Business Cloudification
An Enterprise Architecture Perspective

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Abstract: Cloud computing is emerging as a promising enabler of some aspects of the ‘agile’ and ‘lean’ features that businesses need to display in today’s hyper-competitive and disruptive global economic ecosystem. However, it is increasingly obvious that there are essential prerequisites and caveats to cloudification that businesses need to be aware of in order to avoid pitfalls. This paper aims to present a novel, Enterprise Architecture-based approach towards analysing the cloudification endeavour, adopting a holistic paradigm that takes into account the mutual influences of the entities and artefacts involved, in the context of their life cycles. As shown in the paper, this approach enables a richer insight into the ‘readiness’ of a business considering embarking on a cloudification endeavour and therefore empowers management to evaluate consequences of- and take cognisant decisions on the cloudification extent, type, provider etc. based on prompt information of appropriate quality and detail. The paper also presents a brief practical example of this approach and illustrates, using the Enterprise Architecture viewpoint, the necessity of well-defined business architecture, policies and principles dictating solution selection and design and transition program as *sine qua non* preconditions towards successful cloudification.

1 INTRODUCTION

In today’s competitive and disruptive global economic ecosystem, businesses need more than ever to display agility, i.e. the capacity to quickly adapt to changes in their environment. This implies the capacity to promptly reconfigure and redesign themselves ‘on the fly’ to various extents. Importantly, an essential enabler of agility is the need to be ‘lean’, i.e. avoid excessive investment in areas that are likely to change and can be outsourced.

Cloud computing, as an Internet-based paradigm model enabling on-demand access to configurable computing resources that can be promptly and easily enabled from the client side, holds the promise to answer some aspects of the two requirements described above. This is because typically cloud computing and storage solutions provide services such as Infrastructure (IaaS), Platform (PaaS), Software (SaaS) (see Fig. 1), while making use of shared resources in order to achieve coherence and economies of scale.

For example, in the case of IaaS, cloud computing allows companies focus on their core businesses instead of spending resources on building and maintaining their own computer infrastructure. Cloud computing also promises to allow enterprises deploy and operate applications faster, reduce maintenance, improve manageability, thus directly supporting the said lean and agile requirements (Hirzalla, 2010; Sawas and Watfa, 2015).

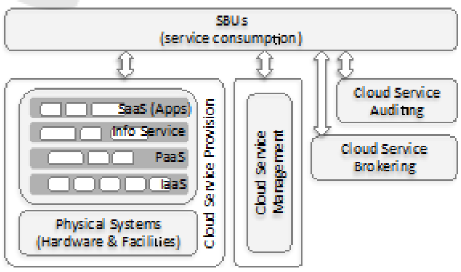

Figure 1: Typical Cloud Architecture – based on NIST Cloud Computing Reference Architecture (Liu et al, 2011).

Figure 1 presents a typical cloud architecture. While following the accepted NIST terminology (Liu et al., 2011), it does however consider the architecture from a functional point of view (i.e., leaving it open on how service, service management and other

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related functions are distributed among organisations). In addition, in Fig. 1 Information Services are singled out separately, given the various new forms of services that are based on various other information sources and repositories other than databases, such as streaming data, unstructured media sources, etc.

Cloud computing may be deployed in various ways, such as private, public, community or hybrid (a combination thereof). Choosing the type of deployment must consider factors such as security, privacy, compliance, availability and reliability (Goyal, 2014; Jansen and Grance, 2011).

This is especially true considering that cloud computing technology has not yet fully matured and as such it cannot always satisfy the above-mentioned criteria to the level required (Badger et al., 2014a; Zhang et al., 2010; Wang et al, 2008, Brian et al., 2008; Grossman, 2009). The recent years have seen the lowering of cost of services, computing and storage, and improvements in scalability and availability and network capacity. This situation, in the context of the emergence, increase in acceptance and subsequent adoption of models such as Information Technology (IT), virtualisation and service orientation by businesses have encouraged the perception that cloudification is an achievable target for most businesses. Gartner (2016) states that currently cloud vendors (and users) are still rushing to the market to gain a position in the growth market, with various service delivery models (IaaS, PaaS, SaaS, etc.) present at all levels of the hype cycle. It is however emphasized that only those businesses who filter out the hype and perform a realistic assessment and matching of the cloud capabilities “to the right scenarios, with the right management and governance” benefit from “[…] increased agility, elasticity, scalability, innovation, and in some cases, cost savings” [ibid.]. This supports the above-stated authors’ stance (detailed in Section 2) that there are important aspects that need to be observed in order to make the ‘cloudification journey’ a successful one. Identifying the aspects that need to be addressed and selecting the appropriate methods and models to prepare for cloudification can be a daunting task given the daily economic pressures and the ‘system-of-systems’ complexity of today’s enterprises. This paper advocates the use of Enterprise Architecture (EA) as a holistic, life-cycle oriented approach towards assessing, creating or improving of what can be called ‘cloudification readiness’ of businesses.

