Bringing Viability to Service-Oriented Enterprises in Cloud Ecosystems

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Abstract - **Cloud Computing is the next evolution of computing systems, which shifts the whole application infrastructure away from old monolithic architectural models to more open, interoperable, modular, reusable and agile building blocks. Many Enterprises realise the benefits of Cloud Computing and position it as the Information Technology (IT) outsourcing solution, which is cheaper to operate and maintain. However, Cloud Computing is not just a technology behind an infrastructure, but also a new model, which needs to be properly merged with legacy paradigms of an Enterprise. In our work, we are focused on the challenges Cloud Computing is bringing to an Enterprise along with the promising benefits. The central issue in the transformation of IT infrastructure of an Enterprise into the Cloud is the uncertainty it is able to bring to a well established Business Architecture (BA) and Business Models (BM) of a system. This disruptive uncertainty, which can be driven by an introduction of new technologies or modification of already integrated ones, needs to be addressed properly and governed accurately to guarantee a viability of an Enterprise. This work proposes solutions to the issues an Enterprise might face in its Cloud transformation initiative.**

Keywords–cloud computing; enterprise architecture; technological innovations; uncertainty management.

I. Introduction

Cloud and Cloud Computing are no more buzzwords in the world of Enterprises. Corporations and organisations slowly realise what Cloud-based solutions can offer and what benefits they can bring. Researchers worldwide, in academia and industry, are involved into analysis of impacts of Cloud Computing on IT infrastructures, organisational changes, business operations, system architectures to mention a few. Research challenges in Cloud Computing are systematically reviewed and addressed in academia [1, 2, 3, 4, 5, 6]. Many white papers are also trying to give a clear definition of the Cloud and its capabilities in system architecture [7, 8, 9]. Market analysts suggest that the Cloud Computing capitalisation is already, almost three times more in 2012 than that of in 2008 [10]. Though, Cloud has slowly became a trend in the world of IT, active research and wide range of definitions clearly indicate that Cloud Computing is still immature as a paradigm. Thus, its integration with complex systems might lead to unpredictable consequences in systems architectures which position Cloud as a source of uncertainty which needs a clear realisation and governance.

In our work, we are looking at the challenges in Cloud ecosystems from the Enterprise Architecture (EA) perspective.

Amongst the typical domains of EA such as Data Architecture, Application Architecture and Technology Architecture we identify the Business Architecture (BA) as the domain of interest, which is purely addressed in academia, however vital for an Enterprise to remain viable and competitive on the market in times of insertions of innovative technologies. In our research, we position Cloud Computing as the *disruptive technology which is capable of bringing uncertainty to a BA of an Enterprise in times of technological insertions*, in one or more of the following scenarios:

1. *Modifications in already integrated technologies*

In times, when an Enterprise faces the changes in the scope of operations of already integrated technologies consumed over the Cloud (e.g., Public Cloud).

2. *Introduction of new technologies*

In times, when new technologies got introduced to the public, but their benefits are not yet realised by an Enterprise.

3. *Parallel Innovations*

In times, when an introduction of new technologies and changes to already integrated ones are happening at the same time.

In our work, we aim to overcome the above mentioned challenges by bringing Cybernetic concepts to the domain of EA to model a system accompanied with the decision models, uncertainty management and risk remedy mechanisms, which would help it remain viable in times of technological innovations.

This paper is structured as follows: Section 2 gives a detailed overview on the risks and challenges Cloud Computing brings to the EA; Section 3 proposes various solutions to overcome the issues Enterprises face in the Cloud and Section 4 summarises the findings and gives a glimpse on our future work.

II. Background and Challenges

Nowadays, reliance of IT systems on remote computational power is accepted as a matter of fact and service providers such as Google, Citrix, Microsoft, VMWare, etc. offer a wide

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range of diverse solutions which can be integrated into architectures of any IT-enabled Enterprises over the Cloud. The National Institute of Standards and Technology (NIST) defines Cloud Computing, as "*a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models.*" [11]

Amongst the deployment models of Cloud Computing such as Community Cloud, Private Cloud, Public Cloud and Hybrid Cloud, we consider the latter models and Public Cloud in particular as more challenging, since in the Public Cloud, Enterprises leverage on remote computational power, which might be out of their direct governance. Absence of direct governance of IT can be challenging to the BA of an Enterprise, since for an Enterprise whose mission is to remain competitive and viable on the market in the long run, BA is considered to be the core unit of its business operations and Enterprise identity. BA is "*a blueprint of the Enterprise that provides a common understanding of the organisation and is used to align strategic objectives and tactical demands.* " [12] In a typical Enterprise, such a blueprint might require continuous monitoring, revision of its artefacts and relevant BMs to remedy possible risks at global and local scales. However, in nowadays IT-enabled Enterprises these types of risks can possibly be part of BMs of BA, which can arise from a reliance on a remote computational power.

