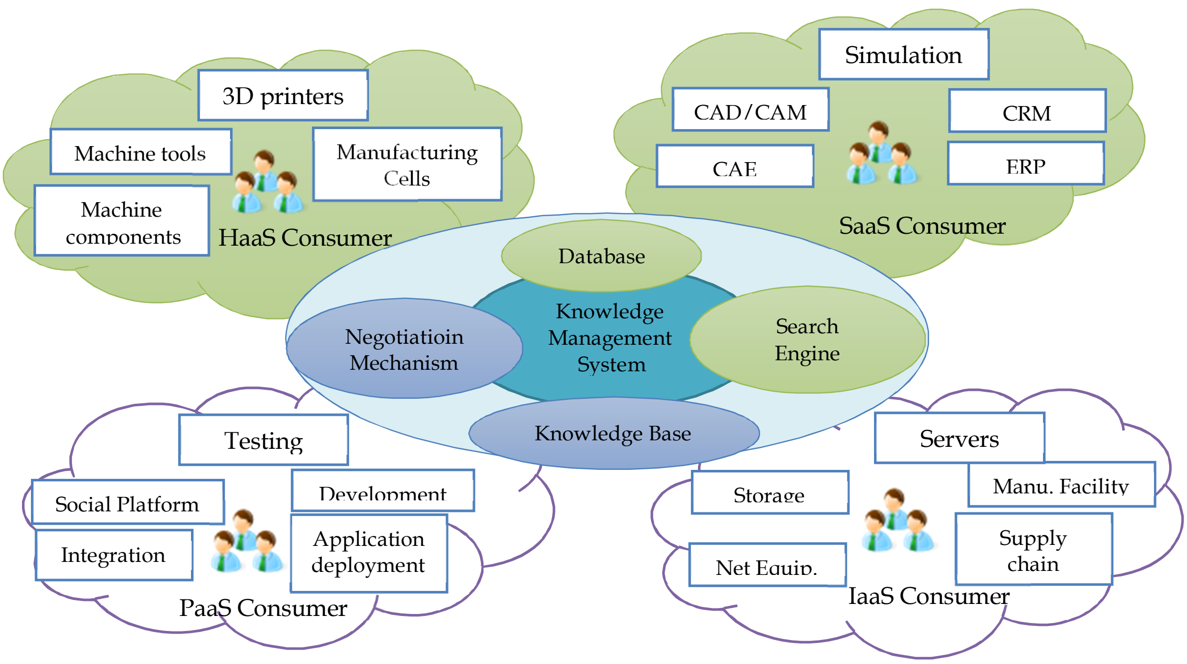


Figure 11 Services of ASforSW

In the first stage of the platform, Knowledge Management System includes Search Engine and Database two main components. SW Company partners manage their services and resources information in Administration Portal. Manufacturing enterprises through a search engine to find suitable services or resources provided by SW Company partners, which allow enterprises to search for potential partners, evaluate and select partners, and final to establish a collaboration with them. In the search partner and resources process, the ASforSW portal or platform serves as an electronic marketplace for manufacturing enterprises to initiate contact with potential suppliers or partners coming from a particular sector.

SW Company partners that intends to provide service or resources should publish their offers first through the Administration Portal. For publishing information, all types of information, such as text, pictures, animations and videos concerning an enterprise are allowed on ASforSW. Manufacturing enterprise users can search potential partners with search criteria on either Web Portal or via a SW Company embedded application refer to following Figure 12. And Figure 13 shows the publish information of partners matched with the search criteria are listed in Web Portal side.

Figure 12 ASforSW embedded application interface

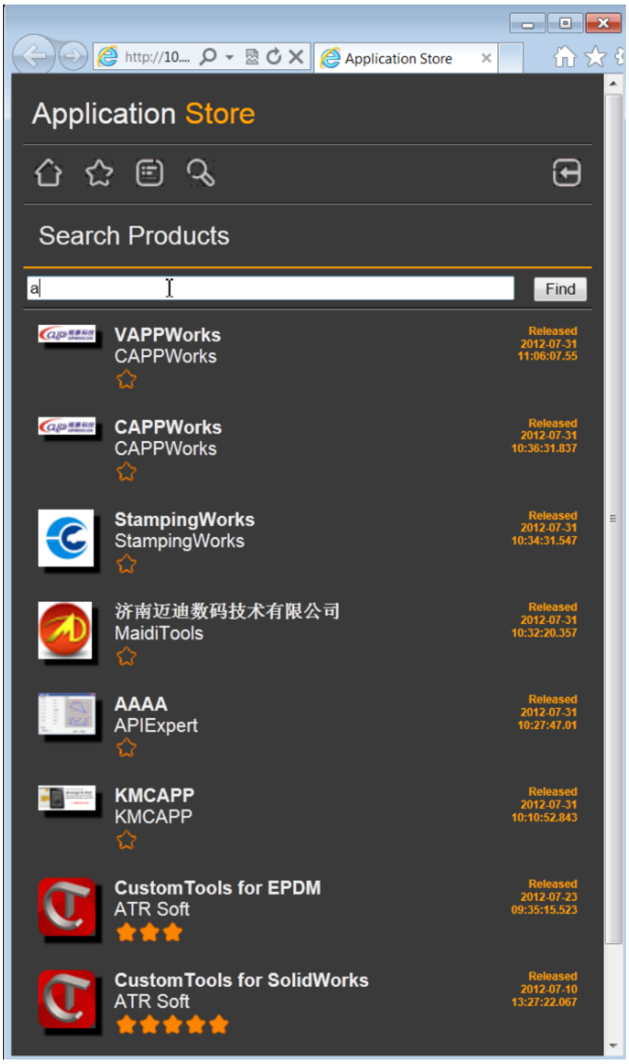


Figure 13 ASforSW Web Portal interface with some search result

The architecture of the ASforSW platform is shown in Figure 14. The platform has three key components in Resource Unit. They are: 1) Search Engine & Resource Pool component deals with searching of services or resources and resource management. All the software, hardware, services and partners’ related information will be included in the product list, respectively. Using this components, both providers and consumers will obtain potential business opportunity. 2) Knowledge Base component help knowledge providers encapsulate and publish their design or manufacture knowledge as a service. This components consists of a collection of knowledge service pools, such as, experts’ service, design or manufacture related publishing service, design related lectures and certification relevant services, etc. As well the component include requirement management. 3) Trade Management component deals with the management of payment, complaints and rating for services or recourses. In the first phase of ASforSW only the Search Engine & Resource Pool component is developed.

