

An analysis of the opportunities and challenges connected with utilization of the cloud computing model and the most important aspects of the migration strategy

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Abstract—This paper is devoted to the cloud computing model and the opportunities and challenges connected with its utilization by business organizations, including the most significant issues related to the cloud migration strategy. It is composed of five parts. In the first, some facts concerning cloud computing as a new technology and the reasons for organizations using this type of computing model are provided. Next, the notion of cloud computing is briefly defined and the most significant opportunities and possibilities linked with cloud-based solutions are presented and discussed. The following part is focused on the analysis of the most important problems and challenges connected with the cloud computing model. The penultimate part of the paper deals with the issues connected with the cloud migration strategy, focusing on the most important elements. In the final part of the paper, the most significant conclusions and suggestions are offered.

I. INTRODUCTION

THE dynamic development of solutions available using the cloud-based model and the growing interest in them can be noticed taking place over recent years. Cloud computing is perceived as one of the components of the next-generation IT infrastructure (NGI) of contemporary organizations and a very important technology of the future [1]. According to the report by the McKinsey Global Institute, it is regarded as one of twelve potentially disruptive technologies that will transform business and the global economy [2].

The importance of cloud computing as a technology has been confirmed by various studies. The results of the 18th Annual Global CEO Survey (1322 company leaders from 77 countries) conducted by PwC indicate that cloud computing is considered by CEOs as one of the six most strategically important developments in digital technologies [3]. According to the results of the 2014 Technology Innovation Survey, conducted by KPMG among almost 800 global technology industry leaders, cloud computing is a top technology that will have the greatest impact in driving business transformation for enterprises [4]. In addition, the results of a survey of ICT professionals, carried out by the German Federal Association for Information Technology, Telecommunications and New Media (BITKOM), confirms the importance of this technology. 64% of those surveyed consider cloud comput-

ing as the leading information and communication technology trend [5].

The significance of cloud computing additionally increases because of the fact that it enables other highly impactful technologies, including: mobile Internet, automation of knowledge work, the Internet of Things, and Big Data [2], [6], [7].

So, in the context of the importance of this technology and its transformational potential, it is pertinent to analyze a few of the key issues connected with it, which this paper will proceed to do. They include the following aspects:

- the opportunities and benefits connected with cloud computing utilization,
- challenges and concerns connected with cloud computing usage,
- the cloud computing strategy and its key elements.

II. OPPORTUNITIES AND BENEFITS CONNECTED WITH CLOUD COMPUTING UTILIZATION

There are many diverse benefits and opportunities arising from the adoption of a cloud computing model and different mixes of the delivery (SaaS, PaaS, IaaS) and deployment (public, community, private and hybrid clouds) models. Although cost is very often indicated as a key benefit, ([8], [9]) in fact there are much more important advantages associated with this approach. According to the results of the above mentioned 2014 Technology Innovation Survey, there are four main categories of benefits connected with this technology. They include [4]:

- improved business efficiencies/productivity (37%),
- cost reductions (22%),
- faster innovation cycle (11%),
- accelerated time to market (10%).

Other reports also often indicate considerations such as [2], [10], [11]: increased agility, opportunities connected with the implementation of new business models, improved collaboration among business units and partners, geographic expansion, creating new opportunities for SMEs. If the issues connected with an organization's productivity are concerned, there are two main considerations. They are [2]:

- infrastructure and operating expenses,
- application development and packaged software.

According to estimates by the McKinsey Global Institute, in relation to the first of these, productivity gains could reach 20-30%. They result from [2]:

- reduced infrastructure and facilities footprint,
- high task standardization and automation.

In the second case the McKinsey Global Institute estimates that productivity gains could reach 10-15%. They result from [2]:

- standardization of application environment and packages,
- faster experimentation and testing.

There are many aspects of the cloud computing model which can result in lower costs. For example, if the physical IT infrastructure is considered the most important aspects include [2], [8], [9], [12], [13]:

1. Reduction or elimination of waste related to the low level of hardware utilization.
2. Reduction of costs connected with hardware maintenance.
3. Lowering costs related to energy consumption.
4. Possibilities for the permanent analysis of costs and the selection of the optimal service level.

In the case of software utilization, the cloud computing model can lead to the reduction or elimination of costs connected with:

1. Purchase and installation of software, its maintenance and upgrade.
2. Purchase of wrongly selected software (see [14]).
3. Low level of software usage.
4. Developing and testing of applications.

There are many new factors connected with cloud computing which have an impact on faster innovation cycles. Easy and cheap access to tools for the development and testing of new products or services, e.g. cloud-based Big Data tools, is a good example in this context [7], [15]. Big Data tools are already being used for this purpose by a growing number of companies [16].

