A Cloud-driven View on Business Process as a Service

Jörg Domaschka, Frank Griesinger, Daniel Seybold and Stefan Wesner
Institute of Information Resource Management, Ulm University, Albert-Einstein-Allee 43, 89081 Ulm, Germany

Keywords: Business Process as a Service, BPaaS, Cloud Computing, Business-IT Alignment, Workflow, Modelling.

Abstract: Cloud computing is the promise to provide flexible IT solutions. This correlates with an increasing demand in flexibility of business processes in companies. However, there is still a huge gap between business and IT management. The evolution of cloud service models tries to bridge this by bringing up fine grained and multi-dimensional service models. One of the new service models is Business Process as a Service (BPaaS), which promises to bridge the gap from business process to cloud computing. Yet, the BPaaS paradigm is not thoroughly classified with respect to the cloud computing characteristics. In this paper we introduce a first classification of the BPaaS paradigm with the focus on the common cloud characteristics. Therefore, we analyze the traditional path from a business process model to its execution via on-demand resources and derive a leveled model for BPaaS. For each level, we introduce the entities on that level in terms of *(i)* correlation to cloud characteristics, *(ii)* concepts and *(iii)* tools, and evaluate its cloudification options, *i.e.* the ability to support the provision of a business process as a service. The presented work enables the categorisation of items in the BPaaS paradigm and outlines how traditional business processes can be enabled for cloud delivery. This classification and analysis will be extended, once the BPaaS paradigm reached wider acceptance in academia and industry, and more standards evolved.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

1 INTRODUCTION

The cloud computing paradigm has evolved from its initial compute-oriented service models (IaaS, PaaS, SaaS) (Mell and Grance, 2009; Foster et al., 2008) to more fine grained and multi-dimensional service models (Kachele et al., 2013) capturing amongst others the storage and networking dimension. Along with this evolution cloud computing has become a large driver of business models and innovation. While adopters of cloud computing originally were IT-oriented companies, SaaS also allows non-technological companies to benefit from cloud computing.

Yet, SaaS offerings are usually inflexible and their vendors expect them to be one-size-fits-all solutions for their customers often ignoring that they need to integrate into the users' existing business processes. In order to work around this inflexibility, new and innovative cloud service models are needed that support non-IT customers with a business-first view (Smith, 2012) and due to that allow support existing business processes. Furthermore, offered solutions should be able to grow (and shrink) with the size of a company.

Here, a promising approach is the *Business Process as Service (BPaaS)* service model (Papazoglou and van den Heuvel, 2011). Despite its use in several publications (Papazoglou and van den Heuvel, 2011; Barton and Seel, 2014; Woitsch and Utz, 2015b), and even the defintion of an architecture and release of an implementation (Woitsch and Utz, 2015a), the term BPaaS has never been defined. In consequence, it is unclear what are the true capabilities and features offered by this service model.

The main contribution of this paper is a first attempt to close this gap by re-visiting classical and widely-accepted definitions of cloud computing and investigating the steps executed in traditional business-IT alignment which executes the necessary steps to support business processes with IT solutions. From these considerations, we derive a hierarchy of five different levels of a business process with varying technical complexity. We then define BPaaS that offers at least a distributed, multi-tenant capable workflow engine where users can upload custom executable business processes that may even access external services. This type of business processes constitutes the lowest layer of our hierarchy. However, we also state that a BPaaS platform should also have support for the respective other layers and in particu-

Domaschka, J., Griesinger, F., Seybold, D. and Wesner, S.
A Cloud-driven View on Business Process as a Service.
DOI: 10.5220/0006393107670774
In *Proceedings of the 7th International Conference on Cloud Computing and Services Science (CLOSER 2017)*, pages 739-746
ISBN: 978-989-758-243-1
Copyright © 2017 by SCITEPRESS – Science and Technology Publications, Lda. All rights reserved

lar for both vertical and horizontal transitions between individual processes.