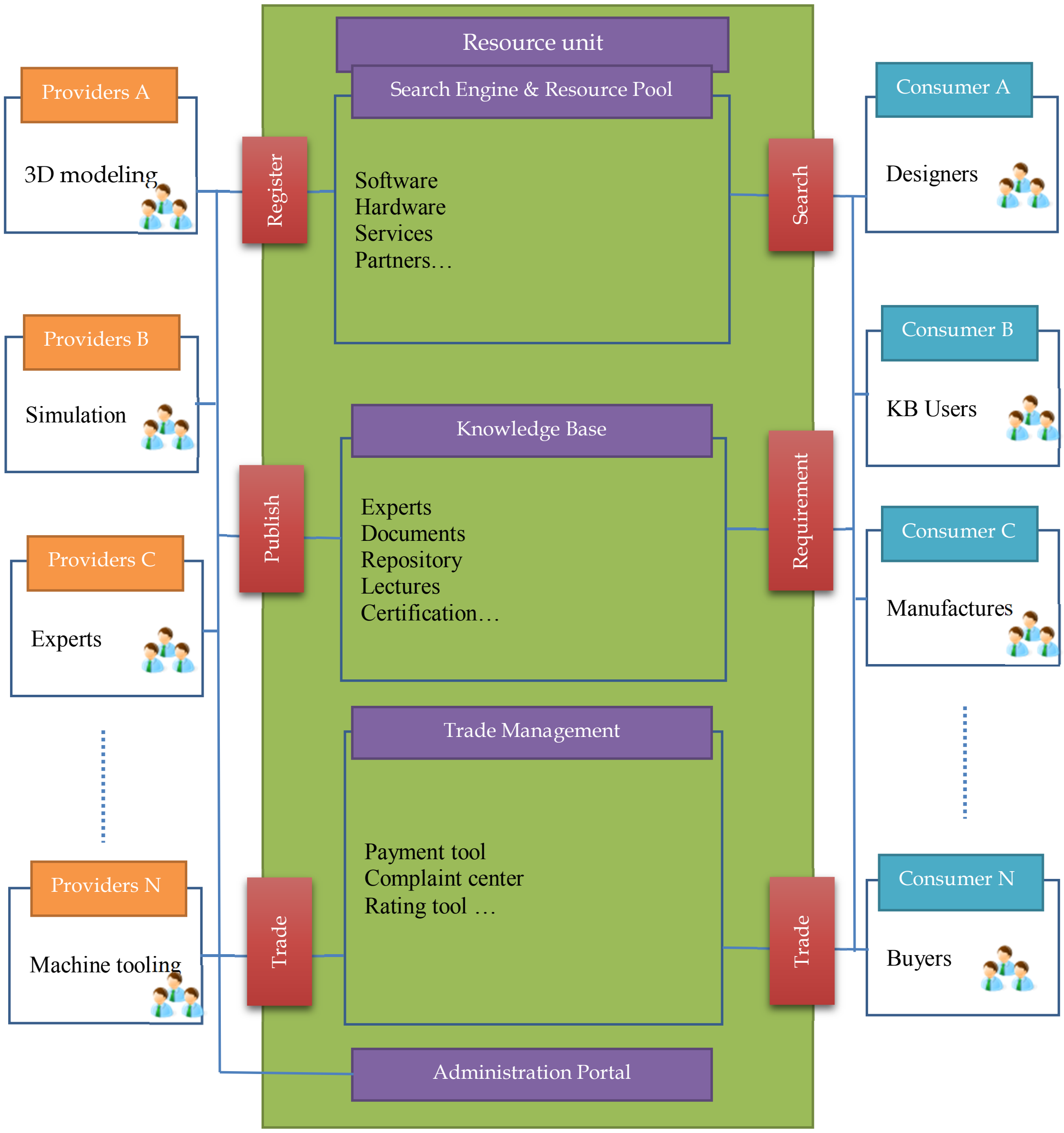


Figure 14 The architecture of ASforSW platform

Administration Portal is an independent site to manage registration of software, hardware, services and partners' related information for ASforSW platform. An Administration Portal interface example is shown in Figure 15.

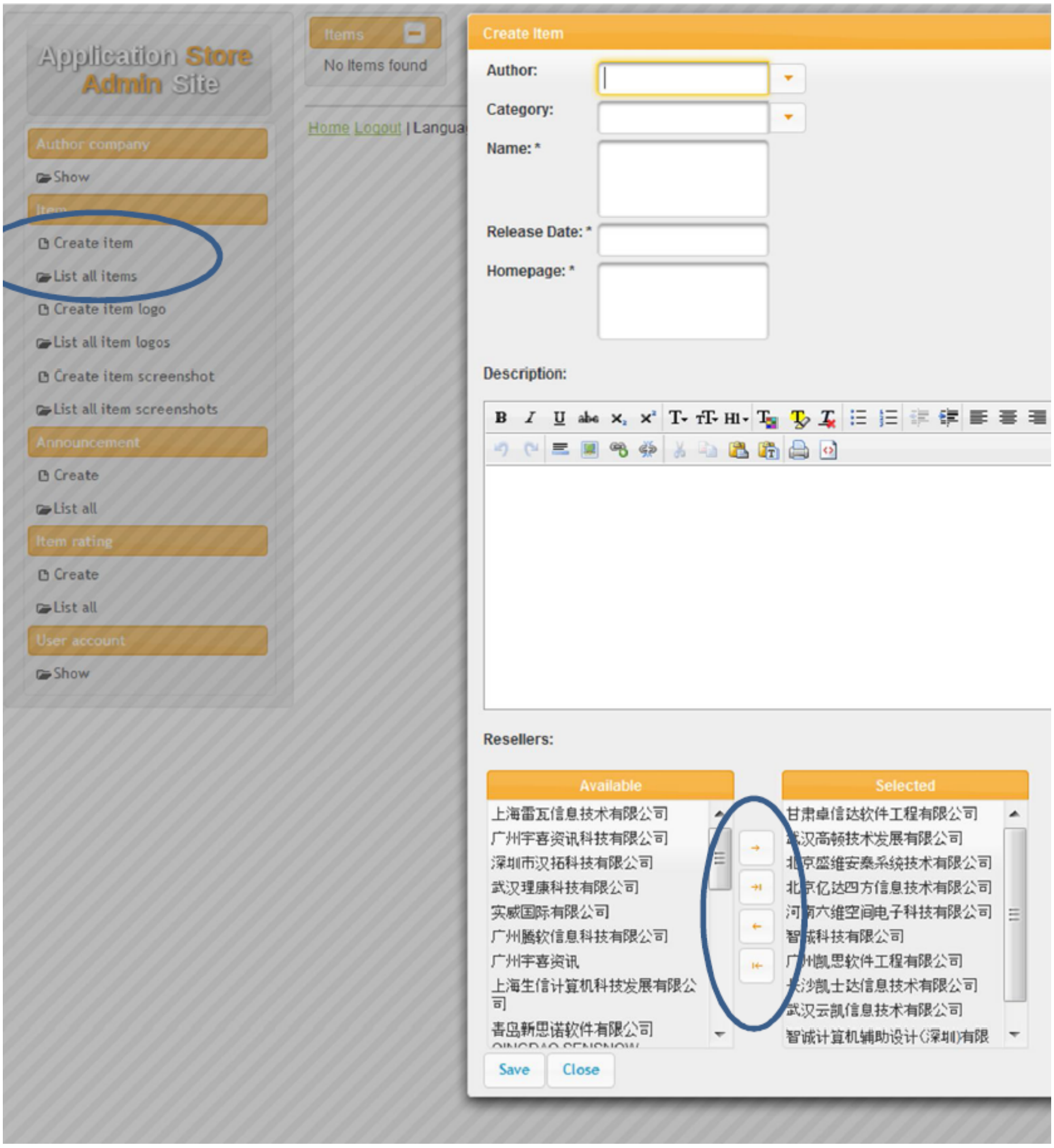


Figure 15 Administration Portal interface for ASforSW

Next an ontology based modeling approach is proposed to represent the service or resource providers' service capacity. As shown in Table 2, the Author Company, Item, Announcement, Item rating and User account compose the ontologies of resource unit, and each ontology consist of one or more attributes. For instance, the Item ontology has the attribute of author, category, name, release date and description, etc., and all the attribute have determined description. Using the Item ontology, the basic information of service or product will be presented and ready for being discovered in the Search Engine & Resource Pool component. Suppose a provider can offer more than one kind of service or resource, such as design related software and simulation related software or different hardware machine tooling service.

