Conceptualising Cloud Migration Process

Conference Paper · July 2016

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Research in Progress

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Abstract

Adoption of cloud computing as an outsourcing strategy has grown rapidly among IT-based organisations in recent years. Research around migrating legacy systems to cloud environments is proliferated with a variety of approaches that are specific to particular scenarios. However, an overarching and integrated view of the cloud migration process does not exist in the current literature. As an attempt to ameliorate this shortcoming, this research applies a metamodeling approach and develops a generic cloud migration process model derived from the extant cloud migration literature. The proposed metamodel is not dependent or restricted to any specific cloud platform; rather it is an abstraction of phases, activities, tasks, and work-products that are incorporated in a typical migration process. It underpins a high-level and conceptual view of the cloud migration process and acts as a reusable knowledge repository to design situation-specific migration process models for a given migration scenario. The validity of the metamodel is demonstrated by analysing three existing cloud migration process models.

Keywords: Cloud Computing, Legacy Systems, Process Model, Metamodeling, Knowledge Sharing

1 Introduction

Many enterprise software systems that support IT services require high computing capability and resource consumption (Buyya et al., 2008, Armbrust et al., 2010, Koçak et al., 2013). Cloud Computing initiatives have received significant attention as a viable solution to address these requirements through offering a wide range of services, which are universally accessible, acquirable and releasable in a dynamic fashion, and payable on the basis of service usage. Hence, organisations consider cloud services as an opportunity to empower their legacy systems.

Moving large-scale legacy systems, which may have been in operation and stored voluminous data over years, to cloud environments is often not an easy task. Previous research acknowledge that legacy to cloud migration needs to be organised and anticipated through a methodological approach (Mohagheghi, 2011, Zhao and Zhou, 2014, Jamshidi et al., 2013, Babar, 2013). With the guidance of a well-structured approach, organisations can carry out an effective and safe legacy migration, instead of an ad-hoc migration which may result in a poor and erroneous result. With respect to this, a literature review reveals that the field is abundant with many methods, techniques, decision tools, and guidelines which help to make legacy systems cloud-enabled and exploit cloud services. Nevertheless, often these studies focus on the technical aspects of legacy migration and present a different viewpoint of the same migration process. Additionally, as people in the cloud computing community may come from different backgrounds, they may use different terminologies and phrases to refer to the same thing. Hence, it is hard to find any two migration approach texts or papers which adopt the same definition of the migration process. The variety of migration approaches which often are combined with specific technical considerations makes it hard for researchers and busy practitioners to digest, synthesise, and fully comprehend the migration process which is unstructured and dispersed in the existing literature. Developing generic models and taxonomies which demystify the ambiguous and multifaceted notion of cloud is a research strand in the field (Mell and Grance, 2009, Armbrust et al., 2010). In this regard, there is need to engage more thoroughly with establishing a unified view of cloud migration process has been requested by some scholars (Hamdaqa and Tahvildari, 2012, Zimmermann et al., 2012). For example, Hamdaqa et al., pointed out *there is need to detach the cloud application development process from specific cloud platforms* (Hamdaqa, 2011). However, to date, there is not an overarching view of such transition that reconciles multiple and disparate migration approaches into an integrated and coherent model. This research takes advantage of the fact that, while existing approaches may vary in their suggested migration activities and technical details, they address the common problems of cloud migration process and are semantically identical though they have been expressed by different terms.

To obtain a general understanding of cloud migration process, we defined this research objective: *to develop a broad and conceptual process model that includes phases, activities, tasks and work-products that are typically incorporated in the legacy system migration to the cloud*. We have developed a generic metamodel, which integrates all domain constructs in the cloud migration literature. The metamodel includes constructs in a descending order of granularity: *Phase*, *Activity*, *Task*, and *Work-Product.* To represent this metamodel in a clear and well-structured manner, we used a simple version of UML (UML, 2004), which is a semi-formal and de-facto standard for information modelling.

The proposed metamodel contributes to the literature in two aspects. Firstly, it uncovers and represents a broad and platform-independent process model of legacy system migration to cloud environments. This helps newcomers to the cloud computing field to envision the migration process of legacy systems to the cloud. Secondly, the proposed metamodel can facilitate the knowledge transfer about the cloud migration process both within and outside the cloud computing community. It serves as a language infrastructure to model and construct and manage situational cloud migration process model.