Simultaneously, the implementation of cloud-based solutions leads to a diminishing demand for IT department employees to be responsible for the maintenance of an organization's physical IT infrastructure and, correspondingly, the possibility to release some of the budget previously allocated for this purpose. This allows for the reinvestment of the savings on innovative products or services. According to the results of the earlier cited survey conducted by the Manchester Business School and Vanson Bourne, this occurred in the case of 62% of the companies surveyed [9].

Use of the PaaS model is a good example as far as accelerated time to market is concerned. In this case companies which develop their own software instead of creating their own environment can instantaneously use ready-made tools for the application building process, delivered to them as a service.

If company agility, understood as the capacity of an organization to identify and capture opportunities more quickly than competitors, is considered, cloud computing significantly increases the possibilities of companies in this respect, due to the fact that utilization of the cloud-based model considerably broadens opportunities for the quick and flexible adjustment of an organization's IT infrastructure to new needs or new market situations. Such situations can require the implementation of new applications, adding new services or increasing computational capacity. In addition, using cloud-based solutions can be quicker than using a company's own staff [2].

Utilization of the cloud computing approach also provides organizations with numerous new opportunities to implement new business models. In many cases, these business models would not be feasible without usage of this computational model. An innovative business model called car sharing, implemented by the Zipcar company, is an example of such a situation. This business model is based on a complicated management system of a single set of cars which are shared by many users, which would not be possible without an advanced IT system where one of the key elements is the utilization of the cloud computing model [17].

Improved collaboration among business units and partners is made possible by the provision through the cloud of easily accessible, continually developing, applications. This aspect, combined with the above mentioned opportunities to build and implement new business models, provides organizations with new possibilities for geographic expansion.

The cloud computing model also provides small and medium enterprises (SMEs) with significant opportunities, especially in respect of costs. In the case of the smallest SMEs or start-ups with only small levels of capital at their disposal, this is not in relation to the reduction of costs previously incurred for IT infrastructure but rather opportunities to access hardware and software which would not be achievable in the traditional computational model, owing to financial barriers, particularly around the purchase of hardware and software and the employment of skilled IT workers to cover maintenance. The cloud model and the associated possibilities of "hiring" services connected with physical IT infrastructures or applications, enables smaller firms to more effectively compete with large organizations [8]. They can also access sophisticated solutions such as the above mentioned Big Data tools or the programming environment in the PaaS model.

III. THE MOST IMPORTANT CHALLENGES AND CONCERNS CONNECTED WITH CLOUD COMPUTING UTILIZATION

As is the case of all IT solutions, those offered in the cloud model bring not only benefits and opportunities but also problems and challenges. According to the results of the above mentioned 2014 Technology Innovation Survey, there are three main groups of challenges connected with the cloud computing model. They include [4]:

- security (23%),
- technological complexity (16%),
- risk management (15%).

Security anxiety is undoubtedly the key concern connected with this technology, and is confirmed by the results of other studies [2]. According to the Cloud Security Alliance there are various types of security concerns including such aspects as: data loss/leakage; account, service, and traffic hijacking; shared technology vulnerabilities or insecure application programming interfaces [18]. Of course the level of the potential risk depends on many factors, including the type of cloud being used, the service provider, the technologies being used (including data encryption) as well as the procedures it uses, or the procedures applied by a client-organization. In the latter case, it also relates to the phenomenon called shadow IT, which is the use by employees of cloud-applications not approved by their IT departments for business purposes [19].

The spread of the cloud computing model should also reduce the issue of technological complexity, due to the fact that service providers are likely to do everything to make their solutions as simple and as easily manageable as possible. Such a trend is already perceivable (see [20]).

The third issue which causes the biggest anxiety among managers is risk management connected with the utilization of the cloud computing model. Apart from the above mentioned security-related issues, some of the most important challenges are those connected with the availability of services. The deeper the dependency of an organization on cloud-based solutions, the more important this issue is. In spite of numerous publicized cases of problems with the availability of cloud services from well known providers, availability of this type of service is generally at a very high level. This fact is confirmed by the results of various studies (see [21]). Regardless of the level of availability of cloud services, every organization which utilizes the cloud computing model has to have appropriate procedures and technological solutions in place in case of problems with access to services. The same relates to the management of other types of risks.

Apart from the above mentioned issues, there are other challenges and limitations connected with the implementation and utilization of the cloud computing model. In the case of technical issues, one of the most important, and often underestimated issues, is network capacity. This is due to the fact that cloud-based technology is deployed through massive data centers that necessitate high-capacity bandwidth [2]. Simultaneously bandwidth requirements can significantly differ depending, for example, on the type of cloud-based application (basic, intermediate or advanced) [6].

