Cloud Computing in Industries: A Review

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Abstract Cloud computing is a new paradigm with a lot of promise. This paper provides a glimpse of how far this technology has come in implementation in industries and what the future holds. The basic concepts of cloud computing and its features have been explained here. A wide variety of industries have been considered. With everything being connected, industries are not far behind. This paper attempts to answer the question whether cloud computing can make industries more interconnected. A survey of 29 papers was carried out with focus on implementation in industries. Some aspects of computer science have also been discussed.

Keywords Cloud computing · Industry 4.0 · Compatibility · Frameworks

1 Introduction

The birth of the industrial revolution was due to the advancement of non-human powered machines. Then came the concept of mass production of goods and services in every sector. Later with the development of computer technology, computer-controlled machines were created improving efficiency even further. Production was becoming more interdisciplinary. Different fields of science and engineering were conceived to help operators work efficiently. As technologies developed in other fields, this also led to the growth of industries and vice versa. Industries are in the brink of a new revolution. A new generation of paradigms called Industry 4.0. With the advancement of computer and electro-mechanical technology, new ways of managing production have developed. Previously, networking could only be used via a local area network, but cloud computing allows resources to be controlled or monitored via the Internet. Cloud computing is classified into models based on the type of service [1]. They are namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS).

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IaaS: It is the base level of cloud computing generally used by system admins. Raw computing power is provided by the IaaS services. Examples are Rackspace.com, Amazon EC2, GoGrid.

PaaS: It is layer above IaaS generally used by developers. It is a platform which provides services such as operating systems, programming language execution environment, database, web server, etc. Examples are Google App Engine, Windows Azure, Heroku, force.com.

SaaS: It is the top layer of cloud computing generally used by end customers. The name might seem misleading, but the installation of software is always not necessary. It can be accessed through a web browser directly. Examples are Google Drive, Microsoft Office 365, salesforce.com.

2 Literature Review

Ramachandra et al. [2] have shown the key issues in cloud computing. The review has been done by taking into account parameters which are cloud architecture, deployment and delivery models. The vulnerabilities of the parameters have been identified, and countermeasures have also been proposed. The vulnerabilities need to be identified, and the concerned stakeholders need to take necessary steps and mitigate them. The implementation of cloud computing requires members from a third party with many layers. As the number of layers increases the points of attacks tend to increase, so security measures are needed to be taken in all the layers.

Alsmadi et al. [3] determine the gap between literature and industrial reports of cloud computing services (CCS) adoption. Six factors were identified from the literature which are performance expectancy (PE), effort expectancy (EE), peers influence (PI), facilitating conditions (FC), perceived security (PS) and perceived privacy (PP). PE, EE, PI, FC correlation was also done with respect to age. After analysis was done, the researchers found that PI was the most important factor, while PE, EE, FC, PS and PP had negligible effect on the adoption of CCS.

Pedone et al. [4] have highlighted the compatibility of Industrial Internet Reference Architecture (IIRC) and Reference Architectural Model Industrie (RAMI 4.0) frameworks. The frameworks were chosen as they are considered as the major standardization frameworks. They have also shown that the implementation of the above frameworks shows similarity to the Open Connectivity Unified Architecture. With the understanding of the aforementioned, an architecture of a prototype smart factory was made. In the cloud computing, space interoperability is important for its implementation in large scale. They concluded that better frameworks need to be devised for better compatibility of frameworks.

Wang et al. [5] have highlighted how the implementation of IoT and cloud computing decongests the bottlenecks in the enterprise systems (ES). This paper deals with the problems faced while generating assembly plans. The problems are expected to be mitigated by the use of IT. In conclusion, the architecture devised should be

modular, flexible which facilitates the reuse of old components, and the assembly planning should be done with the help of relational matrices.