2 CLOUDIFICATION CHALLENGES

As more businesses attempt the move to the cloud, an increasing number of problems are surfacing. This has much to do with the expected inherent complexity of- and turbulence created by any major change in doing business; however, in this case there are also present specific problems originating in the very nature of cloud computing and importantly, in the fact that the business, as well as the cloud computing business model and technology themselves are ‘moving targets’ that evolve during and after the ‘cloudification’ project(s).

A first major hurdle that businesses face is the extent of cloudification. Thus, organizations must apply due diligence when selecting and moving functionality to the cloud, as cost and productivity advantages also bring potential drawbacks in risk and liability (Cayirci et al., 2016). For example, although government organizations may be discouraged to outsource services to a public cloud due to the sensitivity of the data handled, with appropriate risk mitigation a partial deployment in the cloud should still be possible (Jansen and Grance, 2011). However, a proper analysis determining which services and what proportion thereof to be outsourced requires that a common understanding of the AS-IS (present) state of the business is achieved by all stakeholders and in all aspects necessary for the change.

A second important challenge increasing the complexity of the cloudification endeavour is service recursion, where services may call upon other services, such as e.g. in an ‘intercloud’ architecture (Morrow et al., 2009). For example, an E-commerce site needs banking, fraud detection, etc. which are nowadays (also, or often only) offered as external services (Aulkemeier et al., 2016). This situation raises several important questions such as: Who is responsible for reliability if a service fails due to other services it depends on? Can a service be guaranteed if is integrated with / depends on others? If so, who is the responsible / guarantor entity? Therefore, it is important that the degree of recursion is properly understood and therefore, adequate queries are raised by the acquisition panel of the to-be-cloudified business to the cloud computing solution provider.

A main driver for cloudification is the promise of lowered costs; therefore, realising if appropriate savings are indeed achieved in the long run is an important issue (considering also that business needs will change). Thus, the total cost of ownership (including initial migration and deployment to the cloud, operation, continual development and decommissioning / migration) can escalate if the cloud pricing model is not understood and strategically assured by the user. The use of cloud pricing frameworks (e.g. as proposed by Laatikainen (2013)) is useful in this regard so as to understand the options; however, this should not be the only factor and as previously stated, first of all it should be decided why cloudification is necessary or desirable, what is to be cloudified, and to what extent. In addition, cloud solution vendors are increasingly asking for long term contracts and to bundle applications in order to offer discounts; hence, an essential cloud solution incentive is in danger of not being materialised.

A heterogeneous cloudification solution (using several providers) could be cheaper and a better fit for purpose as various providers offer different coverage of specific services and thus best prices may be negotiated for each application type. This option would require more varied in-house competencies compared to relying on a single cloud service provider; however, the latter option has drawbacks such as potential lock-in, or high exit cost should a migration be necessary.

Zardari et al. (2012) argue that analysing Service Level Agreements (SLA) of cloud providers and matching them against the user requirements can reveal potential violations of important principles, or conflicts and risks; while the SLA approach is useful, in the authors' opinion the above discussion has revealed that a much broader spectrum of cloudification challenges is in fact present. Due to their intertwined character, these challenges have to be addressed in a more holistic manner, based on the entire set of applicable quality of service requirements (also called 'architecturally significant' or 'non-functional' requirements (Chen et al., 2013)). The 'applicable' qualifier used above raises the question as to which non-functional systemic requirements, or 'ilities' (de Weck, 2011), are affected by the various cloudification solutions, how (to the better or the worse) and to what extent. The following sub-section attempts to identify the most relevant 'ilities' in question.