The remainder of this paper is structured as follows: Section 2 introduces related terms, Section 3 provides a technical overview on BPaaS and its relation to the cloud characteristics. Section 4 discusses the concepts and tools for the cloud-enabling of business processes. Section 5 presents related work. Finally, Section 6 concludes.

2 TERMINOLOGY

This section sets the basis for classification of BPaaS by introducing basic concepts and terms for the business process and cloud context.

2.1 Clouds and Services

The NIST standard on cloud computing (Mell and Grance, 2009) defines the three well-known cloud service models (IaaS, PaaS, SaaS) and private and public cloud deployment models. It also introduces a hybrid deployment model where multiple cloud environments generate a higher-level service. Besides these descriptive aspects of cloud computing, the standard also demands these five essential characteristics from any cloud offering: on-demand self-service, broad network access, resource pooling and multi-tenancy, rapid elasticity, and measured service.

While all cloud offerings are provided *as a service*, the term *service* can be used with a wider meaning. In general, we assume that a *(remote) service* is a software entity providing a well-defined functionality through a *service interface* and is realised through a *service implementation*. The service interface defines the protocol to use and the API (available operations and input/output to them). A *cloud service* is a remote service providing the five cloud characteristics.

From an inside perspective, a service implementation consists of $1 \ldots n$ *software components*. In order to operate the service, *software deployment* ensures that the components are instantiated by installing them over a set of physical or virtual machines. When the service itself shall be run over cloud resources, *Cloud Orchestration Tools (COTs)* can automate the deployment in terms of communicating with cloud provider APIs and the life-cycle processing of the software component and its respective actions, such as installation, startup, shutdown and adaptations, such as scaling or service substitution (Baur et al., 2015).

2.2 Business Process Terminology

Business Processes (BPs) are seen as a graph of manual, semi-automatic, and automatic actions, aiming to achieve an organisational goal. Their goal is to align all actions within an organisation with the business goals, independent from who performs them (humans, machines). Actions are typically described dependant on time, role, and place; and every "handover" of a task is seen as the border of an activity. Consequently, a *Business Process Model (BPM)* is an abstract representation of a business process, often defined formally, *e.g.* through a modelling language such as BPMN (Group, 2011).

Using BPMs, *business process management* deals with improving corporate performance by managing and optimising the BPs of a company. Business process management sees BPs as important assets of an organization that must be understood, managed, and developed to announce value-added products and services to clients or customers. Traditionally, the business process management lifecycle comprises the steps design, modelling, execution, and monitoring.

BPs can best and most flexible be managed, executed, and improved once large parts of them have been automatised through the use of IT systems. Here, *business-IT alignment* aims at using IT in the most efficient way to achieve business objectives and to improve financial performance or marketplace competitiveness (Woitsch et al., 2009).

In addition, business IT-alignment enables the transformation from domain-centric BPs to technology-centric *workflows (WFs)* leveraging automation. Hence, a WF represent a BP as a sequence of tasks that interact with technical services. The automated execution of WFs is realised by *Workflow Engines (WFEs)* that handle the deployment, execution, and management of different WFs. Consequently, they realise the interaction with remote services and provide an interface to users.

A *workflow instance* represents an instantiation of a WF in a WFE including its current state (*e.g.* counters, path take in execution flow, return values of invoked services, ...) and context (*e.g.* triggering event or person, parent workflow, ...).

2.3 Cloud-enabled Business Processes

Business Process as a Service (BPaaS) introduces a cloud service model for BPs. In consequence, any BPaaS implementation needs to support the five essential NIST characteristics. *Broad network access* requires that BPaaS is offered over a Web-based interface and the servers hosting the service provide sufficient network capacity. *On-demand self-service* demands that all actions a BPaaS offering provides to its users are fully automatised. Similarly, *rapid elasticity* requires a high degree of automation to allow users to acquire more resources on demand. In particular, it is needed that the software components implementing the BPaaS platform are scalable and elastic by themselves.