The next element can constitute a significant hurdle in the process of adoption of a cloud computing approach, which is a reservation regarding the usage of the cloud-based model (lack of trust in cloud-based solutions). Such reservations are typically connected with issues such as concerns about placing sensitive data on third-party servers somewhere in the world. An important element of these concerns is the earlier

mentioned issue relating to the reliability of cloud-based solutions. In spite of improvements in cloud technology, high-profile downtime accidents continue to take place. As a result, they affect public perceptions concerning the reliability of cloud-based solutions.

The next significant challenge which can constitute an important barrier to the implementation of cloud-based solutions are structural issues and cultural resistance in organizations' IT departments. It is connected with the fact that usage of such computation models causes deep changes in IT management practices and the functioning of IT departments. It can, and in many cases does, lead to raising concerns about loss of control and the lowering of significance and position of these departments in companies. In fact, in the new "cloud realities", their role will be significantly different, moving to that of broker of IT services [22].

The newly required skill sets are the next issue which can be a source of fear and which can cause resistance. It relates to the skills of the employees of IT department and not only of technical nature. In this context a demand for a new type of manager, called "true program managers", has been indicated. They should be leaders who know how to cooperate with internal technologists and third-party vendors in order to pull together a particular solution and deliver it as an overall program [1]. Another significant factor is connected with the complexity of migrating enterprise IT systems to the cloud [2].

There are also many legal challenges. They relate to such aspects as: regulations concerning the place of data storage and access to that data, data ownership, privacy and data protection issues, the applicability of the law connected with data protection and the scope of vendors' responsibility (including liability for data residing in a particular online location). These issues have yet to be settled by policy makers, and a significant barrier is the fact that the law in many countries does not address these issues. An important constraint in the ability to take advantage of some of the benefits of cloud-based solutions (especially those connected with public clouds) is the fact that in many countries data protection laws restrict the possibility of storage and transfer of some types of data outside their borders [2], [23]. A further legal issue constitutes a significant concern in the case of the utilization of public clouds. It relates to inquiries from governmental agencies (e.g. the National Security Agency in the U.S.). Namely, public cloud providers can be obliged to provide information concerning their customers, but may be legally barred from informing them about this fact [1].

IV. THE MOST IMPORTANT ELEMENTS CONNECTED WITH THE CLOUD STRATEGY

In spite of the growing interest of organizations of various sizes in adopting cloud-based solutions it does not mean that they have a cloud strategy. According to research conducted by IDC only 17.9% of young organizations (fewer than five years of operation) and 10.2% of mature ones (more than five years of operation) have an optimized cloud strategy. That is:

- a broadly implemented, cloud-first strategy which is proactively managed,
- clearly driving business innovation while improving IT operational efficiency [24].

Although one could perceive the utilization of the cloud computing model as a relatively simple issue, this is in fact not the case. There are numerous potential problems and challenges connected with its implementation and many aspects have to be carefully analysed and planned. It is obvious that implementation of cloud-based solutions is simplest in the case of companies without any previous “burdens” and legacy systems i.e. start-ups. But the bigger the company is, with many complicated business processes, the greater the scale of the challenges. Because of this fact it is especially important for organizations to have clear and comprehensive cloud strategies, including the cloud migration plan, in case they decide to utilize a cloud-based model.

Generally a strategy for the utilization of cloud-based solutions and migration to this computation model should be based on three key phase (see Fig. 1).

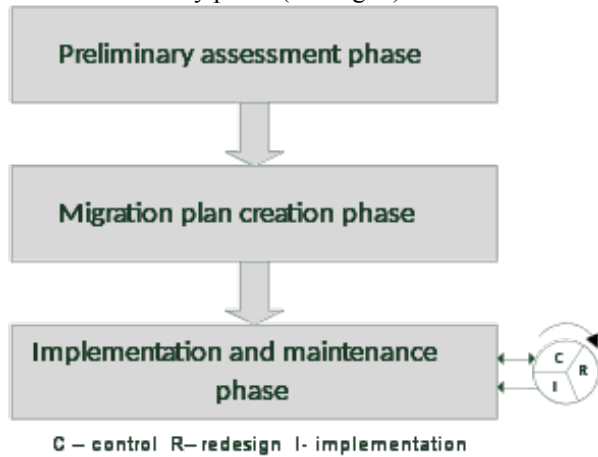


Fig. 1 Cloud utilization strategy and its three phases (source: own source)

In the preliminary assessment phase a management board, or especially established special committee, should make a preliminary assessment of the usefulness of using a cloud computing model in the context of its impact on the organization’s functioning.