A. Risks of modifications in already integrated technologies

Amongst the main challenges of an Enterprise is preserving its identity in a long run and therefore continuously governing and maintaining its BA, which represents corporate values. Enterprises of modern age are trying to be pro-active, rather than reactive to possible changes in their business operations and this in fact requires significant investment of time and money into the management of relevant business units of the EA. One of the widely used system design paradigms, such as Service Oriented Architecture (SOA) is able to bring agility to a BA of an Enterprise through the decomposition of complex BMs into small ones and decoupling of business logic from operational logic. However, this might not be enough when an Enterprise is running its operations in the Cloud. Impacts of SOA and effects of introduction of Cloud to an Enterprise were addressed in range of papers in academia [2, 5, 13]. However, none of the existing works comprehensively analysed the impacts of Cloud Computing on BA of an Enterprise.

The core issue with the Public Cloud deployment model integrated with the IT infrastructure of an Enterprise is that the external services can be part of internal BMs. Though, this is one of the main missions of the Cloud Computing, such integration can also become a source of unexpected risks, which might question the viability of an entire Enterprise. In a Cloud SOA-enabled ecosystem services can be provided and consumed by a range of participants (i.e., service providers and service consumers). In fact, a service consumer on one side is only aware of the end-point on the other, whereas the end-point itself can be a consumer of services external to its Enterprise scope and therefore play a role of a medium. Such role, though promotes the core benefits of service-oriented systems, can still be challenging for an Enterprise when a change in an operational scope of any service in the service consumption chain is happening independently at different levels of service consumers hierarchy (Fig. 1).

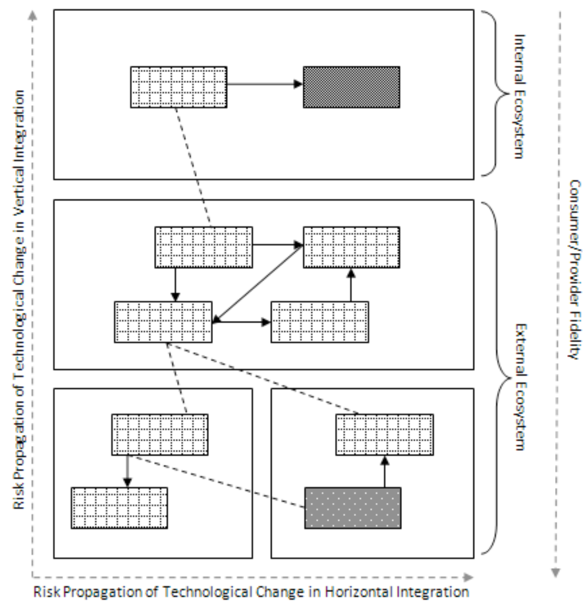

Fig. 1. Impacts of technological modifications

Though, the best practices of SOA teach us the ways to avoid possible risks through the use of dynamic and redundant service contracts and other relevant SOA patterns, they are unable to remedy risks associated with the propagation of technological changes in service consumers hierarchy by the time they got introduced to the end-point Enterprise. Which as a result can affect the BA of an Enterprise in times of *Vertical* and *Horizontal* integrations.

B. Risks of introductions of new technologies

Another challenge to the BA of an Enterprise is the introduction of new technologies. For Enterprises innovations of any kind can be disruptive and shall be managed according to organisational objectives and tactical demands. In modern IT-enabled Enterprises sources of innovations, and thus disruption, can be various Cloud deployment models integrated with the IT infrastructure. Various works [2, 5] in academia position Cloud Computing as a disruptive technology, but no solutions are proposed and much work done towards analysing and overcoming possible risks Cloud ecosystem can generate.