As the growth of IT in industries grows, the interaction between man and machine, machine and machine, man and man has become more efficient. Tao et al. [6] have proposed a cloud computing and IoT-based manufacturing system CCIoT-CMfg and analysed their relationship. In conclusion they have the applications of IoT and CC in different levels of an organization, their advantages, the technological infrastructure needed for implementing these new technologies and the challenges faced while implementing these systems.

Yu et al. [7] have shown the emergence of cloud computing and information and communication technology (ICT) in China. In developing nations, ICT can be used to upgrade their old infrastructure. The adoption of these new technologies depends on a number of factors such as government support and business interest which by looking after their own interests increases the rate of adoption. The researchers highlight the need of having a consensus of what the government and the business want to achieve in order to work towards adoption of new technologies.

Dinita et al. [8] describe the various attributes of an autonomous virtual management system from the perspective of cloud computing. The researchers created a prototype where the following objectives were achieved to know the limitations of the network infrastructure, develop a strategy by which the entire system can manage the workload, show the systems benefits by develop metrics which measures carbon foot print, create an application that detects threats and other vulnerabilities and accordingly reacts. The main conclusion shown here is the less consumption of power of an autonomous virtual management system in cloud computing.

Botta et al. [9] focus on the unification of cloud computing and IoT. The CloudIoT paradigm has been studied in detail. The drivers of these technologies are accessibility, parts, processing capabilities, storage and big data. With the integration of cloud and IoT where the cloud fails, IoT compensates and vice versa. The CloudIoT paradigm can be used to benefit healthcare, make cities and communities smart, make homes smart and improve surveillance, intelligent transport systems. The challenges have also been shown namely security, performance, reliability, legal aspects and massive data processing. Fog computing seems to be next generation of cloud computing technologies which integrates IoT.

Du et al. [10] aim to combine robots and cloud computing. It was achieved by designing a robot cloud stack and the use of service-oriented architecture (SOA). Finally, simulation of the system was done. Three conclusions were drawn from the simulations. Robot cloud computing is a feasible technology, it can improve profits, and it is better to have one large robot controlling centre rather than having multiple robot centres managing small areas.

Fahmideh et al. [11] have proposed a framework for migrating legacy systems to cloud computing systems. The framework is based on evidence-based software engineering and goal-oriented modelling. An evidential repository of obstacles was used to test the system. The framework was corroborated by the use of Pivotal Cloud Foundry and Microsoft Azure cloud platform. The researchers stipulate that the repository used can be further improved by incorporating practical obstacles

faced while migrating. The framework can be used to test legacy systems whether migration is possible, is it cost effective, secure and are the performance goals met. Furthermore, the framework can be used for obstacles faced in future.

Givehchi et al. [12] give an overview of the industrial automation concepts through cloud computing. The present scenario and future scope have been highlighted. The researchers have hypothesized a framework with the help of literature survey. They point out that there is further need of integration of IT services, the need of a well-defined repository, a detailed investigation of the connected devices. This could be accomplished with the integration of cloud services.

Hofmann et al. [13] show the present state of cloud computing implementation. Cloud computing is the next paradigm shift of the technology in industries. Presently, it is easy for small start-ups to adopt clouding computing due to lack of complexity. As cloud computing is a new field where its implementation is not widespread there are a lot of unknowns these include technical limitations as well as competition from other IT services such as ERP. ERP is already a well-established service which has widespread use. This hinders the adoption of cloud services.

Marston et al. [14] have shown two perspectives, one for the information systems researchers and the other for the stakeholders. The advantages have been listed out, and as well as SWOT analysis has been carried out. The roles of the stakeholders, enablers, service providers and regulatory bodies have also been shown. Also, how should an organization approach the adoption of cloud computing be carried out has been highlighted.