This relates to such issues as:

- assessment of whether the cloud computing approach aligns with the organization’s culture e.g. in terms of outsourcing or not outsourcing any of its own operations (a culture of risk avoidance [25]),
- assessment of whether the cloud computing approach aligns with the organization’s objectives and what would be the migration goals (improvement of productivity, cost reduction, increased agility, new business models implementation etc.),
- appraisal of the risk connected with the migration process in the context of the potential impact on it of internal and external factors,

- assessment of which key stakeholders would be impacted by the migration process and how.

In the context of the above mentioned issues, it is evident that many organizations, for various reasons, do not decide to move to the cloud. According to the results of Computerworld’s Forecast survey conducted among 194 IT executives in May and June 2014, almost one third of those surveyed declared that their companies had no such plans (see Fig. 2).

And there is one more significant element of this phase - a comprehensive assessment of the readiness of the organization for the migration process. It is concerned with issues such as technical, human and organizational aspects. According to the results of the Chief Infrastructure Technology Executive Roundtable (CITER) organized by McKinsey, there are six key elements important in the context of an organizations’ “cloud readiness”.

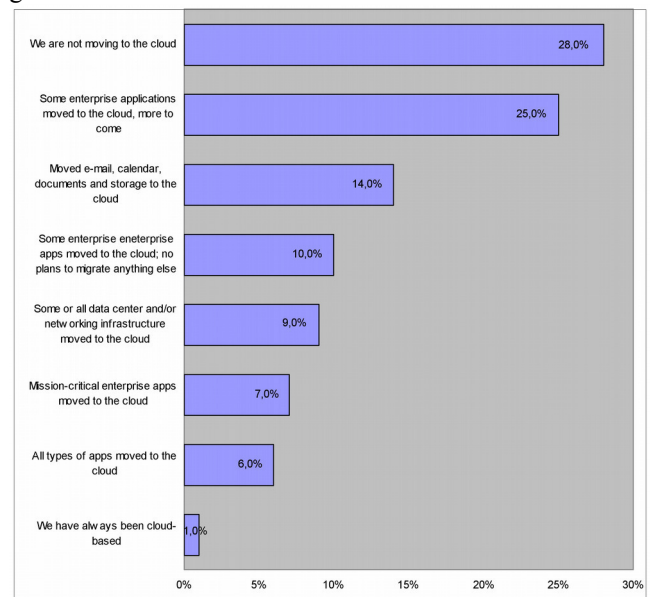


Fig. 2 Organizations’ strategies for cloud computing (source: [11])

They include such issues as [1]:

- well defined and well understood workflows to support cloud offerings,
- highly automated IT infrastructure,
- the right technical skills and training to support cloud of company’s IT department,
- effectively broken down/collapsed by company’s IT department technological silos (e.g., Windows, UNIX, storage, networking),
- extensive self-service options (e.g., development/test servers) offered by the company’s IT infrastructure,
- a strong understanding of the issues connected with forecasting the demand for cloud offerings.

In the case of a positive assessment of the sense and advisability of using a cloud-based solution, it is then necessary to move to the second phase - development of a migration plan. In its scope it is necessary to analyze the more detailed issues (including technical, legal and organizational ones) and make final choices, such as:

- determination of the final migration goals and choosing the business processes which should be cloud-supported,
- selection of the deployment model (cloud type) which will be used by the organization,
- selection of the delivery model(s) (SaaS, IaaS, PaaS) which will be applied and determination of the scope of their utilization (type of cloud-based applications, elements of the infrastructure which will be moved to the cloud etc. – see Fig. 2)
- selection of the approach for adopting cloud-based solutions.

In the case of this last issue there are two basic approaches which can be chosen by an organization i.e. “brownfield” and “greenfield”. The first one concerns the piloting of individual technologies and next deploying them in the current IT environment in order to replace solutions used so far. The second one relates to situations in which an organization deploys a separate standalone environment for new applications, and legacy applications are migrated to this new environment [1]. In the context of decisions concerning deployment and delivery models organizations should remember that such choices have a significant impact on issues relating to the level of direct control of the organization over the solution and risk connected with it (see Fig. 3).

Knowing the specific elements connected with the planned delivery and deployment model, the organization can then start the process of selection of a provider of cloud services. In this context an important aspect is to determine the provider’s role and scope of engagement in the migration process as well as the parameters which should be fulfilled by the services delivered in the cloud mode. As far as the first aspect is concerned, according to the results of the above mentioned Chief Infrastructure Technology Executive Roundtable (CITER) organized by McKinsey, there are four important roles of vendors in the process of cloud migration.

