Business-Oriented Evaluation of the PaaSage Platform

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***Abstract*— Cloud computing is an efficient and cost effective realization of the utility function principle. Over the last years, a vast pool of choices for businesses has been created. This diversity of cloud infrastructures, platforms, and tools creates several challenges. In particular, it hinders interoperability, promotes vendor lock-in, but more importantly prevents businesses from making informed and optimal decisions when transitioning to the cloud. This paper presents the results of a business-oriented evaluation for cloud computing in the industry in Cyprus. The evaluation confirms that a set of key features is important for overcoming the above challenges and enables businesses to exploit the full potential of the cloud. Finally, PaaSage, a platform for autonomic multi-cloud deployment addressing these key features, is shortly presented.**

Keywords—cloud computing; cloud deployment; component-based development

I. INTRODUCTION

Cloud computing has changed the business landscape since it offers a new model that promises to deliver cost-effective utility computing based on a pay-on-demand business model. This market uptake has created a diversity of cloud technologies and a landscape of an ever-growing number of providers offering a multitude of infrastructure-as-a-service (IaaS) and platform-as-a-service (PaaS) solutions [1]. This has the advantage that businesses have a variety of technologies and cloud offerings to choose from. However, these choices create interoperability challenges, promote vendor lock-in and impede businesses by increasing the complexity in making informed decisions in terms of transitioning to the cloud.

There are different aspects to take into account when considering moving to the cloud. The decision is based on an assortment of requirements, conditions, constraints and preferences. For instance, financial businesses such as banks, audit and law firms have a strong requirement for data confidentiality, and thus the decision is expected to be a choice of a private cloud. If we take also into consideration the necessity for firms to reduce costs, a hybrid cloud deployment is also a desirable choice, where for example the applications servers can be deployed in a public cloud, while the database servers are deployed in the private cloud of the firms. Hence, the business needs to decide and make a selection among many different cloud providers.

This work focuses on identifying, defining and validating the key features supported by diverse Cloud tools, including the PaaSage[1] platform, a Model-based Cloud Platform Upperware. In particular, these tools offer agility for the business in terms of deployment, monitoring, adaptation, and deployment of Cloud applications. Foremost, a business-oriented evaluation is performed during two industrial events in Cyprus, which aims to prove the importance of these features for exploiting the potential of the Cloud. Moreover, relevant tools are examined to showcase that these tools base their efforts on providing the best possible support for these key features. Finally, the features of the PaaSage platform that address the above are briefly presented.

The rest of the paper is structured as follows. Section II presents the results of the business evaluation and the definition of the key features. Section III defines the study and examination of relevant Cloud tools and their support for the features. The next section serves as an introduction to the PaaSage platform and finally, section V concludes the paper.

II. A BUSINESS-ORIENTED EVALUATION

The evaluation presented in this section was performed in two cloud computing events conducted in Cyprus earlier this year: the 5th ICT Summit and Exhibition and TechConnect. The key objective was to identify and validate the significance of key features for exploiting the full potential of the Cloud, as viewed by professionals involved in ICT but also business activities that consider the Cloud as an enabler.

Fig. 1 presents the results obtained from the completion of Part A of the business questionnaire[2], in relation to the experience of participants and their organisations with Cloud computing. In specific, Question A refers to the participant's personal experience with Cloud computing, as well as Cloud deployment. Moreover, Questions B and C refer respectively to the organisation's experience with Cloud and Multi-Cloud deployment. The answers to the questions show, respectively, that 76% of the participants and their organisations have medium-to-very-high knowledge in terms of the concepts of Cloud computing and Cloud deployment, while for Multi-Cloud deployment the percentage drops to 68%. This confirms