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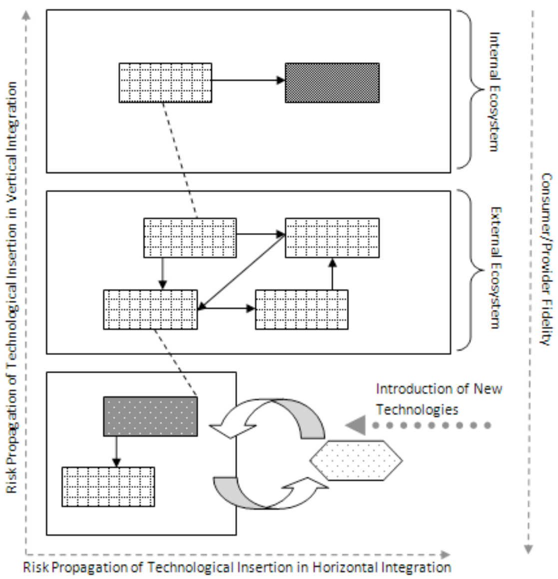

Fig. 2. Impacts of new technologies introductions

Scenarios that need deeper understanding and scientific analysis are those associated with the merge of an infrastructure of an Enterprise with the Public or Hybrid Cloud deployment models. In such scenarios an Enterprise does not have direct governance over some parts of its IT infrastructure and thus any introduction of a new technology can confuse decision makers (Fig. 2). In other words, time required for an Enterprise to realise possible opportunities or dangers of a newly introduced technology might not be enough and as a result increase or decrease its competitiveness on the market as well as question its viability.

C. *Risks of Parallel Innovations*

Lastly, a challenge, which needs careful analysis, is the one associated with the decision making in times of Parallel Innovations. We position Parallel Innovations as *the process of simultaneous modifications in existing technologies and introductions of new ones to an Enterprise*. In the context of Parallel Innovations we divide an introduction of a new technology into two processes: *1) introduction of a technology closely related to the one already integrated into the infrastructure of an Enterprise*; *2) introduction of a technology which is not yet integrated and unrelated to any existing technology of an Enterprise*; whereas innovation in already integrated technologies is a sole *process of modifications in the scope of services functionalities in the hierarchy of service consumers*. All these processes are capable of bringing uncertainty to an Enterprise and require relevant tools to support the management in making relevant decisions based on the possible events. For example, a new technology, closely related to the already integrated one, can substitute the old technology and bring financial benefits to an Enterprise, whereas a technology unrelated to the existing can bring uncertainty or destruction to the BA and Enterprise itself. There are of course various other possible scenarios of BA evolution in such integration initiatives that require deeper research and analysis.

III. METHODS AND SOLUTION SEEDS

A. *Using Ontologies*

One of the solution seeds, which can help in handling possible issues in propagation of risks from IT to a BA of an Enterprise, is to decouple these domains from each other. Such an approach was addressed in a number of works in academia [14, 15] and suggests the use of ontologies as mediums between these domains. In Information Science (IS), ontology is a "*formal, explicit specification of a shared conceptualisation*" [16]. Aier and Winter [14] propose a method for the identification of alignment artefacts using the example of domain clustering which is reflected in their Meta model. Kalogeras et al. [15] suggest using Web-Services technology as universal interfaces to achieve the decoupling of IT from BMs due to their wide utilization of open standards. Both approaches claim that through ontologies any modifications to the IT infrastructure of an Enterprise will have less impact on its BMs and therefore bring more agility to the BA. However, both methods have flaws and it was identified that the decoupling through ontologies can aid the BA, but is not enough for an Enterprise to become pro-active to possible technological modifications in the chain of service providers.

The core issue with the use of the methods is associated with the lexicon terms in system ontologies, which in times of technological innovations can sometimes encompass wider meanings and system might not necessary be aware of this (e.g., when there is change in a technology, somewhere in the chain of service providers). In most cases, a careful design of ontologies may not help, since the core issue is the - *unexpected change in a service scope*. So, for instance a service, which was proving radar services, will still be providing radar services, but the radius it covers might change from 5km to 10km, which will eventually affect a BM that consumes it. Another significant issue is that, it is not that easy to change system ontologies once they are established, more than that if such a decision was made it might lead to over-cluttering of system taxonomy. Semantically-aware approach seem to be a solution, but once it got integrated into a system it acts as a black-box and interpreting inputs just from outputs might not be so effective, since a *dangerous* output can only be statistically detected after a particular amount of inputs, period of time, which means: lose of opportunities, decrease of competitiveness, viability and so on. Both works [14, 15] suggest automation, which makes sense in such complex systems, but this automation lacks a feedback mechanism. More importantly, feedback mechanism is not enough and such systems need a more comprehensive tool. We see a need for the Decision Support System (DSS), a tool that can aid overall Enterprise design and governance of its underlying systems. In our work, this tool is inspired by Cybernetics concepts and therefore called the Cybernetic Decision Model (CDM).