They include such issues as [1]:

- implement and integrate solutions,
- provide managed services (e.g. hosting, storage, incident monitoring/response),
- provide IT staff augmentation for ongoing operations,
- design a company's architecture and/or IT infrastructure environment.

As far as the second aspect is concerned, in this case it is necessary to determine the parameters which should be fulfilled by the services delivered in the cloud mode and working out the metrics (Key Performance Indicators) as precisely as possible, allowing for their control [10]. It is also extremely important to determine requirements for such issues as: data security, back-up procedures, location of data, ownership of data or the scope of the provider’s responsibility.

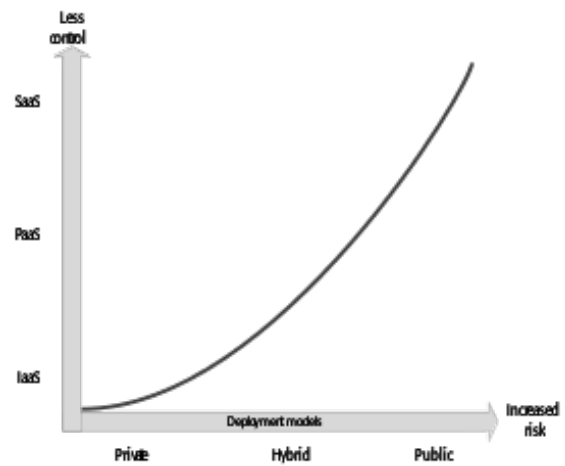


Fig. 3 Inherent risk relationships with cloud service delivery and deployment models (source: [25])

Other important issues which have to be planned include:

- the means of integration of the cloud-based solutions with those which will remain functioning in the traditional way,
- determination of a disaster recovery plan and procedures including a risk management program and incident management,
- organizational changes (especially in the IT department) i.e. their scope, their implementation and overcoming potential cultural resistance,
- necessary training and its scope,
- a cloud governance model.

The third and final phase of activities connected with the introduction of cloud-based solutions to an organization is the implementation phase, the maintenance and monitoring of their functioning in the context of the performance of the organization as a whole. The key issues which have to be realized in this phase include:

- final selection of the service provider and signing the contract including a Service Level Agreement (SLS),
- elaboration, together with the vendor, the migration plan based on the selected approach of adopting cloud-based solutions, including the scope and dates of necessary trainings,
- execution of the planned trainings,
- implementation of the planned cloud-based services and their integration with those functioning in the “traditional” way, as according to the plan,
- testing the functioning of the implemented solutions and making required corrections,
- monitoring the functioning of the implemented solutions based on a previously prepared cloud governance model and making necessary improvements and corrects.

V. CONCLUSION

The results of numerous surveys clearly indicate the growing interest of organizations of varying types in IT solutions available using the cloud computing model. This fact is also confirmed by the data concerning the dynamic growth of the cloud computing market and cloud data center IP traffic [6].

Undoubtedly, utilization of cloud services provides organizations with many opportunities. They are not only connected with such issues as the reduction of IT-related costs or productivity improvements, but they also have significant influence on a faster innovation cycle, increased agility or implementation of new business models. Also more and more organizations discern that without cloud-based solutions it would be more difficult to be able to store, analyze and use the rapidly increasing amounts of data critical for their market success and development.

But utilization of cloud-based solutions also brings numerous potential challenges and concerns related to such issues as the reliability of cloud services, data security, privacy or cloud-platforms compatibility. Also the migration process to cloud solutions includes many aspects which have to be well thought out and carefully planned. It relates not only to purely technical issues but also to legal and organizational ones. In the context of the last aspect, one should remember that implementation of a cloud-based approach, especially when it is a larger scale program, will be a type of reengineering project, as it is connected with a deep rethinking of the way an organization conducts its own operations. In this case problems of the various types of potential resistance (especially connected with the IT department and its changing role) and overcoming it, should be carefully addressed. An important challenge is also the lack of so called "best practices" which could be applied by organizations in their migration process (see [11]). In this situation properly planned and executed cooperation with vendors is a very important aspect and one of the success factors.

Taking into consideration the above mentioned remarks, it is necessary to stress that an incorrect and ill-considered approach to the cloud computing phenomenon can lead to a situation where, instead of expected benefits, numerous problems arise, negatively or even destructively influencing an organization's functioning and the realization of its goals. This results from the fact that cloud-based projects are connected to the IT infrastructure, a crucial component of every contemporary organization and the foundation of their functioning.

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