[1] http://www.paasage.eu/
[2] https://goo.gl/NoyvSZ

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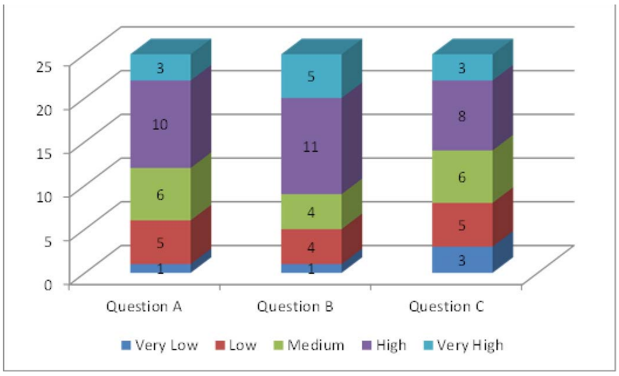

Fig. 1. Results of the Business Questionaire – Part A.

that businesses in some cases are not well informed on the capabilities, and thus do not fully exploit the potential of the Cloud. The very-low-to-low results refer to businesses outside the technology domain (e.g., auditing, lawyer firms), which completed the questionnaire.

The second part of the questionnaire was defined so as to validate the main features that a platform should provide in order to allow exploiting the full potential of the Cloud. The following list enumerates and defines a set of cloud key features evaluated using the prepared business-oriented questionnaire.

- ***Multi-Cloud Provisioning***: Provision your Cloud infrastructure easily and across multiple providers [2]. Manage your Cloud servers throughout their full life-cycle, including your physical servers.
- ***Automated Deployment***: Deploy applications flexibly, automated and independently from the Cloud providers according to the applications' technical requirements.
- ***Monitoring and Adaptation***: The consumer can dynamically provision and release computing resources without requiring human interaction with the provider.
- ***Scalability***: Scalability is a planned level of capacity, with appropriate overhead, that you anticipate your company's systems to require over time, in addition to the ability to scale in a quick and easy manner when (and if) you need more (or less) resources.
- ***Elasticity:*** Ability to handle sudden, unanticipated, and extraordinary loads in an automated manner. This results in a massive, but brief, influx of users and load on the system.
- ***Deployment Optimisation***: The consumer can unilaterally be supported with continuous monitoring and optimisation of the deployment solution.
- ***Cloud Bursting***: Allows an application that runs in a private Cloud to burst into a public Cloud or hybrid deployment when the demand for computing capacity spikes.

Appropriate questions were defined for each of the aforementioned features in order to assess their importance. For instance, in terms of Multi-Cloud provisioning the participants were asked to state their answer to the following: *"I think that my organization would benefit from exploiting multiple Cloud infrastructures"*. The results showcased that businesses do value as important the ability to exploit multiple cloud infrastructures. In fact, as shown in Fig. 2, 20 out of the 25 businesses (80%) agree that it is vital to exploit multiple cloud providers. In respect to having the capability to perform automated deployment independent of the cloud provider, more than 80% of the participants declared that they somewhat agree or strongly agree with this point. Specifically, for Question E: *"I think that simplifying the management of Cloud services is useful"*, essentially all participants stated that they agree with this statement and also believe that automated deployment provides a vital feature for businesses (Question D). The optimization feature, i.e., Question F: *"Taking into account the characteristics of available cloud platforms (e.g. costs), the data to be used and the end-user preferences or restrictions (e.g. price, location, availability, privacy, etc.) for producing an optimal deployment solution is important for my business"*, is highly important for all businesses as shown in Fig. 2.

Finally, the evaluation results reveal that the ability to monitor and adapt applications is vital for a business. Going a step further, up to 24 out of 25 businesses acknowledged that monitoring, scalability, elasticity and Cloud bursting are critical for ensuring operational integrity of the business. Overall, the results of the survey demonstrated the need for more flexibility in the management of cloud environments and applications deployed on the cloud.