3 CLOUDIFICATION AND SYSTEMS 'ILITIES'

As de Weck (ibid.) explains, "[…] the ilities are desired properties of systems, […] (usually but not always ending in 'ility'), that often manifest themselves after a system has been put to its initial use. These properties […] typically concern wider system impacts with respect to time and stakeholders […]". He also provides a ranking of the ilities based on journal articles' coverage and Google hits, and identifies and further describes four classic engineering ilities, i.e. safety, quality, usability and reliability. Willis and Dam (2011) provide a more complete list that includes what they call 'the forgotten ilities'.

In this paper, the authors will attempt to select the most relevant ilities from the point of view of cloudification and analyse how they are affected by various cloud service delivery models, and if possible, analyse the extent of impact.

It is important to state some overall observations beforehand. For example, some ilities appear to subsume others, or at least overlaps are present. E.g., quality is a very general ility that appears to be one of the most cited; in addition, quality can be evaluated from several points of view (see Table 1.), thus illustrating another general ility aspect.

The discussion of ilities in the context of cloud computing presents two main aspects: i) cloud computing (in its various forms) promises to solve a number of business problems, by allowing the achievement of some systemic properties that otherwise may be out of reach, however, ii) adopting a cloud solution changes many existing systemic properties of the IT ecosystem, and therefore in a cloudification project (or more often than not a programme) it is not possible to simply concentrate on the desired additional benefits. This makes the cloudification attempt more complex than might initially have been assumed.

As mentioned, the ilities are not a set of mutually independent systemic properties; in addition, some important ilities are in fact aggregations of others (see Table 1). Therefore, to reach an optimum (or at least an acceptable trade-off) one must employ multi-criteria decision making- and cost analysis techniques known from systems engineering to explore the ilities 'trade space' Boehm et al (2014).

In general, the typical problems that cloud computing promises to solve are as follows: concerns about the total cost of ownership of information technology services, the scalability / elasticity of the IT solution, the rigidity of investment timing, and agility (e.g., quick time to market).

However, security, privacy, trust, compliance with legislations, and a number of other strategically important architectural properties could substantially

Table 1: Categories of ilities (Source: Boehm, 2014).

Individual ilities
- Quality of Service: Performance, Accuracy, Usability, Scalability, Versatility
- Resource Utilization: Cost, Duration, Personnel, Scarce Quantities (size, weight, energy, …)
- Protection: Safety, Security, Privacy
- Robustness: Reliability, Availability, Maintainability
- Flexibility: Modifiability, Tailorability / Extendability, Adaptability
- Composability: Interoperability/Portability, Openness/Standards Compliance, Service-Orientation

Composite ilities
- Comprehensiveness/Suitability: all of the above
- Dependability: Quality of Service, Protection, Robustness
- Resilience: Protection, Robustness, Flexibility
- Affordability: Quality of Service, Resource Utilization

deteriorate or even be lost when adopting a cloud solution. Therefore, both governments and vendors are working very hard to guarantee that these limiting factors are removed from the pathway to adopt cloud solutions in order to reap its benefits. For example NIST (Badger et al, 2014a) define security, interoperability and portability to be the top priority ilities for government.

Governments have been playing a pro-active role in laying the ground rules for the cloud computing market, and this has had a substantial benefit for all involved stakeholders e.g. by funding the research and standardisation work to establish a cohesive terminology and nomenclature (Liu et al., 2011)..

Furthermore, some governments played a substantial role in organising the consensus definition of capability deficits that need research and development e.g., (Badger et al, 2014a) and defining accreditation of cloud products (IaaS, PaaS and SaaS) to create a cloud market and a service delivery and quality control framework, in regard to both organisational and technical aspects – called FedRamp in the USA (Federal Risk and Authorization Management Program) and IRAP in Australia (Information Security Registered Assessors Program) and the Australasian Information Security Evaluation Program (AISEP). Several other countries have similar arrangements.

The above-mentioned efforts include reference models for Service Level Agreements (Aljoumah et al., 2015) and the definition of service metrics (de Vaulx, Simmon and Bohn, 2015) that can be used to decide required capability and capacity and to monitor the actual service performance.

Large enterprises and governments are in a substantially different situation relative to small and medium sized businesses who could never afford to own and internally run a complete professional-quality IT service. Therefore the potential gain for the latter is to achieve ilities that were previously out of reach, as opposed to the large players mentioned who could take those for granted and now must be careful to be able to keep them.