From a provider perspective, *resource pooling* is a key feature to realise the functionality. In consequence, this means that all resources used by all BPs are pooled over one or more pools of resources (which may themselves be physical or virtual) while still isolating users from each other. Hence, any BPaaS implementation requires support for multi-tenancy. Finally, *measured services* are the foundation for the provider to optimise resource usage and for offering pay-per-use billing models. In consequence, also monitoring, fine-grained accounting, and flexible billing models are needed in order to benefit from this kind of feature.

From these demands and constraints it becomes clear that the realisation of BPaaS only works in highly automated environments and has huge impact on business-IT alignment. In particular, the business-IT alignment for a single BP does not have to be static any more. Through a cloud-oriented approach, the size of the IT infrastructure can grow and shrink as needed and also potential third party services used to implement and automatise a business process are not necessarily statically bound. We refer to a BP/WF that supports these characteristics and can be run in a BPaaS environment as *Cloud-enabled Business Process (CeBP)*.

3 TECHNICAL VIEW ON BPaaS

Leveraging the flexibility of business-IT alignment as described in Section 2.3, requires to identify the degrees of freedom that exist when aligning a high-level BP to IT environments. For that purpose, we first provide an overview of business IT-alignment from a more traditional non-cloud perspective. In a second step, we divide business IT-alignment into five levels that can be mapped to cloud computing features.

3.1 Executing Business Processes

BPs represent the basis for all companies and can be executed through IT services. Traditionally a *business expert* acquires and retains the BPs of a company. Then, the company assigns internal and external *IT experts* to automatise as many parts of the BP as possible and aligns the BPs to their IT infrastructure to operate the BP in a cost and performance efficient way.

The business-IT alignment (cf. Figure 1) comprises the mapping from BPs to WFs. WFs orchestrate services which have to be selected and allocated. Service selection includes steps such as on/off-premise decision, hardware sizing and acquisition, continuous (manual) monitoring and adaptation of the service execution. As these steps are company- and BP-specific, changing business demands have to be answered by an updated BPs and WFs which is only possible to a certain extent, as the flexibility of the manual process is limited.

Since the business IT-alignment is cumbersome and includes many manual steps, a direct and automated mapping to cloud offerings is not possible.

3.2 CeBP for BPaaS

Realising BPaaS requires flexibility for many of the steps executed in the business-IT alignment to support both the pay-as-you-go model, but also the elasticity demanded from cloud services. In order to identify sources of flexibility and approaches to cloud-enabling, this section formalises business-IT alignment and divides it into steps that—starting from a non-technical BP—enriches the BP with technical details. More precisely, we introduce a novel hierarchy of five levels of CeBPs depicted in Figure 2.

In the following, we present for each level a high-level definition and describe how level n can be derived from level $n-1$.

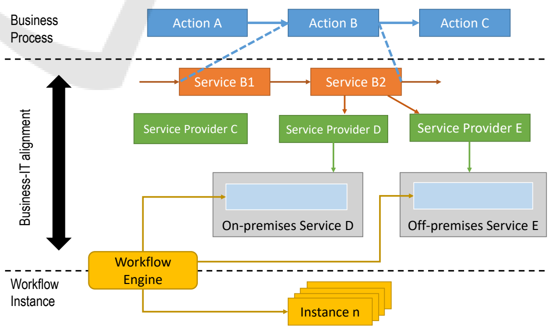

Figure 1: Traditional view on business process execution.