The rest of this paper is structured as follows: First, Section 2 describes the background on metamodeling literature. Section 3 presents the research methodology that was applied to develop the proposed metamodel which is described in Section 4. Section 5 describes a theoretical validation of the metamodel through a comparing with other existing migration model encompassing all migration activities. Finally, this paper ends with a discussion on the future research plan and conclusion in Section 6.

2 Background and Related Work

A metamodel is referred to as *a model of a model* or *a model of a collection of models* (Atkinson and Kuhne, 2003). A metamodel for a particular domain is a specific language to describe the domain in a well-structured manner along with guidelines to specialise it into a given context (Gonzalez-Perez and Henderson-Sellers, 2008). It includes all related constructs, their semantics and relations in the domain. A well-defined metamodel can provide a language infrastructure to generalise, freely model the domain with abstract constructs, and facilitate exchanging knowledge within the domain (Atkinson and Kuhne, 2003).

Developing metamodels is a common practice in information systems research and they have been applied in various domains, for example, disaster management (Othman and Beydoun, 2013), agent-based systems (Beydoun et al., 2009), and game industry (van de Weerd et al., 2007). The common feature of these metamodels is to help users in better understanding the domain of interest. Metamodeling has been continued as an interesting topic in the cloud computing field. Some examples are the metamodel for risk identification (Keller and König, 2014) and compliance and risk management for cloud services (Martens and Teuteberg, 2011). Given this promising background on the adoption of metamodels, this research distils the knowledge of cloud migration process into a generic metamodel. In contrast to existing metamodels in cloud computing, we focused on the lifecycle of cloud migration including phases, activities, tasks, and work-products which are common in a typical cloud migration.

3 Research Methodology

Following the guidelines in the design science research (Hevner et al., 2004), we develop our metamodel as a specific artefact and plan to iteratively evaluate it in the course of our research process. This paper focuses on presenting the developed metamodel as the result of the first phase of this research program. The metamodel creation process was carried out in two steps and started from February 2014 and finished in July 2015. A full document of these two steps is available at (Fahmideh, 2015). The following describes these two steps.

3.1 Step 1— Preparing of Knowledge Source

In the first step, we conducted a systematic literature review (SLR) to rigorously identify existing migration approaches in the literature. On the basis of the research objective was set in Section 1 and recommendations proposed by (Kitchenham et al., 2009), the SLR procedure was performed including the following steps.

Step 1.1- Defining Search Strings. The search strings that describe the research area were defined on the basis of guidelines described in (Dieste and Padua, 2007). The terms “Cloud”, “Cloud Computing”, “Service Computing”, “Legacy”, “Methodology”, “Process Model”, “Reference Model”, and “Migration” were set as the main keywords and based upon them, the different search strings were defined using the logical operator OR to include synonyms for each search string as well as the logical operator AND to link together each set of synonyms.

Step 1.2- Selecting Study Sources. The following databases were searched against the predefined search strings: IEEE Explore, ACM Digital Library, SpringerLink, ScienceDirect, Wiley InterScience, ISI Web of Knowledge, Google scholar. These databases cover the vast majority of published studies in IS and software engineering. In addition, the manually conducted search took into account topic-specific journals, conference, workshop proceedings and technical reports related to cloud computing.

Step 1.3- Defining Study Selection Criteria. The criteria for selection were based on a careful reading of the collected papers in order to select the most relevant ones addressing the research question stated in Section 1. Five kinds of research papers were identified from the literature: existing cloud migration methodologies, general approaches/frameworks, industrial experiences, patterns, and decision making framework. This research focused on the importance of selecting papers with a proper validation. Such papers would improve the reliability of the resultant metamodel.

Step 1.4- Conducting Review. This step dealt with the searching of the defined strings in Step 1.1 over scientific databases determined in Step 1.2. The title, abstract, and in the most cases, the content of each paper were scrutinised regarding the inclusion and exclusion criteria, as defined in Step 1.3. Forward and backward searches were conducted so that studies were cited in the references or related work sections of the paper, were fed into the conducting review process as additional sources. At the end of this step 78 papers were found for further review after applying the inclusion and exclusion criteria.

Step 1.5-Extracting Constructs and Their Definitions from the Source. In this step, all the constructs and their definitions required for the metamodel were manually identified and extracted from all the 78 papers. It was performed by reading each paper and identifying constructs which had been defined by it. The output of this step was a list of 413 constructs along with their definitions as extracted from the identified studies.