Table 2 Ontology based modeling of resource providers' service capacity

Vendor	Ontology	Attributes	Description
Service providers	Author	Name	Providers' name
		Email	Providers' contact information
		Homepage	Providers' official webpage
	Item	Author	Product or service's provider info
		Category	Service or Product's type, e.g. Software, Hardware, Service, Repository, etc.
		Name	Service or Product's name
		Release Date	Official release or publish date
		Homepage	Product or service's webpage
		Description	Describes the product or service's functions and how to use the service object, etc.
		Resellers	Tell product or service resellers
		Item Logo	Provider or product logo, *.png file
		Screenshot	Some screenshot of product
	Announcement	Item	Service or Product's name
		Date	Publish date
		Title	Subject of the announcement
		Content	Describe the details of the note
	Item Rating	Item Name	Service or Product's name
		Score	Rating service or product 1-5 stars
		Date	Rating date
		Comment	Feedback for the product or service
		Signature	Consumer's name
	User account	First name	Admin Site user's first name
		Last name	Admin Site user's last name
		Password	Admin Site user's password

4.3 Data collection

Data collection is an important phase of any research study. Inaccurate data collection can impact the results of a study and finally lead to an invalid results. In this study data collection implements two sets of data: a quantitative method by using web statics analysis and qualitative data collected by conducting five informal conversational interviews. The goal of web analytics is to capture and analyses data on the use made websites, and gathered data can help evidence impact of platform such as Application Store for SW Company in terms of the reach and significance of the work. In another hand, informal conversational interview is type of interview may occur in an open-end ad hoc conversation, and the respondent may not know that an "interview" is taking place.

4.3.1 Qualitative data

In September 2012, Vincent Lu, the former Solution Partner Specialist of SW Company China office has collected all SW Company solution partners' contact information and informed each partner through email about ASforSW platform. Two web conferencing referred to as webinars were carried out separately on September 10, 2012 and on September 14, 2012 by Vincent Lu and the author. First webinar's main attendees are SW Company services and resources solution partners which has local office in China. And the second webinar was opened for all SW Company solution partners worldwide.

There are around 300 solution partners worldwide of SW Company, among them there were 41 solution partners has had representatives attended the two webinars. Until June 30, 2013 there are 32 partners have joined the ASforSW platform, this means these 32 companies has official account for ASforSW administration site and regularly use and add their services and products information into the system. Company A, B, C, D and E were selected out of these 32 SW Company solution partners for the study purpose, the main reason is they were very active in the two web conferences. Five informal conversational interview took place in the webinars. The interview questions were sent via email to company A, B, C, D and E on October 10, 2012, the author was able to obtain valuable data in the answers from these companies. Company A, D and E are from Europe, company C is from Japan and company B is from United State (Table 3).

Table 3 Company in the informal conversational interview

Company	Place/ Means	Interview partners	Answer by Date
Company A	Webinar & email	Person 1	October 11, 2012
Company B	Webinar & email	Person 2	October 17, 2012
Company C	Webinar & email	Person 3	October 19, 2012
Company D	Webinar & email	Person 4	October 25, 2012
Company E	Webinar & email	Person 5	October 26, 2012

4.3.2 Quantitative data

The tool used to collect necessary data is Google Analytics, which a service is provided by Google to generate and report real time statistics over a website's traffic. See an example of Google Analytics in Figure 16.

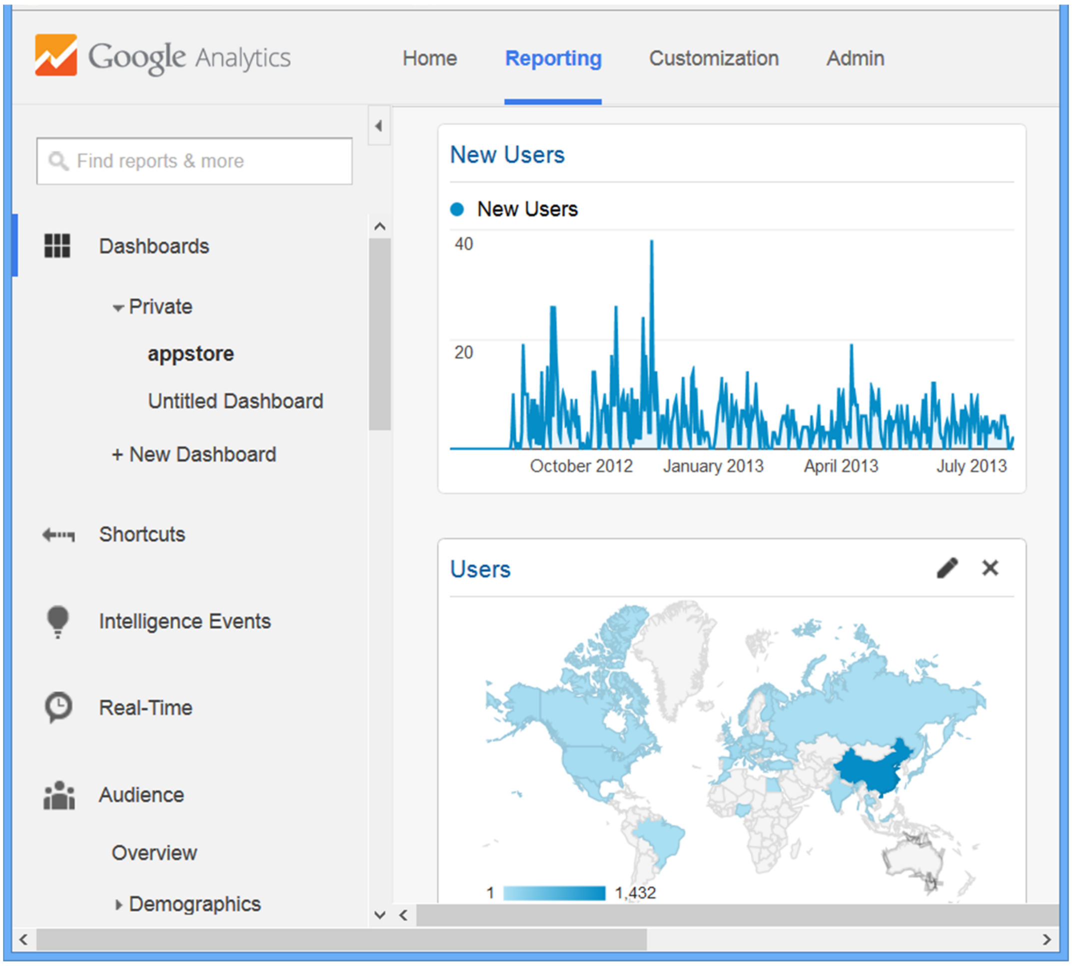


Figure 16 Google Analytics

The platform was published online since July 2012, and the project was pended after one year because of lacking of development resources. Under this condition, the most suitable date range of gathering data is from July 1, 2012 to June 30, 2013.

In order to describe the usage of Application Store for SW Company holistically, multiple dimensions and metrics are used to generate reports. The metric used for gathering data are Users, Visitors, and Sessions, Time on Page, Bounce Rate and Entrance / Page views. Metrics are the measurable values of attribute and it measure the data (Cutroni, 2014). Dimensions describe the data. They are the labels in the rows of the reports. In general, a dimension describe the "what," as in "what country is the visitor from" or "what pages were viewed". Dimension used for gathering data are User Type and Page in this study. Metrics were used in this study are listed in Table 4 with their brief definition and application according to Glossary of Metrics Used in Google Analytics.