III. Open Source and Commercial Cloud Tools

In order to further demonstrate the necessity for introducing Cloud tools, the PaaSage platform and related tools are validated against the set of features that are defined as essential in this work for exploiting the benefits of the Cloud. In fact, the study is not performed as a means of comparison, but to showcase the added value that these shared features bring for many businesses and their importance in making informed and optimal decisions when transitioning to the cloud. Fig. 2 showcases the list of products that can be positioned within the SaaS and PaaS sphere. Azure, Amazon Web Services (AWS), VMWare and OpenStack are considered as IaaS offerings used by these tools, and thus excluded from the comparison. Note that the study and analysis on tools' support of these features is based on their documentation, white papers and tutorials. The level of support of a feature by a tool is defined as: *YES* (*Y*), *NO* (*N*) or *Limited* (*L*).

Tools support the *multi-cloud provisioning* feature along two directions. The first direction is the support for applications' deployment on mainstream Cloud providers (i.e., AWS, Azure, OpenStack and VMWare), even on the basis of hybrid configurations. Such systems refer to the PaaSage platform, RightScale and Apache Brooklyn, which support major providers, and Cloudify, which has an open plug-in architecture to support other Clouds such as Amazon AWS, GCE, CloudStack, as well as Linux containers such as Docker. Cloudify currently has built-in plug-ins available for SoftLayer, Apache CloudStack and VMware. On the other hand, tools like OpenShift, IBM Bluemix and CloudFoundry offer multi-cloud provisioning capabilities respectively to Cloud Foundry Core compatible instances (AppFog, Tier 3, Uhuru Software, Micro Cloud Foundry and CloudFoundry.com), Bluemix-enabled.

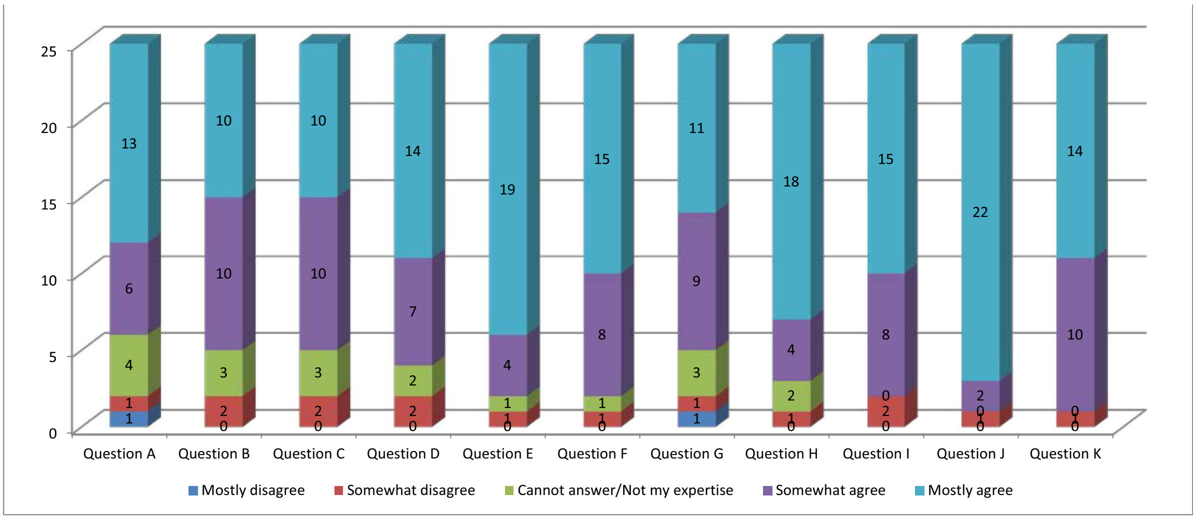

Fig. 2. Result of the Business Questionaire – Part B.

Clouds (mainly OpenStack) and clouds running OpenShift Runtime Environments. These tools support public, private and hybrid configurations on their own proprietary clouds.