Mezgár and Rauschecker [15] have shown what the future holds after cloud computing integration into industries. Manufacturing companies need to continuously evolve their system architectures of network enterprises (NE) for the changing demands of the market. Cloud computing seems to be the offers an insight of the problems faced by NEs. Also, a new scheme of classification has been proposed by taking into account interoperability and standardization issues. Based on the classifications, four use cases have been shown. A new approach has been devised, namely Manufacturing as a Service (MaaS) which increases network flexibility and helps in managing manufacturing services through a proprietary cloud connector with a few modifications. The researchers hypothesize based on their own work and present the literature connecting virtual enterprise (VE) and cloud computing show a lot of promise. Also, for this integration to be possible, the interoperability and portability issues need to be mitigated.

Nieuwenhuis et al. [16] have shown how all the parties of the business environment are affected by the adoption of cloud computing technologies. The change in the network of old enterprise model has also been shown here. Taking into consideration three case studies, literature and consulting experts, they have created a new network of enterprise model after integration of cloud. The conclusions that were drawn are the complexity involved for the customer is shifted to the vendor, as the complexity decreases, a standardized software emerges, customization of the software becomes limited, and new value-added services are needed to be developed instead.

Ooi et al. [17] have shown how variables such as performance expectancy (PE), effort expectancy (EE), firm size (FS), top management support (MS) and absorptive

capacity (AC) of cloud computing technology can lead to innovativeness (IN) and firm performance (FP) among the manufacturing firms of Malaysia. It is also shown how the implementation of cloud computing increases IN and FP. Comparison of their data with available literature was done. With the help of tools such as partial least squares-structural equation modelling-artificial neural network (PLS-SEM-ANN), a conceptual framework was developed. It was concluded that PE predicts IN, EE predicts PE, MS is important for EE, FS is vital for IN and EE. AC is the most important for the development of IN.

Shu et al. [18] have tried to enable technologies for Complex Industrial Applications (CIA) by combining Cyber-Physical Systems (CPS) with cloud computing. They have formed an architecture called cloud-integrated CPS (CCPS). They have also summarized the technologies that drive cloud computing adoption. Three problems were analysed, namely virtualized resource management techniques, scheduling of cloud resources for CIA and life cycle management (LCM), and suggestions were given to mitigate these problems.

Trigueros-Preciado et al. [19] focus on the gap between adoption and literature of cloud computing in Small and medium-sized enterprises (SMEs). The main focus is to identify the barriers and effects of the adoption of cloud computing in SMEs. Ignorance of the technology of cloud computing was identified as the main barrier, followed by security issues, distrust in transferring data to third parties, the managers not knowing how to measure the effect of cloud computing adoption, compliance with the laws and regulations. The effects of adoption of cloud computing include cost reduction for software, systems and IT specialists, pliability and expandable nature, and also, these SMEs cannot use other technologies that cloud computing provides.

Varghese and Buyya [20] highlight the latest developments of cloud computing technology. It seems that computer power is being decentralized. The processing power as well as the software seems to be heading to a decentralized architecture as it can be seen in the case of VM ware. This makes it easier for devices as well as people to be better connected by utilizing the IoT paradigm. Eventually leading to the emergence of new fields to the paradigm of cloud computing which is being led by both academia and industries.

Xu [21] has highlighted the facets of cloud computing, organizations that use cloud computing and cloud computing service providers. Two models have been suggested in manufacturing industries, namely cloud manufacturing with absolute adoption of cloud computing technologies and cloud manufacturing. The author speculates that the pay by use model will revolutionize the manufacturing. Production-oriented manufacturing and service-oriented manufacturing have been discussed in detail.

Singh et al. [22] propose a model which distributes the customer data into different cloud service providers and which is economically feasible. Distributing data has one major advantage that is there is no single point of failure. If one server is compromised, then all the data is not lost. The model was subjected to two scenarios, one where there were no budgetary constraints and the other where the budget was fixed. Both these cases can be used depending on the situation of the customer.