Table 4 Metric list with definitions and applications

Metric	Definition	Application
Bounce	Bounce represents a Visit with only one Pageview. It doesn't matter how long the visitor was on the page or how they left.	Technically, it is a visit with only one interaction. Bounce Rate= Total Bounces / Total Visits. Bounce Rate is the percentage of single-page Visits.
Entrance	Entrances represent the number of Visits that started on a specific Web page or group of Web pages.	Entrance is incremented on the first pageview hit of a session.
Pageviews	Pageviews is usually automatically generated and measures a user viewing a piece of content.	Pageviews is a page-level metric. It represents the total number of pages that visitor looked at on our site.
Session	A session is a group of interactions that take place on website within a time frame by default a session lasts 30 minutes.	When the analytics tool detects that the user is no longer active it will terminate the session and start a new one when the user becomes active. For example, a single session can contain multiple screen or page views, event, etc.
Time on Page	Time on Page represents the average amount of time, in seconds, a Visitor spends on a particular page.	Technically, it is the time between the start time of a given Pageview and the start time of the subsequent Pageview or Event.
User	User is identified using an anonymous number or a string of characters when a user first time is detected and sent to Google Analytics tool until the identifier is expired or deleted.	Google Analytics measure a cookie sent by a browser. If the browser open the desired webpage, one cookie will be detected and stored for further analysis.
User Type	User Type is a Boolean indicating if a user is new or returning.	Possible values are New Visitor and Returning Visitor.
Visitor	Visitor represent the number of actual people that visited our site.	Visitors are defined by a unique ID which stored in a visitor's cookies.

4.4 Data analysis

4.4.1 Analyzing the qualitative data

Creswell (2003) revealed that certain steps including several levels of analysis need to be followed in qualitative research in order to process from a specific to a general level. First, the data were organized and prepared for the analysis, which involved the transcription of interviews. Secondly, the researcher read through the whole set of the data in order to develop an understanding of the general sense of the acquired information. Next the contents of the interviews needed to be analyzed and coded. In this study, the interview questions and answers were sorted separately (see appendixes 1 and 2). Finally, outline the themes which cover the major findings of the study with interpreted descriptions.

First of all, five SW Company solution partners are all small-and-medium size companies. Thus, the cases represent a good basis for evaluating the companies' motivation to join such ASforSW platform. All of five companies thought the platform is important and necessary for them in order to easily entrance China market.

Second, their motives are same. Particularly attention is paid to the question, what the major concern about ASforSW platform. The answer from all five companies are similar. They care about what end-users see their contents, e.g. product or service information and images.

Third is concerning language or cultural differences. In general case, the final customer needs to be served in the local language. Among five interviewed companies, only C&G SYSTEMS has Chinese localized content in ASforSW platform. Two out of four companies have answered that they would need localization help in their content. It means 50% of the solution partners which did not have Chinese local office would like to translate their contents into Chinese language.

Final, it was stated in all companies' answers conformably that the biggest challenge in the ASforSW is the insufficient training to use the administration site, e.g. four out of five (80%) companies asked help to upload their content or images.

4.4.2 Analyzing the quantitative data

According to Creswell et al. (2007) quantitative approach most often uses statistical analyses for making deductions. Creswell and Plano Clark point out that data analysis include give generic phases. They are 1) Preparing the data for analysis, 2) Exploring the data, 3) Analyzing the data, 4) Representing the data analysis, and 5) Validating the data.

These phases were followed when analyzing the statistical data since in this study Application Store for SW Company is a web-based platform, so public engagement or knowledge transfer activity, the use made of the pages can provide an insight into the impact of the activity. The analysis reports provide information on the number and location of website visitors over a specified time period, which can be used to evidence reach. Metrics of Users, Visitors, and Sessions, Time on Page, Bounce Rate and Entrance / Pageviews are used to generate following reports on Google Analytics.

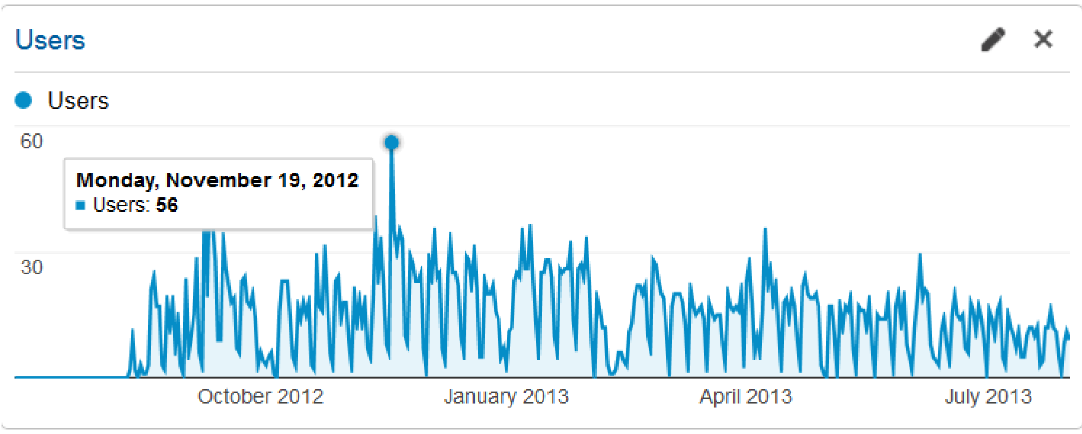


Figure 17 Users statistic report

The Figure 17 illustrates an overview of total users on each day during the defined date range. The peak value is obtained on November 19, 2012, the highest users number is 56.

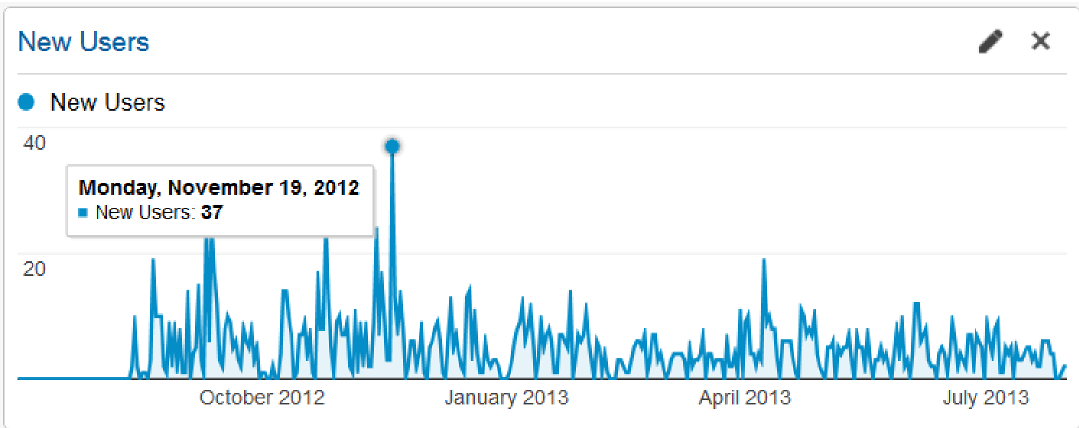


Figure 18 New Users report statistic report

The Figure 18 shows an overview of total new users on each day during the defined date range. A new user defined as who did not have Google Analytics cookies when they hit the first page in the visit, simply it is a first-time user. As same as in Figure 18 the highest new user's number is obtained on November 19, 2012.

Users by Country / Territory

Country / Territory	Users
China	1,432
France	99
Finland	68
India	60
United States	47
Germany	19
Hong Kong	14
Israel	8
United Kingdom	7
Brazil	6

Figure 19 Users by Country statistic report

The Figure 19 shows an overview of total users by country during the defined date range. The countries of website users, derived from IP addresses. Figure 19 shows most of visitors on ASforSW come from China. It is up to 81,3% of total visitors during the data collection period are Chinese consumers.