Level I (business process level) deals with domain-specific business processes that describe the business activities of a worker in a non-technical manner. The BP on this level is not technically executable.
On *Level II*, *technical workflows* enhance the Level-I description with technical details, enabling automation and the allocation of services (Van Der Aalst et al., 2003) by deciding how to map BP actions to

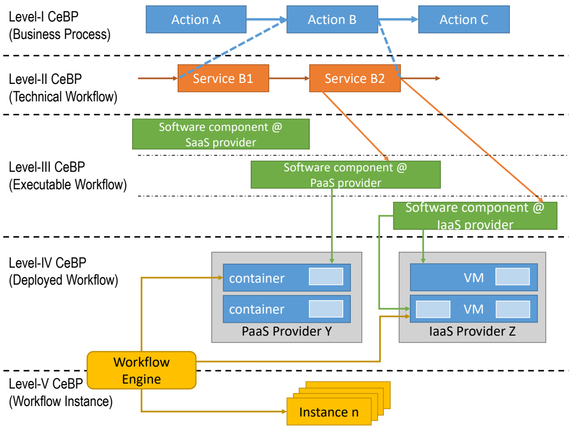

Figure 2: Levels of a Cloud-enabled business process.

service calls. Hence, it is decided which service interfaces are being used and how the different (so far abstract) services interact with each other. Each Level-II WF realises a Level-I process, but a Level-I process can be realised by multiple Level-II WFs. They vary depending on the desired level of automation, the services to use, and other non-functional properties that shall be respected.

Level III comprises *executable workflows*. These differ from technical WFs, as they not only capture the types of services to be used in the workflow implementation, but also define which concrete available service shall be used. Hence, it is on this level where it is decided if the workflow uses a particular commercial SaaS offer, one of the company's legacy services, or a self-hosted service. A self-hosted service is a service instantiated on a public or private PaaS, IaaS, or bare metal platforms. Hence, on this level the information required to access the service is specified. For self-instantiated services, additional information on how and where to create a service instance is specified as well. We refer to this information as deployment description. As before, multiple executable WPs can realise the very same technical WF. The selection of service instances and selection of PaaS and SaaS providers respectively defines the SLAs, pricing, and other non-functional properties of the executable WF.

Pushing an executable WF to production moves it to *Level IV* and by instantiating a *deployed workflow*. This step includes the deployment of services, if needed (cf. Level III) including the acquisition of required resources from cloud platforms. Therefore, a major part of the cloud-enabling process takes place here. Users can make use of Level-IV deployed workflows. Obviously, a Level III workflow can have been instantiated multiple times.

Level V defines the *workflow instances* that are triggered by users, run in a WFE, and exploit the provisioned services. This level captures the instance-specific details with respect to monitoring and rule enforcements. An arbitrary number of instances of a deployed WF can exist accessing the same services.

3.3 Dimensions of BPaaS

This section discusses possible features of a BPaaS offering and identifies on which of the levels this feature has to be implemented. It is up to Section 4 to introduce the necessary tools needed to realise the features.

As discussed in Section 3.2, business processes exist on different technical levels. In consequence, there is no intuitive semantics of the *BP* part of BPaaS. The two most obvious options are the following: *(i)* Offering a web-based design tool for Level I processes. This would classify BPaaS as a specific kind SaaS, but would not allow the deployment and execution of the BP. *(ii)* Offering a workflow engine capable of executing uploaded processes. Here, BPaaS would be a special kind of PaaS that provides an platform for the execution of customer logic.

From these two options, we use *(ii)* as the starting point for our discussion, as it seems more beneficial to its users. However, just as other PaaS offerings are commonly enhanced with IDE integration or even online programming environments, an option-*(ii)* based offering should be enhanced with designer support or even an option-*(i)* online designer. This could be enhanced with the user interface that has to be provided by the WFE in order to allow users of the business process (*e.g.* case workers) to access the process instances and *e.g.* check completed tasks.

Traditional PaaS providers offer additional services such as databases and message queues to the applications they host. Yet, with their focus on computing and particularly on the processing of web requests, it is commonly not expected nor supported to access external services hosted by other operators. Scalability for applications is achieved by giving more compute resources to the executed application which requires a scalable runtime environment and/or a limited programming model. Due to the limited execution model of BPs, a BPaaS does neither require message queues nor databases as additional services. In case the BPaaS operator provides a distributed, multi-tenant WFE, the setting is scalable, as workflow instances are independent from each other and can run on any instance of the WFE.