Thus, it appears that two main current problems in achieving a successful cloudification are (1) cloudification cannot be just done off the shelf - the business needs to transform to some extent (while still operating as it cannot afford to stop) so as to minimize turbulence and best take advantage of the service structure offered by the cloud and (2) even if (1) is accomplished, how can the end user avoid the bad side effects of moving to the cloud? The current lack of emphasis on the interactions between the various entities inhabiting the layers created by (1) and the interaction among the life cycle phases of these entities carries the risk of creating sub-standard ‘solutions’ that suffer from multiple systemic aspects in unanticipated ways.

A systematic treatment of moving to the cloud can be regarded as a specialised application of an Enterprise Architecture (EA) effort. It must be noted from the beginning that clearly, the limited view of EA as a ‘business – IT alignment’ exercise that is sometimes adopted e.g., COBIT (Isaca, 2012), TOGAF (Open Group, 2011) will not be sufficient, because the change will fundamentally affect the way business is done, will change the human organisation (including roles and responsibilities) and also alter legal, financial and contractual relationships (and the IT sub-system itself as well, where the IT architecture view of EA is applicable).

In other words, such transformation requires a holistic approach that considers mission fulfilment (manufacturing, mining, banking, health care, transportation, logistics, etc. technology, processes and human (TPH) organisation) as well as management and control (command and control) TPH, the redesign of business relationships, carrying out ensuing organisational changes, human competency development, and the introduction of new governance constructs, to only name a few.

The authors therefore propose the use of a framework that provides this broader view of enterprise architecture (ISO 15704) thus enabling a perspective that sees the embodiment of the enterprise as an evolving socio-technical system of systems. As a result of this framework adoption, the standard vocabulary of EA (as present in ISO 15704) and Systems Engineering (as espoused by ISO 15288 will be used throughout the discussion in Section 4 that demonstrates through an example an approach that considers 'moving to the cloud' to be an EA endeavour.

4 THE EA PERSPECTIVE ON CLOUDIFICATION

The goal of adopting Enterprise Architecture practice in an enterprise is to ensure that strategy, human organisation, utilised technology and processes are all in alignment (Doucet at al., 2009). Alignment, however, is not a one-off transformation project, but rather part of the enterprise's evolution

This article assumes that the reader is familiar with the basic terminology of ISO 15704 / GERAM nevertheless a brief overview of the most important concepts is given below and illustrated in Fig. 2.

The scope of the architecture is equivalent to the scope of the NIST Cloud Computing Reference Architecture (which is in ISO15704 terms an architectural level reference model of the IT system of the enterprise, also called a 'Reference Architecture of type I').

Given the open nature of enterprises, when looking at the entities of interest in describing the enterprise, one cannot limit to organisational boundaries; rather, rather include other relevant entities, such as suppliers and customers, as well as supporting entities that provide services to sustain the enterprise's operations and/or other entities that may be called upon to help any transformational tasks.

This extended scope is justified as cloudification requires so-called 'generative interactions' among participating entities. (A generative interaction is defined as the operations of one entity performing or contributing to one or several life cycle phases of another (e.g. entity A develops or changes the business concept of entity B.).

Figure 3 shows a life cycle diagram representing the life cycles of all typically involved entities. The model includes existing infrastructure as well as new cloud entities and a transformation programme (coordinating multiple projects). Interestingly, the decomposition of the system into a system of systems is not a uniform disaggregation: those systems whose subsystems will be expected to change in a similar fashion are not further decomposed, which controls the number of entities in the model (to the extent possible of course).

The model can also be thought of as a first-cut structural decomposition of the enterprise into functionally-independent entities. This is necessary because cloudification typically implies that part of the IT Stack would be 'carved out' and moved. It therefore makes sense to first fence off parts of the IT stack that are candidates for cloudification (whether into a private, public or hybrid cloud). Essentially this is tantamount to re-organising the IT stack in a service-oriented way (Rabelo, Noran and Bernus, 2015).

Various techniques are known to achieve the desired maximum functional independence among service entities (these are not discussed in detail in this article as they are out of scope); the necessary methods are available in the literature on Service Orientation (Keith, Demirkan and Goul, 2013) axiomatic design (Suh, 2001) and enterprise architecture complexity management (Kandjani, Bernus and Wen, 2014).