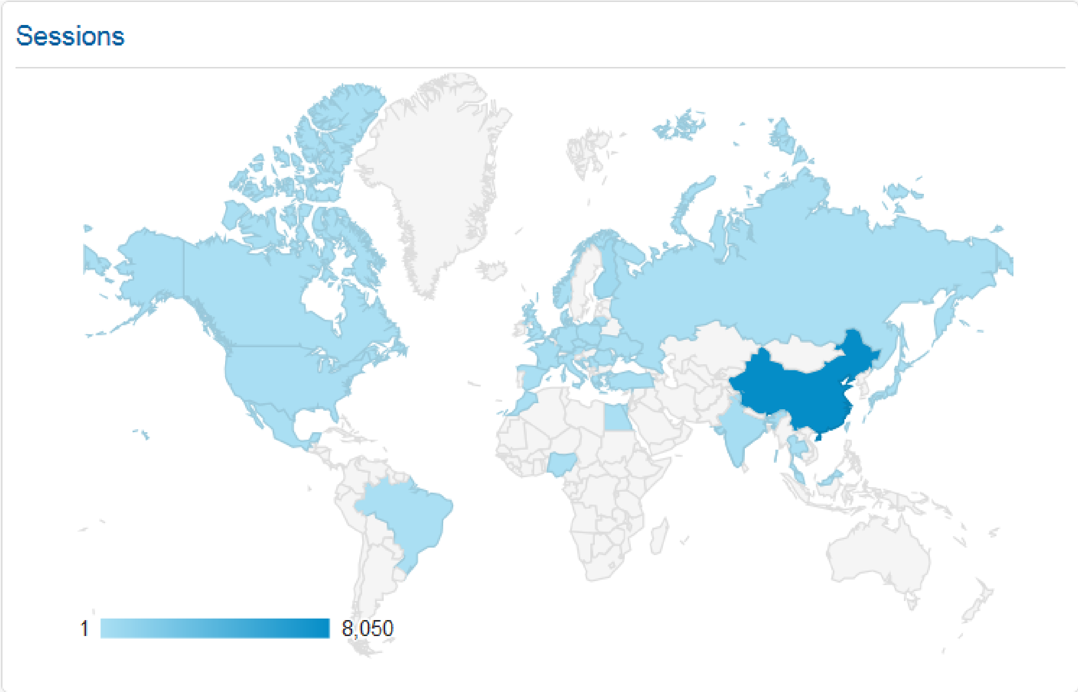
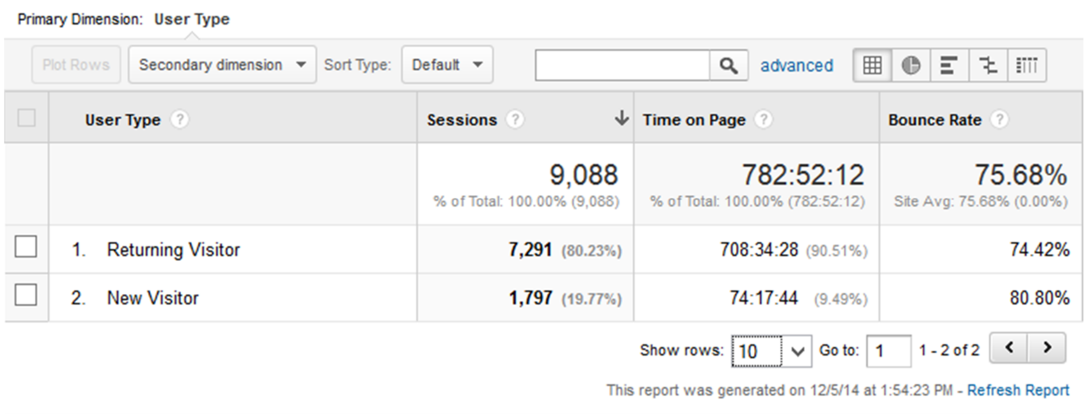


Figure 20 Sessions statistic report

When discussing the sessions Figure 20 above tracking data from individual countries, see how many sessions start in each sales regions. It illustrates the same result that most sessions started in China region.


Primary Dimension: User Type

Plot Rows | Secondary dimension | Sort Type: Default | advanced

User Type	Sessions	Time on Page	Bounce Rate
	9,088 % of Total: 100.00% (9,088)	782:52:12 % of Total: 100.00% (782:52:12)	75.68% Site Avg: 75.68% (0.00%)
1. Returning Visitor	7,291 (80.23%)	708:34:28 (90.51%)	74.42%
2. New Visitor	1,797 (19.77%)	74:17:44 (9.49%)	80.80%

Show rows: 10 Go to: 1 1 - 2 of 2

This report was generated on 12/5/14 at 1:54:23 PM - Refresh Report

Figure 21 User Behavior Report

Returning Visitor is measured as a visitor with existing Google Analytics cookies from a previous visit, in another word, returning visitors are not first-time visitors. Combining the result from above Figure 21 and following Figure 22, total of 82,2% of visitors are returning visitors. The result illustrates that some feature or services are attractive for most of ASforSW users.

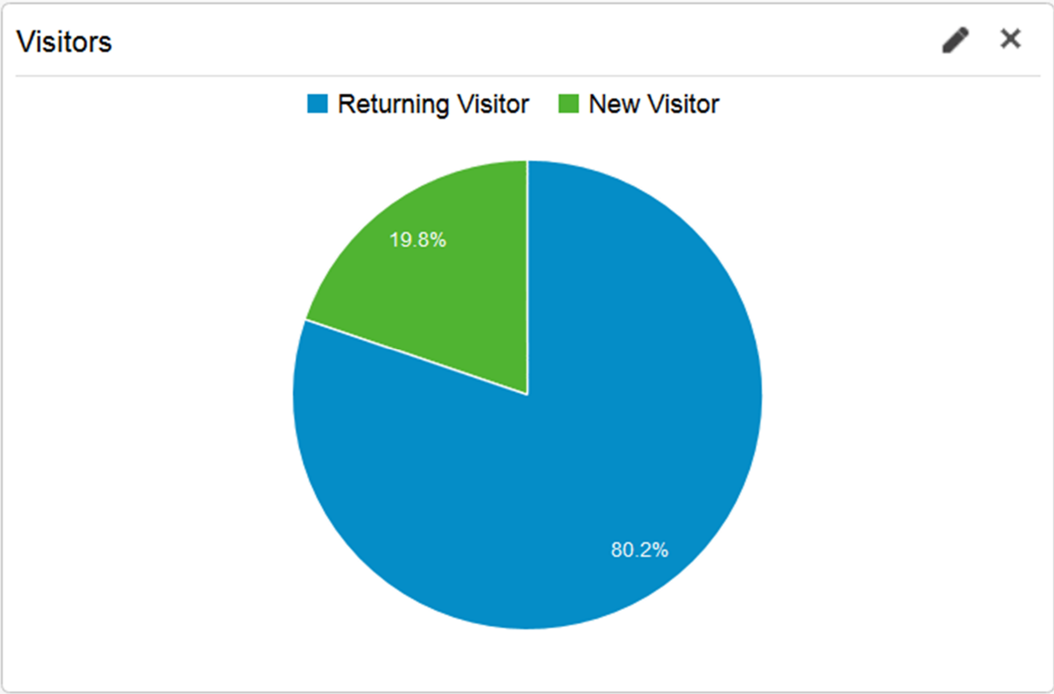
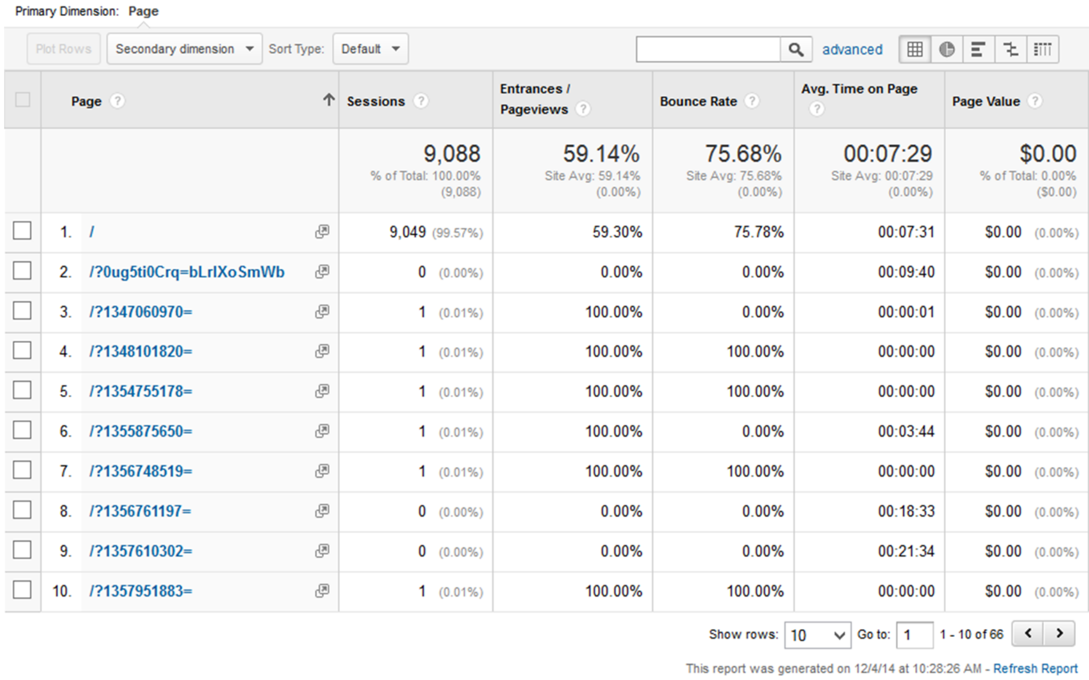