3.2 Step 2— Creating the Metamodel

Following the guidelines for metamodeling introduced in (Othman et al., 2014, Beydoun et al., 2009), a top-down and bottom-up iterative process was performed to create the target metamodel from the 78 studies in the second step. The following sub steps were performed.

Step 2.1-Grouping Similar Constructs. The objective of this step was to group the identified constructs into a list of overarching constructs on the basis of their similarities. This step was a gradual process and conducted in a number iterations namely, creating an initial set of overarching constructs as a frame to group 413 identified constructs in step 1 and restructuring and perfecting the overarching, especially tuning their granularity and the degree of classification or aggregation level.

Step 2.2-Organizing the Constructs into Activities and Phases. In order to achieve a coherent metamodel and reduce complexity of understanding of the cloud migration process, the identified constructs were organised into three hierarchical levels. Organising the constructs was based on SPEM (Software Process Engineering Model) formalism (OMG, 2002), a common notation to represent building blocks of software development processes in a descending order of granularity mainly *Phase*, *Activity*, *Task*, and *Work-Product*. Furthermore, we defined stereotype *Principle* which refers to constructs that should be taken into account during cloud application design.

Step 2.3-Defining the Relationships Between the Constructs. In this step, the relations between the constructs were identified and depicted. The symbols (—), (—▷) and (—◇) were used to represent Association, Specialization and Aggregation relationships, respectively. The relationships were identified on basis of the identified studies from the literature and output from Step 2.3.

4 The Resultant Metamodel

The derived metamodel from the cloud migration literature provides a broad understanding of cloud migration process. At the same time it does not narrow down the technical and implementation details demanded in specific cloud migration scenarios. Those details are deferred to the individual instantiation of the metamodel where the users of the metamodel can apply their own implementation techniques. This enables gradual refinement and maintains appropriate separation of concerns during the migration process. As shown in the diagrammatic sketches 2 to 5, the metamodel presents the classes of development constructs in the four phases of *Plan*, *Design*, *Enable*, and *Maintain*. Each phase encompasses a number of classes of activities which constitute tasks corresponding to the required workproducts. This hierarchical approach allows expressing cloud migration at multiple abstraction levels where a lower level adds detail to the level above. A full description of the metamodel constructs can be found at (Fahmideh, 2015).