The *automated deployment* feature is supported by all tools, while the differences in the scores have to do mainly with the support or not of mainstream Cloud infrastructures. The PaaSage platform offers a model-driven approach, which incorporates workflow-driven, script-based deployment, of applications. Cloudify offers a similar approach based on a standard (i.e., TOSCA) [3]; although not model-driven. It provides a TOSCA-based Cloud orchestration platform that allows graphical-based design of blueprints for portability and management of Cloud applications. A blueprint defines the application topology and deployment plans. Both PaaSage and Cloudify support workflow-driven, script-based deployment, but at a higher level of abstraction than other solutions and with aim to increase automation. Apache Brooklyn uses a similar approach to Cloudify, since it employs the blueprint concept that defines an application, using a declarative YAML syntax supporting JVM plugins. The rest of the tools employ mainly web dashboards that offer application development and workflow-driven, script-based automation capabilities.

Monitoring and adaptation is an enabler for scalability, elasticity, optimisation and cloud bursting. The PaaSage platform supports monitoring and adaptation through the developed probes for CPU and memory, but also provides the capability for the application owner to develop additional monitoring probes. These probes can be used irrespective of the Cloud provider. For CloudFoundry, monitoring is supported on the five Cloud Foundry Core compatible instances. Moreover, for Cloudify, there is the need to develop monitoring tools and interface them with Cloudify to get events and metrics into Cloudify's Policy Engine. In terms of OpenShift the capabilities are limited to basic web traffic monitoring, Heroku core product does not support this feature, while monitoring and adaptation can be supported by paid add-ons such as HireFire and Scale Adept. RightScale supports server and application monitoring, as well as triggering of adaptation and notifications with alerts and escalations. This is achieved with the use of Tags that utilise CPU and memory metrics. Monitoring and adaptation in Bluemix is provided through the auto-scaling add-on and its triggers (CPU, memory, Java heap memory). Finally, Apache Brooklyn supports the collection of metrics that can be fed into policies, which automatically take actions.

Both *scalability and elasticity* are features provided by the PaaSage platform: The CAMEL language allows defining scalability rules acting on simple and user defined composite metrics. Based on the developed probes, these metrics are continuously monitored and the rules are evaluated, triggering the needed scalability and elasticity actions within a single Cloud provider when the conditions are violated. Using comparable approaches, RightScale and IBM Bluemix provide strong support for scalability and elasticity. In the case of RightScale, horizontal auto-scaling is configured with Voting Tags. These server tags are used for the purpose of setting up scalable, alert-based server arrays. In specific, a server array is defined so that additional server instances are launched into the array (grow) or removed (shrink). Correspondingly, Bluemix provides an auto-scaling add-on and uses the currently implemented auto-scale triggers (CPU, memory, Java heap memory) at runtime. Overall, these three cloud tools support CPU and memory metrics, while they provide capabilities in order to develop extra probes for supporting other metrics.

The rest of the products have various levels of support for scalability and elasticity. CloudFoundry has support for horizontal scalability on the CloudFoundry Core compatible instances, while Cloudifyis similar since it offers support for Softlayer, Apache CloudStack, and VMWare by writing scalability rules in text-based recipes. In terms of OpenShift, the developed applications are not scalable by default. It offers the possibility to enable the auto-scale functionality in the web dashboard for monitoring web traffic. Furthermore, manual scaling is also possible by issuing console commands. The Heroku Cloud offering does not provide support by default, but third-party add-ons such as HireFire and Scale Adept can

TABLE I. OPEN SOURCE AND COMMERCIAL CLOUD TOOLS

Feature / Product	Model Driven	Multi-Cloud Provisioning	Automated Deployment	Monitoring	Scalability	Elasticity	Deployment Optimisation	Cloud Bursting
PaaSage	Y	Y	Y	Y	Y	Y	Y	Y
CloudFoundry	N	L	Y	Y	Y	Y	N	Y
Cloudify	N	Y	Y	Y	Y	Y	N	Y
OpenShift	N	L	Y	L	L	L	N	L
Heroku	N	L	Y	N	N	N	N	N
RightScale	N	Y	Y	Y	Y	Y	L	N
IBM Bluemix	N	Y	Y	Y	Y	Y	Y	Y
Apache Brooklyn	N	Y	Y	L	L	L	L	N

be purchased and used for load-based scaling and schedule-based scaling. Finally, Brooklyn includes the available policies of Auto-scaler and Load Balancer, and provides the possibility to develop new policies (e.g., CPU, memory) to perform custom runtime management.