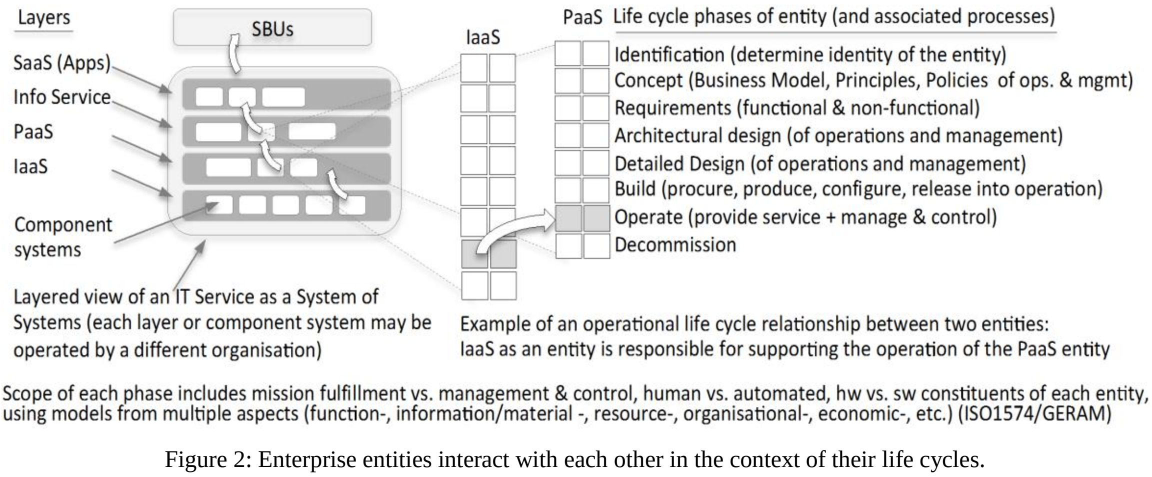

Figure 2: Enterprise entities interact with each other in the context of their life cycles.

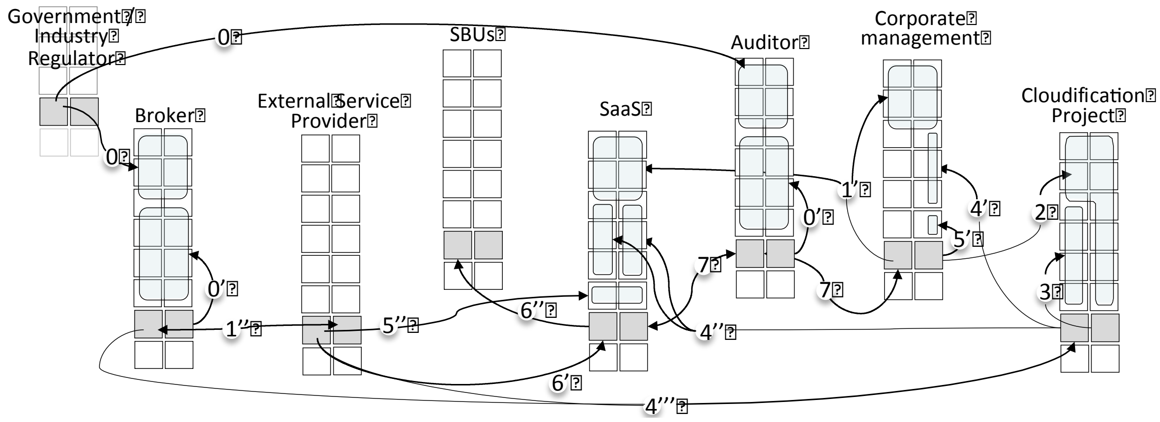

Figure 3. Life cycle relationships among service entities and cloud service consumers.

Using such a decomposition allows to separately consider several systemic properties and make independent decisions, namely:

o) As part of a preliminary stage for cloudification we assume that Government and Industry bodies have defined policies, principles and laws regarding cloud services, including the roles and responsibilities of cloud service brokers and auditors (arrows marked 0 in Fig.3), and that these have been implemented and rolled out by respective organisations (arrow 0' in Fig. 3).

i) Decide the desired improvements that each service layer must undergo (for example, creating dynamically established 'many-to-many' (M:N) infrastructure-platform and application-platform relationships, in order to allow load sharing and elasticity, to achieve increased responsiveness and availability of IT support to the business), as layer by layer the business benefit may vary. Systems engineering methods and tools exist to support the cost optimisation of investment (Boehm et al., 2014), taking into account through-life support, total cost of ownership, as well as performing risk mitigation and probabilistic optimisation based on the analysis of possible future scenarios (arrow 1 in Fig. 3).