B. *Modeling Decision Support System*

The goal of the CDM is to become a comprehensive EA tool that will bridge the gap between what is needed for planning for the viable systems in times of disruptive change and what is available. Its main application is within a DSS and it based on the GRAI Grid Decisional Model [17] developed in the University of Bordeaux. The CDM incorporates the GRAI's concepts of *horizons* and *periods* to support continuous improvement of overall EA. In CDM ontologies can play a role of seeds with terms, which can form the pieces of decisional solutions (e.g., sentences). Domains of ontologies can be modeled as decision centres and impacts of changes in IT domain can be initially analysed at these centres and then decisions can be made to either approve or decline the integration of a particular service into the BMs (in a manual and automated fashions). GRAI can also be used to decompose each process based on various possible criteria, such as: resource structure, steps of transformation, etc. CDM can help in the analysis of possible changes in system evolution through *horizons*, which are used in the context of future planning. Future planning is associated with services that are part BMs of a system, and relevant analysis can be conducted on tasks basis to emulate likelihood of possible events in times of technological innovations. As in GRAI, in CDM *horizons* are quantified and aim to represent decisions scopes in short-term, mid-term and long-term time scales. That is, if a plan was made for six months then a *horizon* is six months. *Horizons* can be key instruments of decision-making and are also useful in the assessment of likelihood of ungoverned system shifts (e.g. technological, management). *Periods* of CDM aim to re-evaluate the time allocated to a particular plan and can either shrink the time or extended it. *Periods* allow managers to take into account dynamic changes in the environment of a DSS. This change might include internal (e.g. change of system managers, change of system architecture) and external (e.g. service modification, introduction of new platforms) disruptions.

C. *Building Uncertainty Management Engine*

There is also a need for the tool that would help in computation of conditional probabilities. In our system, this tool is based on the Bayesian Belief Network (BBN). The aim of this tool is to analyse posterior probability distribution to aid the governance and course of evolution of EA. One of the core advantages of the Bayesian Network (BN) over the most of predictive models, such as neural networks, is its capability to explicitly represent the interrelationships between the dataset attributes [18]. *Periods* of the CDM can be transformed into forecasting centres that can use Bayesian Belief Network for the assessing the circumstances and conditions that influence system performance. This in turn can create system buffers where possible deviations from the forecasted system evolution path are calculated.

D. *Bringing Viable System Model into the Cloud*

The heart of the CDM is built upon the Cybernetic model developed by Stafford Beer in 1972 [19]. This model, called the Viable System Model (VSM), consists of 5 sub-systems that help an entire system to operate autonomously, make strategic decisions and remain viable in continuously changing environments. The VSM has a feedback mechanism that escalates alarms and rewards through different levels of recursion when there is a change in a system performance. The CDM incorporates the VSM to aid the viable design of an Enterprise and handle the impacts of technological innovations on the performance of a BA. Various sub-systems of the VSM are different roles in the decision-making. That is, System-1 and System-2 are used in the analysis of current states of a system, whereas System-3 and System-4 are used in the analysis and forecasting of future states.

E. *Risk Remedy System Design*

Contemporary Enterprises deliver their goods through services, which in fact are their end products. Shift towards service delivery requires understanding of complex system processes and designs to secure investments and guarantee increasing scalability of a system in the future. SOA [20] and Service Oriented Enterprise Architecture (SOEA) [21] paradigms are the most modern approaches that can handle and meet these needs. The philosophies of SOA and SOEA are based on open system architecture and can help in building systems with time buffers so critical for the smooth integration of innovative technologies and management of uncertainty in times of integrations.

IV. CONCLUSION, DISCUSSION AND FUTURE WORK

In this work, we highlighted various challenges Cloud Computing can bring to the world of EA in the context of BA and proposed the methods that can be used to overcome them. These challenges are associated with the modifications in technologies integrated into existing BMs of an Enterprise; introductions of new technologies; as well as challenges in decision-making when both modifications and introductions are happening at the same time.

There are various tools that can assist, the transition process of moving an IT system into the Cloud; however, no tools are provided to support Information Systems Management (ISM) once in the Cloud. Our future work aims to develop a method that can analyse relationships between resources across business processes, forecast their evolution at various time scales, and improve the overall quality of systems management. The method is the practical implementation of the CDM that is based on the GRAI Decisional Model and amalgamates the Design Structure Matrices and the Cybernetic concepts of the VSM. It is to be used to determine shifts in system states, detect deviations in the course of system evolution, and aid decision makers with clear schemata of all system entities.

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