A key characteristic is the capability to *optimise the deployment* of an application. PaaSage offers the capability to define requirements in the CAMEL model optimisation, which are types of soft-requirements that indicate optimisation objectives on metrics or properties. In this sense, optimisation requirements indicate to the PaaSage platform that the respective values of these metrics or properties should be optimised in the context of a particular application or the component of an application. For instance, an optimisation requirement could indicate that the cost for the deployment of a particular application must be minimised. IBM Bluemix provides an analogous approach and strong support for dynamic optimisation. It provides the Decision Optimization on Cloud (DOcloud) tool that is part of the BlueMix (PaaS) system. DOcloud utilises the Optimization Programming Language (OPL) models [4], which are defined using the CPLEX Optimization Studio. The OPL language provides a natural mathematical description of optimization models. Its powerful syntax supports the expressions needed to model and solve problems using both mathematical programming and constraint programming. Explicitly, OPL offers mathematical and constraint programming models that allow defining decision variables and decision expressions over index sets to represent choices and key performance indicators affected by them. Hence, it enables the definition of an objective function of the decision expressions to maximise or minimise.

Finally, the concept of *Cloud bursting* allows provisioning an application that runs in a private cloud to burst into a public (or hybrid) cloud when the demand for computing capacity spikes. In many cases this is critically important for a business since it enables to meet unpredicted demands, e.g., by transitioning to the public cloud that offers more resources, and then reverting back to the private cloud. Many of the tools provide support for the Cloud bursting feature. In specific, the PaaSage platform provides support for Cloud bursting based on the scalability rules and metrics defined in the model. CloudFoundry supports Cloud bursting, as with scalability and elasticity, on the Cloud Foundry Core compatible instances. It is performed with the autoscaler-process, which monitors the queues, and based on configurable thresholds, increases or decreases the number of worker- process instances via the Cloud Foundry API. Cloudify supports Cloud bursting on the supported clouds by writing recipes, while OpenShift allows deploying across private and public (OpenShift) Clouds with the intelligent capacity on demand capability of the tool. In terms, of Heroku and RightScale the study of relevant documentation did not reveal any support for Cloud bursting. The IBM Bluemix system does not offer built-in support for Cloud bursting, but it can be used together with the IBM UrbanCode tool to support Cloud bursting and hybrid cloud deployment. Finally, the study of relevant documentation did not reveal any details for the support of Cloud bursting by Apache Brooklyn.

Overall, PaaSage proves to comply with all key features defined for Cloud environments in comparison to the other tools. Note that, however, emphasis is given in the facilitation of the development process and in the automation in cloud-relevant decisions (i.e., hybrid deployments).

IV. FEATURES OF THE PAASAGE PLATFORM

The key objective of PaaSage, served at the core by the CAMEL domain specific modelling language (Fig. 3), is to define a CAMEL model, which is then transformed by the rest of the PaaSage components to a deployed application in one or more Clouds (i.e., private, public, or hybrid). PaaSage adopts CAMEL models that are progressively refined throughout the PaaSage workflow and which drive the integration with and across the components responsible for the *three life-cycle phases of (i) modelling, (ii) deployment and (iii) execution of multi-cloud applications* [5]. CAMEL integrates and extends existing domain-specific languages (DSLs), namely the Cloud Modelling Language (CloudML) [1], Saloon, and the Organisation part of CERIF [5]. In addition, CAMEL integrates new DSLs developed within the project, such as the Scalability Rule Language (SRL) [6]. The abstract syntax of CAMEL describes the set of cloud concepts, their attributes, and their relations, as well as rules for combining these