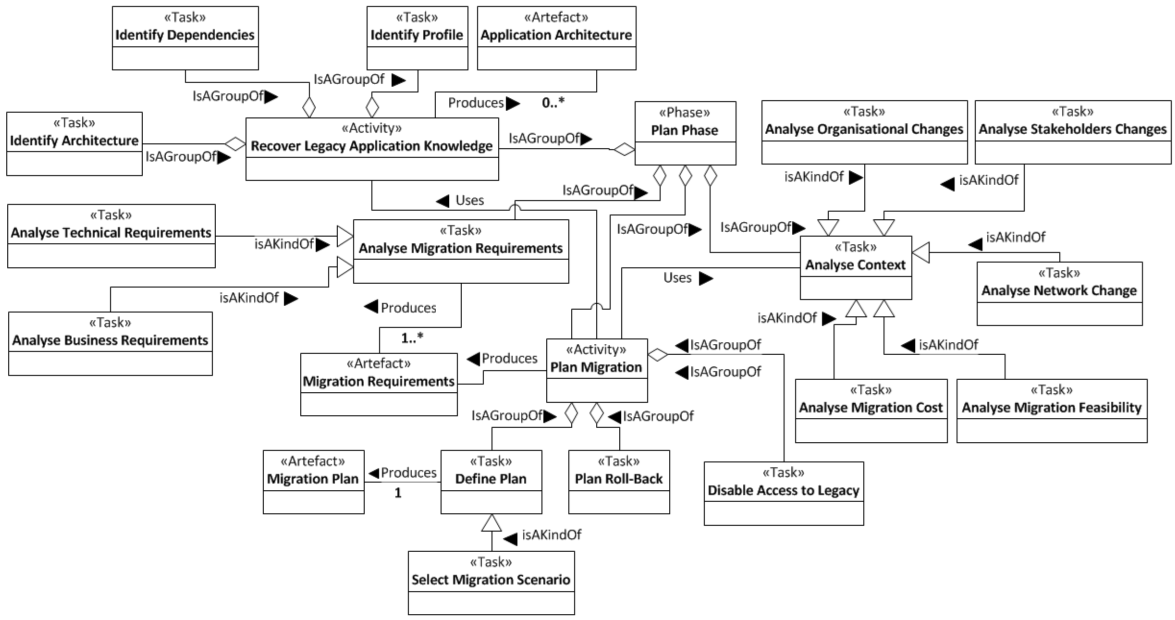

Figure 2. Plan phase

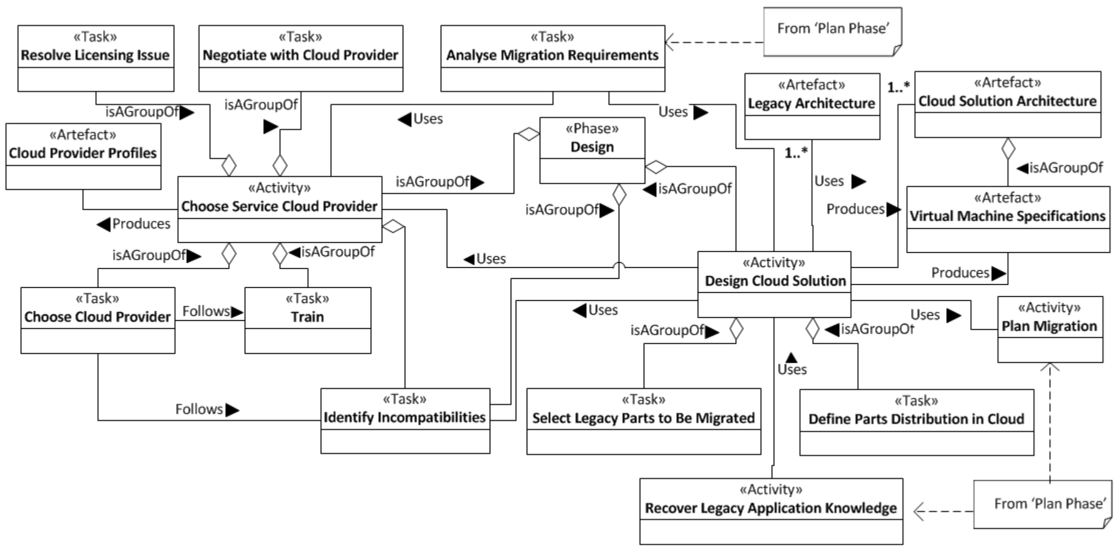

Figure 3. Design phase

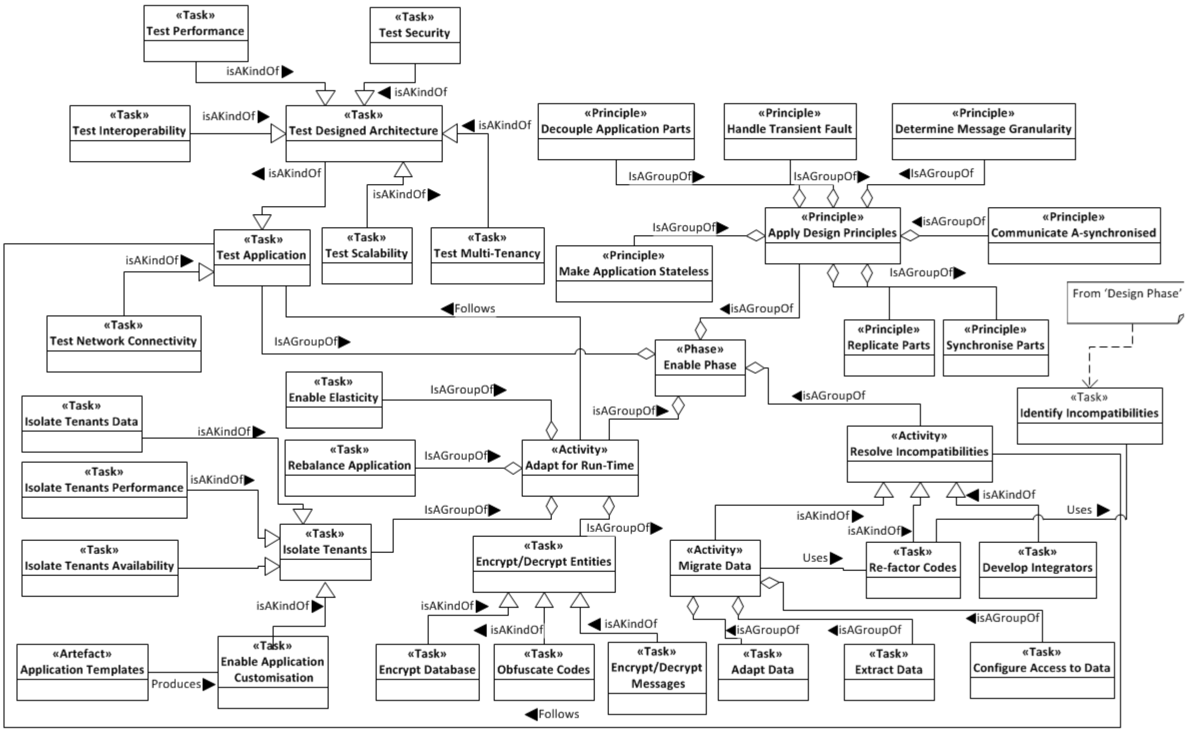

Figure 4. Enable phase

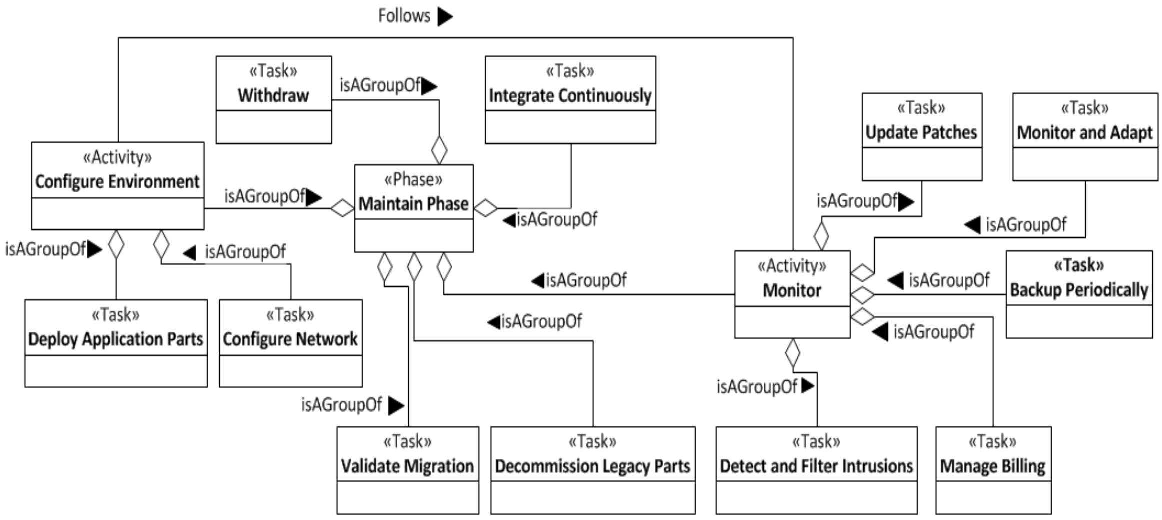

Figure 5. Maintain phase

5 Validation

The proposed metamodel is expected to have sufficient generality and expressiveness. Several techniques are used to validate it. A first common technique, suggested in Sargent 2005 (Sargent, 2005), compares a metamodel with existing metamodel/models to verify that metamodel constructs can be mapped to them. Another technique described in De Kok (De Kok, 2010) recommends a *frequency-based selection technique* based on the premise that the quality of a metamodel depends on using most common constructs in the domain. Lindland et al. define another technique, *pragmatic quality assess-*