Figure 22 Returning visitor rate report

For Returning Visitor, the Bounce Rate is 74,42% and for New Visitor is 80,80%. Bounce Rate is the percentage of single-page sessions, for example, a person left the web site from the entrance page without interacting with the page. There are many reason that contribute to a high bounce rate. Such as, users might leave the web site from the entrance page if there are site design or usability issues. In another hand, users might also leave the site after viewing a single page if they've found the information they needed on the one page, and had no interest in going to other pages. Quite often Bounce Rate was used to tell if the right consumers coming to webpage and if the content are meeting their expectations. Bounce Rate for Visitors tells New Visitor is more often only view one page on ASforSW site than those Returning Visitor. Bounce Rate will be explained more in next paragraph.



Primary Dimension: Page

Plot Rows | Secondary dimension | Sort Type: Default | advanced

	Page	Sessions	Entrances / Pageviews	Bounce Rate	Avg. Time on Page	Page Value
		9,088 % of Total: 100.00% (9,088)	59.14% Site Avg: 59.14% (0.00%)	75.68% Site Avg: 75.68% (0.00%)	00:07:29 Site Avg: 00:07:29 (0.00%)	$0.00 % of Total: 0.00% ($0.00)
1.	/	9,049 (99.57%)	59.30%	75.78%	00:07:31	$0.00 (0.00%)
2.	/?0ug5ti0Crq=bLrlXoSmWb	0 (0.00%)	0.00%	0.00%	00:09:40	$0.00 (0.00%)
3.	/?1347060970=	1 (0.01%)	100.00%	0.00%	00:00:01	$0.00 (0.00%)
4.	/?1348101820=	1 (0.01%)	100.00%	100.00%	00:00:00	$0.00 (0.00%)
5.	/?1354755178=	1 (0.01%)	100.00%	100.00%	00:00:00	$0.00 (0.00%)
6.	/?1355875650=	1 (0.01%)	100.00%	0.00%	00:03:44	$0.00 (0.00%)
7.	/?1356748519=	1 (0.01%)	100.00%	100.00%	00:00:00	$0.00 (0.00%)
8.	/?1356761197=	0 (0.00%)	0.00%	0.00%	00:18:33	$0.00 (0.00%)
9.	/?1357610302=	0 (0.00%)	0.00%	0.00%	00:21:34	$0.00 (0.00%)
10.	/?1357951883=	1 (0.01%)	100.00%	100.00%	00:00:00	$0.00 (0.00%)

Show rows: 10 Go to: 1 1 - 10 of 66

This report was generated on 12/4/14 at 10:28:26 AM - Refresh Report

Figure 23 Landing Pages Analysis report

This Figure 23 shows some Visitor behavior on the first page it encounters on the site, which is a landing page. Landing page means the first page in a user's session (Kaushik, 2010). From the report can be seen that root page of ASforSW has been most of time became a landing page.

The total Pageviews for the root page can be calculated as (Kelly, 2012): Pageviews = Session ÷ (Entrance/Pageviews) = 9049 ÷ 59,30% ≈ 15260

In Figure 23, Bounce rate 75,78% only applies to visit entrances which was a total of 9049. It means 75,78% of 9049 is 6857 (9049×75,78% ≈ 6857) visits out of the total 15260 pageviews are bounced. The total bounce rate for the root page of ASforSW (landing page) is 6857 ÷ 15269 ≈ 44,9%. In details, this percentage means 44,9% of visitors that viewed only this page, and did nothing else. This value compares to the average website bounce rate 40% (Kelly, 2012) has slight up, this might give a sign that content of ASforSW should be concerned or improved.

5 DISCUSSION, LIMMITATION AND FUTURE RESEARCH

5.1 Discussion and Limitations

This research found that ASforSW, the prototype of cloud manufacturing, has positive impacts between service or resource providers and manufacturing enterprise users. The qualitative study reveals that the need for cloud manufacturing application is strong. All case companies agreed on that ASforSW platform could facilitate their businesses and felt that an implementation of such platform would benefit them by accessing end user easily. Also, the quantitative study reveals that end users are keen of using ASforSW platform to discover more shared resources. All of these study results from the case study are also answers to the major research questions of this study. The research questions are: what are the main motivations and impacts of applying cloud manufacturing system, and what are the new challenges derived from cloud manufacturing.

In all researches, there are limitations. The functionality of ASforSW platform is limited at the first stage of release. The main reason came from insufficiency of the platform development resources. At the first stage of the platform, only the Search Engine and Resource Pool component was included from the architecture point of view. The Knowledge Base component and Trade Management component considered core components for ASforSW are still missing. However, a measure of success for content sites is not necessarily whether the users bounce or not, but whether or not they read the article and more importantly come back. From data of the case study, the loyalty of users for ASforSW platform is obtained because the Returning visitors' rate is as high as 80,2%.

From the content point of view, the services and manufacturing resources offered on the platform are far from enough at this stage, since at the end of the data collection date only 13,6% of SW Company service or solution partners has joined to the ASforSW. Furthermore, SW Company is only one brand of CAD and CAM engineering design software. However, the qualitative study result shows that the current service and resource providers are all interested in ASforSW, and they treat such a platform as a good and important approach to their end users, that is, manufacturing enterprises.