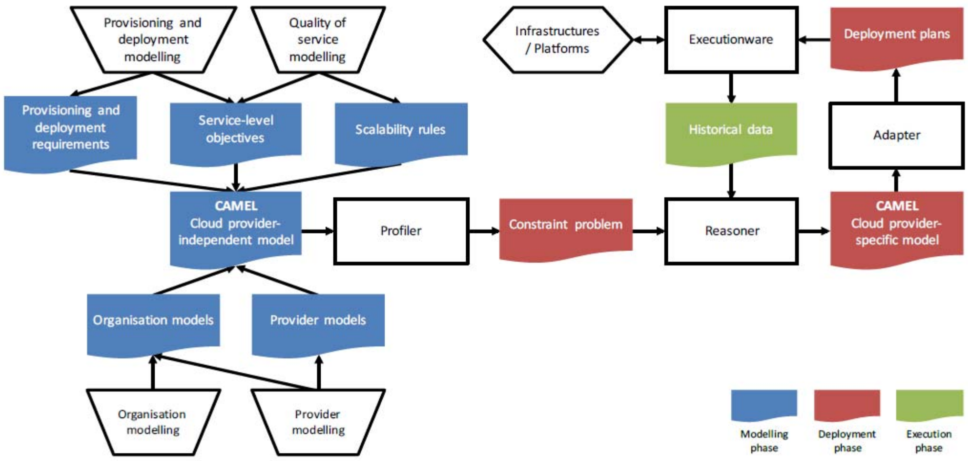

Fig. 3. The PaaSage workflow.

concepts to specify valid statements that conform to this abstract syntax.

The application's CAMEL model is first defined using the developed Eclipse-based modelling editors, which in turn is transformed by the *Upper Ware*. The *Upper Ware* consists of a set of software components (i.e., a profiler, a reasoning engine, and an adapter) that transform the model, to derive application deployment plan, which satisfies all the constraints and goals for the deployment set defined by the user in the CAMEL model. The generated deployment plan enables selecting one or more Cloud providers and platforms (i.e., private, public, or hybrid). The result of the Upper Ware's model transformations is the generated deployment plan, i.e. the application's installation scripts passed to the *Execution Ware*, which is responsible to instantiate the various application components on the selected Cloud providers and platforms. Furthermore, the *Execution Ware* is responsible to monitor the set of defined metrics, so as to make autonomous scalability, elasticity and Cloud bursting decisions within the boundaries of the deployment plan. In the case the application execution triggers conditions that cannot be satisfied by the current deployment plan, the *Execution Ware* will pass control back to the *Upper Ware* to find a more suitable plan for the current application context if the scaling limits of the current deployment plan are reached. The monitored metrics will subsequently be consolidated as statistical knowledge in the metadata database to guide decisions on future deployment plans. This feedback loop controlling the application deployment is depicted in Fig. 3, showcasing the PaaSage workflow and the different parts of the *Upper Ware* and the *Execution Ware*.

V. Conclusions

In the current paper we have presented a business-oriented evaluation reflecting properties of Cloud computing that are important for organizations. The survey confirmed that businesses require flexibility and the possibility to select different providers for deploying different applications. In many cases Multi-Cloud deployment between private and public Clouds is also desirable. The evaluation also validated that another fundamental requirement is to be able to take informed and optimal decisions, as well as be able to efficiently monitor, adapt and optimise deployments. This work proceeded with a study and analysis of existing cloud tools, including the PaaSage platform, in regards to the level of support they can offer for the key cloud features confirmed via the evaluation as important. Based on this comparison we introduced briefly the features of the PaaSage platform.

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