ii) Decide the desired business, technological and organisational benefits of creating a cloud and balance it with the known limitations to cloud service security and trust, interoperability and portability (and also other important ilities discussed in Section 2.2). Note that these limitations are different between SaaS, PaaS and IaaS, as well as depend on the choice of Private-, Public- and Hybrid cloud. There are various systems engineering methods that help holistic decision making in this regard. For example, system thinking diagrams (Meadows, 2008) may reveal the cause and effect relationships among multiple change factors and are helpful in assisting management to avoid unexpected effects of the cloudification effort. Boehm et al. (2014, p28.) discuss known cross-relationships among ilities in the cloud. (arrow 1 in Fig.3)

iii) Based on the above two decisions, determine the current, future and transition boundaries between services provided from inside the organisation and those from the outside. Some decisions may be conditional based on technology analysis / forecasts; however, management may decide to build preparedness for being able to make certain future cloudification decisions, even though current technology may not be deemed mature or appropriate (arrow 1 in Fig.3).

iv) Determine a 'rolling' strategic roadmap with clearly defined benefits after each stage of the transition (rolling meaning that the roadmap is periodically reviewed in light of new information or developments in business, technology or organisation). (arrow 2 in Fig.3)

v) Define the design activities performed by the cloudification project (including the external service provider's possible participation in the project - arrows 4'…4''' in Fig. 3)

vi) Describe the rollout of changes in the business (including contracting, see arrow 5' in Fig. 3) and the deployment of the SaaS service by the service provider (arrow 5'' in Fig. 3)

vii) Define the respective service provisions in operation (arrows 6' and 6'' in Fig. 3).

Note that the SaaS entity has two parts: the actual service and the management of that service. The latter is supported by an Auditing Service to monitor performance and adherence to quality criteria against standards and SLAs (arrow 7 in Fig. 3).

viii) Select the SaaS service – which may be performed by Corporate Management or by the cloudification project (N.B. arrow 4''' shows the case where a cloud broker entity is engaged by the project).

Note that in Fig. 1 the cloud carrier (such as telecommunication service providers) was omitted, but when intending to commit to using a cloud service, the availability, bandwidth and trust aspects need to be checked and brokering and auditing services need to be engaged, in the same way as they would be used in conjunction with the cloud service and its provider.

It must be stressed that some entities represented in Fig. 3 are 'representative' rather than individual; e.g., 'SaaS' stands for multiple applications (bundles or suites), on the condition that organisationally speaking each bundle undergoes similar transition.
The similarity is based on the governance relationship between a transition programme, transition projects, and such bundles. This greatly simplifies the management of transition projects, because they all share the same architecture principles and mostly similar strategic objectives.

5 CONCLUSIONS AND FURTHER WORK

This paper has presented an Enterprise Architecture-based approach towards the cloudification effort, involving the adoption of a holistic paradigm that models the mutual influences (generative interactions) of the entities and artefacts involved in the project, in the context of their life cycles. The authors have argued and demonstrated that this approach enables a richer insight into the current and planning of 'cloudification readiness' of a business.

Using the EA-based approach, the findings are that firstly, cloudification requires the business to prepare 'on-the-fly' and the cloud services to be customised to achieve a useful match. Thus, moving to the cloud requires increasing and improving architecture competencies. Policies and principles dictating the design / select solution and the transition program must be put in place beforehand.

Secondly, cloudification is not a 'done-and-dusted', one-off exercise; the solution has to be maintained as the business structure and its environment (including the cloud it now resides in) constantly evolve. There is a need for an increase in human resources prominently featuring architecture competencies. Thirdly, successful cloudification requires (a) a good understanding of the enterprises' needs driving the value that can be derived from cloud computing, (b) an architected design of the solution to be able to efficiently utilize cloud services (Dodani, 2009) and (c) the ability to *grow* the cloud capabilities and value delivered in time.

The scope of this paper was limited to presenting cloudification on the example of the adoption of software as a service (such as expense management services). Further work should extend the present model by developing a reference model of a typical SaaS adoption roadmap, as well as expanding it into a more complex scenario demonstrating a combination of IaaS, PaaS, Information as a Service and SaaS in a hybrid cloud.

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