From a cloud computing perspective, the early state ASforSW platform is missing two essential characteristics of cloud computing: multi-tenancy and the virtualization. According to Wu et al. (2014) the multi-tenancy enables a single instance of application software to be shared by multiple users or tenants. ASforSW is lacking such component to manage and map solution providers with their demands at this stage. At the moment the search engine of ASforSW does not have function of a query server that delivers results of a search query to users based on specifications such as expected prices and quality levels. The services and resources on ASforSW are stored at designated server, and users know where they are as well who is providing them. In short, ASforSW does not utilize virtualization for sharing resources yet. In future ASforSW platform, the data should be stored not only in ATR Soft Oy's server but also in virtualized data centers to make the resource more virtualized. The virtualized data centers are generally hosted by third parties. In such way users may neither know who service or resource providers are nor where data are stored.

From a management perspective, the ASforSW platform does not have clear defined business models. For cloud manufacturing the business models include following three considerations according to Wu et al. (2014). First, how the design and manufacturing services or resources can be delivered; this will go through whole cloud manufacturing service structure, e.g. IaaS, PaaS, SaaS and Haas/ MFGaaS. Second, how the services can be deployed on cloud; here three type of cloud deployment as private cloud, public cloud and hybrid cloud should be analyzed carefully, since ASforSW could use the mix cloud deployment in practice. Third, how the services can be paid by consumers and providers; this particular prospect business model will be discovered more in next Section 5.2.

ASforSW has already included the core conceptual model of a cloud manufacturing, such as users, web portals, applications, service and resources, however manufacturing processes part is missing, which links product designs to associated manufacturing processes. At this stage, the web portal provides a centralized interface which service and resource provider can communicate with their consumers. The web portal includes web-based user interfaces, content database, authentication module (administration site) and account management, etc. It would have been more suitable to study the complete ASforSW platform, because then the results would have been more extensively.

5.2 Future research possibilities

From theoretical literature studies to the case study the focus are mainly on cloud manufacturing resource allocation and deployment. More attentions need to be paid on business model and work flow. According to Wu et al. (2013) an efficient business model is the argument to why the cloud manufacturing paradigm will succeed. Business model explains critical things such as who the customers are, why they would like to use such cloud manufacturing environment, how service and resources providers are going to add value to the system, and how they would make business succeed. For instance, Shapeways business model is a good example for manufacturing industry (Wirth et al, 2014). Shapeways business model is operating two models within one company. On the one hand, Shapeways operates a large number of 3D printers and acts as a 3D printing service provider. Customers can manufacture their own design to physical objects. On the other hand, Shapeways is an online platform for 3D content, on which objects are modelled by a large community of designers who sell their designs. However, the appropriate business model for cloud manufacturing field might not be easy to determine when the cloud manufacturing system is collaborated between numerous parties. Traditional business models are often firmly defined, but in cloud manufacturing environment all collaboration between service or resources partners will build up a complete business model. It is very possible that cloud manufacturing will require multi- business models to operate.

In the case study ASforSW platform is a prototype of cloud manufacturing environment. For ASforSW to be implemented on a wide spread basis it must have a feasible business model, in which all parties like users, service and resource providers, and cloud computing providers etc., must benefit from the system. What could be appropriate business model for the ASforSW platform? The following business models would be considered: the Advertising model, the Affiliate model, the Direct Sales model, the Subscription model and the Pay as You Go model.

According to Osterwalder et al. (2010) the Advertising model is well known business model for Internet businesses to derive revenue as a result of being able to offer advertisers access to highly target customers. Since ASforSW's main target consumers are manufacturing enterprises, manufacturing service and resource providers would use this platform to attract audience to know their products or services.

The Affiliate model is simply someone who helps to sell a product in return for commission. This model will very well fit to ASforSW, because the service and resource providers do not direct contact with end users in most of time, instead a reseller who will never take ownership of the service or resource make a sale (Osterwalder et al., 2010).

The Direct Sales model is fit into the platform operation when Trade Management of ASforSW would be deployed. This business model became more efficient since the emergence of the Internet. Internet as a distribution channel meant that service or resources providers will not need any more costly resellers and sell direct to customers themselves (Osterwalder et al., 2010). A good example of Direct Sales model is the PC manufacturer Dell.

Osterwalder et al. (2010) also states that the Subscription model is to secure the service and resource providers on a long term contract so that they are consuming ASforSW service to make their business succeed. Most Internet service like SaaS service provider operates under this model.

The Pay as You Go model is to measure service actual usage and consumer will pay on the amount of what one consumes. This model is especially well used by cloud computing IaaS service provider (Ogunmefun, 2011).

Taking into notion the very limited commercial example of cloud manufacturing system, this research assumes that the above five business models can be operated altogether in ASforSW platform and applied by different parties. The number of research within business model area for cloud manufacturing is limited. Feasible business model for cloud manufacturing is still undetermined, there are many future work need to be done in this area. In this study, defining business model for cloud manufacturing is considered as a big challenge.

Meanwhile there are many other challenges that need to be investigated in the future for cloud manufacturing paradigm. For example, there are lack of standards and criteria to implement such system, undetermined regulation at the personal, enterprise, local national and international level, as well cloud computing safety and security issues should be addressed as always (Wu, 2013).

6 CONCLUSION

A cloud computing and service-oriented manufacturing model called cloud manufacturing has emerged as a promising paradigm for future manufacturing industry. Early research on cloud manufacturing has been reported. Cloud manufacturing consists of cloud computing, IoT, advanced manufacturing technologies, virtualization and service-oriented technologies. This concept is proposed in order to enhance resource sharing and reduce resource consumption, and on-demand use of manufacturing resource and capacity to speed up the transformation from production-oriented manufacturing to service-oriented manufacturing. The purpose of this research has been to represent the transformation from cloud computing to cloud manufacturing, and understand the motivation and impacts of cloud manufacturing. The concept, architecture, core enabling advanced manufacturing technologies, typical characteristics and advantages for cloud manufacturing have been discussed. The research is based on mixed qualitative and quantitative methods, and a case study. The case is a prototype of cloud manufacturing, which is software platform cooperated by ATR Soft Oy and SW Company's China office.

The major finding of the research is that traditional manufacturing becomes distributed manufacturing. It developed from product-oriented to service-oriented industry through the transformation from cloud computing to cloud manufacturing. It seems that cloud manufacturing would be the next generation of manufacturing because it enhances resource utilization and reduces resource consumption by sharing manufacturing resources and capabilities. In the future, cloud manufacturing will impact manufacturing industry in many perspectives. For example, the benefits of cloud manufacturing on engineering level are ubiquitous access to design service and resource and more collaborative design works. For manufacturing perspective, the benefits of cloud manufacturing are improved service and resource sharing, speeded up production and reduced cost. For marketing perspective, the benefits of cloud manufacturing are reduced time-to-market, improved service and user experience. These findings are answers for the major research questions of the thesis. The major research questions are what are the main motivations and impacts of applying cloud manufacturing system, and also the new challenges derived from cloud manufacturing.

However, the related theory, methodology and commercial application of cloud manufacturing system are far from maturity. Thus it is still an open field where many new technologies and issues need to be studied. This research pointed out also some general challenging issues for future research on cloud manufacturing. For instance, the business model area is a big challenging area for cloud manufacturing and it should be studied further. In addition, further related research could consider like standards and regulation, security and privacy challenging area for cloud manufacturing.

REFERENCES

Atzori, L. – Lera, A. – Morabito, G. (2010). The Internet of Things: A Survey. *Computer Networks.* Vol. 54(15), 2787-2805.

Bandyopadhyay, D. – Sen, J. (2011) Intenet of Things: Applications and challenges in technology and standardization. *Wireless Personal Communications*. Vol. 58(1), 49-69.

Baxter, P. – Jack, S. (2008) Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report*, Vol. 13(4), 544-559.