Alshamaila et al. [23] propose an adoption model for cloud computing which is based on the technological organizational and environmental (TOE) framework. This model was made by surveying SMEs in the north east of England. Various factors which played a significant role in adopting cloud computing were identified. The factors have been divided into three categories. Technological-relative benefit, unpredictability of results, closeness to the existing technology, degree of complexity, degree of experimentation; Organizational-scale, higher management support, ingenuity, experience; Environmental-competitiveness, sector, scope of the operations, supplier support. Cloud computing firms need to bring awareness to their technologies so that adoption occurs in a wide scale. Security does not seem to be an issue for adoption of cloud computing.

Oliveira et al. [24] identified the factors which influence the adoption of cloud computing in industries. This was accomplished by creating a research model which incorporated diffusion of innovation (DOI) theory and TOE framework. Data was collected from various firms in Portugal to test the hypothesis. The factors are relative benefit, closeness to the existing technology, higher management support and scale of the organization. Other factors found with DOI theory are better quality of business functions, quicker completion of tasks, higher productivity and emergence of new commercial opportunities.

Gangwar et al. [25] identified the factors which influence the adoption of cloud computing in industries. This was accomplished by creating a research model which incorporated technology acceptance model (TAM) and TOE framework. Data was collected from various IT, manufacturing and finance firms in India. The factors are relative benefit, closeness to the existing technology, degree of complexity, higher management support and experience.

With the advent of IoT, the amount of data to be processed increases exponentially. Jiang et al. [26] propose a model for the storage and management of the data generated from IoT devices. Generally, older technologies without IoT integration would store its data on local servers without access to the Internet. This model allows data from the IoT devices to store data whether it is structured or unstructured data.

Hsu et al. [27] have done a TOE analysis with incorporation of diffusion theory to find the factors which influence an organizations willingness to adopt cloud computing technology. The results were verified with firms in Taiwan. Cloud adoption mainly depends on recognizable benefits, IT potential and business effect. Recognizable benefits is the strongest factor among the three. It was found that the size of the firm does not matter, but IT potential matters. Pricing mechanism also depends on IT potential.

Gupta et al. [28] have found the factors which affect adoption of cloud computing in SMEs and SMBs. Advantages offered by cloud computing services have also been identified. Cloud computing is user friendly and convenient which are the factors which carry the most weightage. Privacy and security are the second most important factor. It is safer to store data in a remote location which is operated by a third party whose sole job is to safeguard the data of its customers. Protecting data is not the responsibility of the SME or SMB. The aforementioned factors have an effect on the cost of operations that is it reduces cost substantially.

Wu et al. [29] highlight the drivers which push firms to support their supply chain with cloud computing. The research has been done by the use of diffusion information theory. An empirical study and regression analysis were done to examine the model. It was concluded that factors such as the firms business process complexity and compatibility with the existing information systems determine the degree of ease by which cloud computing can be adopted (Table 1 and Fig. 1).

Table 1 Overview of the papers reviewed

Summary	Authors
Parameters, vulnerabilities	Ramachandra et al. [2]
Six factors identified concerned with adoption	Alsmadi et al. [3]
Compatibility of frameworks	Pedone et al. [4]
Cloud and IoT integration	Wang et al. [5]
IoT-based manufacturing system CCIoT-CMfg	Tao et al. [6]
Development of ICT in China, adoption factors	Yu et al. [7]
Autonomous virtual management system	Dinita et al. [8]
CloudIoT paradigm application, fog computing	Botta et al. [9]
Integration of cloud computing and robots	Du et al. [10]
Framework for migrating legacy systems to cloud computing systems	Fahmideh et al. [11]
Hypothesis of framework based on literature	Givehchi et al. [12]
Present scenario and competition from ERP	Hofmann et al. [13]
Role of concerned parties, method of adoption	Marston et al. [14]
Interoperability and standardization issues	Mezgár and Rauschecker [15]
Creation of network enterprise model	Nieuwenhuis et al. [16]
Ranking of factors which lead to cloud adoption in Malaysia	Ooi et al. [17]
Formation of cloud-integrated CPS (CCPS), drivers of cloud adoption	Shu et al. [18]
Identify barriers and effects of adoption of cloud computing in SMEs	Trigueros-Preciado et al. [19]
Latest trend of cloud computing technology, decentralization of processing power	Varghese and Buyya [20]
Models of cloud computing in manufacturing industries	Xu [21]
Distribution of data into different cloud providers	Singh et al. [22]
TOE analysis in SMEs of north east England	Alshamaila et al. [23]
TOE and DOI analysis of firms in Portugal	Oliveira et al. [24]
TAM and TOE model for firms in India	Gangwar et al. [25]
Model where data from IoT devices stored in the cloud	Jiang et al. [26]
TOE and DOI analysis of firms in Taiwan	Hsu et al. [27]
Factors affecting cloud adoption in SMEs and SMBs	Gupta et al. [28]
Supply chain and cloud computing integration	Wu et al. [29]