ment, which evaluates how a model can be constructed, comprehended and modified by its audience. This is determined with many properties such as quality of diagrams or text, icons and names, layout and closeness of models in the domain (Lindland et al., 1994). They also define *Semantic quality assessment* of the correctness and relevancy of the metamodel to the domain, and its completeness to check that the metamodel makes all the constructs, as much as possible, about the domain (Lindland et al., 1994). A last technique worth mentioning too is *Traceability* which validates the metamodel applicability to represent different real world scenarios. This ensures metamodel constructs can be instantiated in various scenarios (Sargent, 2005). Our research plan is to use a combination of these techniques. Specifically in this paper, we use the *comparison* technique to demonstrate how the metamodel is sufficiently comprehensive to generate different constructs defined in other existing cloud migration models. We selected three examples as benchmarks to appraise the completeness of the metamodel. These cloud migration models are Cloud-RMM (Jamshidi et al., 2013) Legacy-to-Cloud Migration Horseshoe (Ahmad and Babar, 2014), and ASDaaS (Benfenatki et al., 2013). For each model, we compare its defined constructs with the metamodel's constructs. That is, the definitions of constructs in the process model are checked against the metamodel to find the corresponding constructs. We indeed found that the metamodel supports most of the constructs in these process models. For example, in Legacy-to-Cloud Migration Horseshoe, there is a construct named as *Decision on Cloud Providers*. The metamodel generates this construct through its concept *Cloud Provider Selection*. Similarly, the construct *Migration Planning* is generated from our proposed metamodel supports using its concept *Define Plan*. All such correspondences between the proposed metamodel and Cloud-RMM are examined. For instance, Cloud-RMM defines the construct *Requirement Analysis* which is covered by the metamodel through the construct *Migration Requirement Analysis*. Table 1 shows how constructs in these models correspond with the constructs in the metamodel. The results seem to indicate that the constructs in the metamodel can indeed generate the constructs defined in the existing migration models. That is, the selected examples can be modelled by using the proposed metamodel. This gives an initial confidence that the metamodel is valid. However, we do not claim that the metamodel is comprehensive at this stage and there still is a possibility to extend the metamodel with new constructs as discussed in the next section.

Process Model	Model's construct	The metamodel's construct
Legacy-to-Cloud Migration Horseshoe	Feasibility Study	Analysis Context
	Requirement Analysis	Analyse Migration Requirements
	Decision on Cloud Providers	Choose Service Cloud Provider
	Migration Strategy Development	Select Migration Scenario
	Legacy Architecture Description	Recover Legacy Application Knowledge
	Architecture Change Implementation	Resolve Incompatibilities
	Code Consistency Conformance	Recover Legacy Application Knowledge
	Migration Planning	Plan Migration
	Cloud-Service Architecture	Design Cloud Solution
Cloud-RMM	Feasibility Study	Analysis Context
	Requirement Analysis	Analyse Migration Requirements
	Decision on Provider	Choose Service Cloud Provider
	Sub-System to be Migrated	Select Legacy Parts to Be Migrated
	Migration Strategies Development	Plan Migration
	Code Modification	Re-factor Codes
	Architecture Recovery	Recover Legacy Application Knowledge
	Data Extraction	Extract Data
	Architecture Adaptation	Resolve Incompatibilities
	Test	Test Application
	Deployment	Deploy Application Parts
	Training	Train
	Effort Estimation	Analyse Migration Cost

	Organization Change	Analyse Organisational Changes
	Distribution	Define Parts Distribution in Cloud
	Multi-Tenancy	Isolate Tenant
	Elasticity Analysis	Enable Elasticity
ASDaaS	Requirements Expression	Analyse Migration Requirements
	Service Discovery	Choose Service Cloud Provider
	Service Composition	Define Parts Distribution in Cloud
	Establishing the Contract between the Customer and the Provider	Negotiate with Cloud Provider
	Tests and Validation	Test Application
	IaaS Selection for Application Deployment	Choose Service Cloud Provider

Table 1. The metamodel supports constructs in existing cloud migration models

6 Future Research and Conclusion

The analytical comparison of the metamodel discussed in the previous section is the first step to validate the metamodel. We plan to get insights of cloud computing experts to further refine and extend the metamodel through an iterative process. We will perform a structured on-line survey to collect experts' viewpoints about the completeness and perceived importance of the metamodel. More specifically, they will be asked to rate the importance of the constructs in the proposed metamodel on a 1–7 Likert scale, provide comments on the metamodel, and suggest additional constructs for consideration in the metamodel. Furthermore, while the metamodel is domain-independent and generic, we anticipate that real-world cloud migration scenarios can be modelled through the metamodel constructs. This conformity can be validated through conducting a series of case studies. The results of this validation can be used to refine the metamodel, leading to the next version of the metamodel.

This paper introduced a generic cloud migration process model which enhances our understanding of what such cloud migration entails from a process model perspective. It essentially acts as a language infrastructure which unifies describing the various extant process models for moving legacy systems to cloud environments. The metamodel includes constructs which are common for such transition while not providing details demanded for every cloud migration scenario. The formalism used to represent the metamodel enables later extensions of the metamodel adding new constructs and customisations for different migration scenarios.

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