Brown, A. – Johnston, Simon. – Kelly, K. (2002) Using Service-Oriented Architecture and Component Based Development to Build Web Service Applications. *A Rational Software White Paper.*

Cai, M. – Zhang, W.Y. – Chen, G. – Zhang, K. – Li, S.T. SWMRD: a Semantic Web-based manufacturing resource discovery system for cross-enterprise collaboration. *International Journal of Production Research*. Vol. 48(12), 3445-3460.

Chituc, C.-M. – Restivo, F.J. (2009) Challenges and Trends in Distributed Manufacturing Systems: Are wise engineering systems the ultimate answer? *Second International Symposium on Engineering Systems, MIT*.

Columbus, L. (2013) 10 Ways Cloud Computing Is Revolutionizing Manufacturing. Forbes. Internet WWW page, at URL: http://www.forbes.com/sites/louiscolumbus/2013/05/06/ten-ways-cloud-computing-is-revolutionizing-manufacturing/ .

Creswell, J.W. (2003) Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 2nd edition, *Sage*.

Creswell, J.W. – Plano Clark, V.L. –Gutmann, M.L. – Hanson, W.E. (2003). Advanced Mixed Methods Research Designs. *Tashakkori, A. & Teddlie, C. (2003 Edition) Handbook of mixed methods in social and behavioral research. Thousand Oaks, CA:Sage.* (pp. 209-240).

Creswell, J.W. –Plano Clark, V.L. (2007) Designing and Conducting Mixed Methods Rsearch. *SAGE Pulication Inc, California*.

Cutroni, J. (2014) Hit, Sessions & Users: Understanding Digital Analytics Data. Internet WWW page, at URL: http://cutroni.com/blog/2014/02/05/understanding-digital-analytics-data/ .

Erl, T. (2004) Service-Oriented Architecture: A Field Guide to Integrating XML and Web Service. *Prentice Hall.* ISBN: 0-13-1428898-5.

Fan, Y. – Huang, C. – Wang, Y. – Zhang, L. (2005) Architecture and operational mechanisms of networked manufacturing integrated platform. *International Journal of Production Research*. Vol. 43(12), 2615-2629.

Green, J. – Bricki, N. (2007) A Guide to Using Qualitative Research Methodology, Medecins Sans Frontieres Field Rsearch.

Gubbi, J. – Buyya, R. – Marusic, S. – Palaniswami, M. (2013) Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*. Vol. 29(7), 1645-1660.

Hennink, M. – Hutter, I. – Bailey, A. (2011) Qualitative Research Mehtods. *SAGE Publication Ltd.* ISBN: 978-1-4129-2225 -8.

INFSO D.4 Networked Enterprise and RFID INFSO G.2 Micro and Nanosystems. (2008) Internet of Things in 2020, Roadmap for the Future. Version 1.1.

Kaushik, A. (2010) Occam's razor. 3 Awesome, downloadable, custom web analytics reports. Internet WWW page, at URL: http://www.kaushik.net/avinash/best-downloadable-custom-web-analytics-reports.

Kelly, K. (2012) What is bounce rate? Avoid common pitfalls. Internet WWW page, at URL: http://www.blastam.com/blog/index.php/2012/02/what-is-bounce-rate.

Li, B. – Zhang, L. – Wang, S. − Tao, F. – Cao, J. – Jiang, X. – Song, X. – Chai, X. (2010) Cloud manufacturing: a new service-oriented networked manufacturing model, *Computer Integrated Manufacturing Systems*, Vol. 16(1), 1-7.

Mell, P. – Grance, T. (2011) The NIST Definition of Cloud Computing. Special Publication 800-145.

Ogunmefun, T. (2011) Effective Data Protection for Cloud Computing and its Relevance in the Nigeria Economy. *Toyin Ogunmefun's space*. Internet WWW page, at URL: https://toyinogunmefun.wordpress.com/2011/06/16/effective-data-protection-for-cloud-computing-and-its-relevance-in-the-nigeria-economy/

Osterwalder, A. – Pigneur, Y. (2010) Business Model Generation. *John Wiley & Sons, Inc.* ISBN: 978-0470-87641-1.

Raines, G. (2009) Cloud Computing and SOA. *The MIRTE Corportation*. Case Number: 09-0743. Document Number: MTR090026.

Ren, L. – Zhang, L. – Wang, L. – Tao, F. – Chai, X. (2014) Cloud manufacturing: key characteristics and applications. *International Journal of Computer Integrated Manufacturing*, Vol. 0 (0), 1-15.

Tao, F. – Zhang, L. – Hu, Y. (2012) Resource Service Management in Manufacturing Grid System. ISBN: 978-1-118-12231-0.

Tao, F. – Zhang, L. – Venkatesh V.C. – Luo, Y. – Cheng, Y. (2011) Cloud manufacturing: a computing and service oriented manufacturing model. *Journal of Engineering Manufacture.* Vol. 255(10), 1969-1976.

Tata Consultancy Service (TCS 2012) The State of Cloud Application Adoption in Large Enterprise.

Trochim, W.M. (2006) The Research Methods Knowledge Base. 2nd Edition. Internet WWW page, at URL: http://www.socialresearchmethods.net/kb/.

V.Nandgaonkar, S. – Prof. A.B.Raut. (2014) A Comprehensive Study on Cloud Computing. *International Journal of Computer Science and Mobile Computing*, Vol. 3(4), 733-738.

Valihai, O.F. – Houshmand, M. (2014) Aplatform for optimization in distributed manufacturing enterprises based on cloud manufacturing paradigm. *International Journal of Computer Integrated Manufacturing,* Vol. 27(11), 1031-1054.

Wirth, M. – Thiesse, F. (2014) Shapeways and the 3D printing revolution. *Twenty Second European Conference on Information System, Tel Aviv*.

Wu, D. – Greer, M.J. – W.Rosen, D. – Schaefer, D. (2013) Cloud manufacturing: Strategic vision and state-of-the-art. Journal of Manufacturing System. Vol. 5(32), 564-579.

Wu, D. – W. Rosen, D. – Schaefer D. (2014) Cloud-Based Design and Manufacturing (CBDM), ©*Springer International Publishing Switzerland*, ISBN 978-3-319-07397-2.

Xu, X. (2012) From cloud computing to cloud manufacturing. *Robotics and Computer-Integrated Manufacturing*. Vol. 28(1), 75-86.

Yin, R. (2003) Case Study Research Design and Methods, *Sage Publications*, Thousand Oaks.

Zhang, L. − Luo, Y. − Tao, F. − Li, B.H. − Ren, L. – Zhang, X. − Guo, H. − Cheng, Y. – Hu, A. – Liu, Y. (2012) Cloud manufacturing: a new manufacturing paradigm, *Enterprise Information Systems*, Vol. 8(2), 167-187.

APPENDIXES

APPENDIX 1 Interview Questions

1. Do you company see ASforSW platform offers an opportunity to access end users?
2. Is your company interested join to ASforSw platform?
3. What is your major concern regarding ASforSW platform?
4. Do you have localization issue for your content in ASforSW platform?
5. What are the major challenges to utilize ASforSW platform?

APPENDIX 2 Answer of interviewee

Questions \ Company	Company A	Company B	Company C	Company D	Company E
Do you company see ASforSW platform offers an opportunity to access end users?	Yes	Yes	Yes	Yes	Yes
Is your company interested join to ASforSw platform?	Yes	Yes	Yes	Yes	Yes
What is your major concern regarding ASforSW platform?	How output looks like for users?	Our product is not localized.	Is the platform free of charge?		
Do you have localization issue for your content in ASforSW platform?	No	Yes	No, we have content in Chinese.	Yes	No
What are the major challenges to utilize ASforSW platform?	Could not upload content correctly.	Need content in Chinese.	How to change content and logo.	Modified Logo does not appear correctly	Need a good guide.