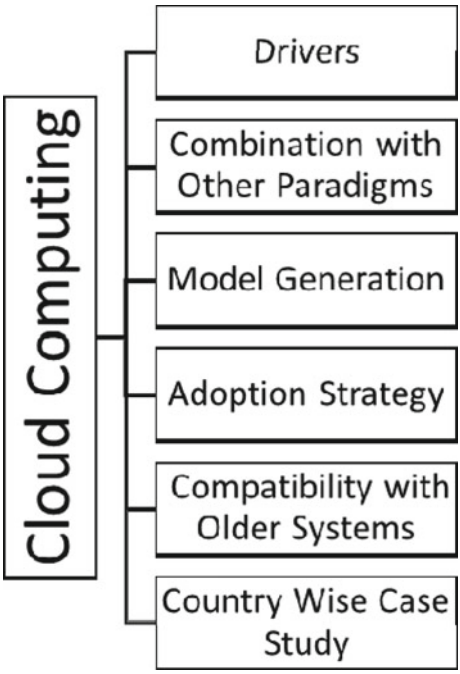

Fig. 1 Factors discussed in the paper

3 Conclusion and Research Gaps

Cloud computing is still in its early stages, and experimentation is still underway to find the best suited process for its implementation. The term cloud computing was first used in an internal document of Compaq in 1996. The present state of cloud computing in industries can be attributed to the various drivers and barriers in which analysis has also been done. Framework models have been created to find the optimum model which satisfies the criteria that the organization is looking for. The frameworks need to be created as one framework cannot be used in all applications. Models have been made by incorporating TOE framework with other theories and approaches like TAM and DOI. The distribution of data into multiple cloud servers has also been shown to have benefits. Cloud computing offers a way to mitigate the issues of older systems like ERP. Various combinations of technology such as CPS, IoT with cloud computing show great promise in increasing efficiency in industries. The integration of IoT and cloud computing is known as fog computing. This is the next stage of cloud computing which incorporates the use of edge devices. As the cloud is decentralized, it can provide processing power for large calculations otherwise impossible without the cloud. The data from robots can be processed with the cloud alone. Cloud computing has been widely adopted in SMEs due to lack of complexity and scale. Cloud computing is being adopted in all aspects of everyday life starting from a city's infrastructure to household appliances. In industries,

cloud computing is a new paradigm which provides lots of opportunities for the organizations to capitalize in this new technology.

As far as research gaps are concerned, the implementation of cloud computing in developing countries is negligible, and this is due to poor infrastructure, unwillingness to adopt new technologies and the justification of spending a lot of capital to adopt cloud computing. Due to these reasons, research of cloud computing in developing countries is limited. Most networking systems used in industries use primitive technology like LAN and private databases migrating to cloud computing systems require new hardware to run which requires capital. This investment may not show immediate benefits but may show long-term benefits. There is no research on long-term benefits of cloud computing adoption, so it is difficult for industries to know whether their investment is profitable. Furthermore, industry-wide adoption is required to actually reap the benefits of cloud computing.

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