The fact that BPs and their workflows depend on external or even self-hosted services introduces more degrees of freedom and hence, more flexibility for BPaaS operators with respect to service quality and deployment. This is the case due to the $1:n$ relationships between all levels and their sub-levels. In particular, the following options exist: *(a)* On workflow instance-level, limits on the allowed number of Workflow Instances per time can be changed; *(b)* On the level of a Deployed Workflow, the resources allocated to a self-hosted service can be changed as well as the hoster of these resources; *(d)* On the level of an Executable Workflow, the SaaS operators of an external service can be changed or the a used SaaS might be changed to self-hosting and vice-versa; on the same level *(e)* scaling rules for the enacting Level-IV can be changed; *(f)* on the level of a Technical Workflow, the workflow itself can be changed so that BP actions are broken down into different steps; Finally, *(g)* on Level-I the entire BP can be changed.

3.4 Supported Cloud Properties

Section 3.3 has identified that at its core any BPaaS should realise support for executing workflows in a workflow engine (Level V). However, in order to really benefit from the flexibility offered by a cloud-based solution, a BPaaS should also add support for higher layers and it is the task of the operator of such a service to find the right balance between the power of supporting many levels and making the system easy to use for the customers. In the following, we investigate which of the five cloud properties can be supported at what level of the CeBP. For each level, we analyse the necessity of the cloud characteristics based on *mandatory (!)* or *optional (or not applicable) (**0**)* to cloud-enable the business process on that level. The result of this analysis is shown in Table 1.

The need for the cloud characteristics is evaluated based on the *definition phase (def)* of the CeBP, *i.e.* when the specification of the BPaaS happens on the respective level, and its *execution phase (exec)*, *i.e.* running the fully specified Deployed Workflow.

For supporting Level I, the BPaaS operators need to offer *broad network access* and allow *rapid elasticity* in terms of an easy way to change requirements and process descriptions. *Measured services* are required throughout the life-cycle of a CeBP to support multi-tenancy.

Level II requires support for *broad network access* and *rapid elasticity* to allow the flexibility of changing market situations, such as new services are available. Further, to allow *rapid elasticity* for the BPaaS, different technical implementations must be definable as alternatives. As this is a connection point for experts of different areas, we see multi-tenancy as mandatory in terms of *resource pooling* of different actors working on the same technical WFs. During execution, new services can occur on the market that better fit the needs for the BPs. Hence, it is mandatory that the tools allow *rapid elasticity* and provide *measured services* in order to quickly re-allocate the tools and change the task-service mapping.

Level III requires support for *measured services* as this is part of a BPaaS provider and will be needed to calculate the price for offering a BPaaS. Other characteristics, such as *elasticity* and *self-service* are not mandatory as the steps on Level III happen offline. During the execution of the business process, this level supports the cloud-enabling in terms of choosing service implementations and service providers that are conform with the NIST characteristics. A major aspect for the technologies is the ability to handle this.

Level IV focuses on the execution phase, therefore no changes happen during the BPaaS definition phase. The engaged tools have to support all cloud characteristics as they are used for orchestrating the cloud services, *i.e.* deployment, configuration and run-time management. The resulting services are interlinked with the respective WF. Hence, the tools have to support the enactment of *on-demand self-service*, *broad network access*, *resource pooling*, *rapid elasticity* and *measured service* of the employed services. Concerning the cloud-enabling, the same possibilities of Level IV hold true for Level V as it uses the previously deployed services.

4 CONCEPTS AND TOOLING

For all five levels of Business Processes as supported by a BPaaS offering, this section discusses existing concepts and tools that may be built upon for realising a BPaaS offering. This is necessary to be able to identify them and classify them in terms of their requirements towards the cloud-enabling process.

4.1 Business Process

As the landscape of business process technologies is extensive, we select two common technologies which can be exploited for the business level of BPaaS.

The Business Process Model and Notation (BPMN) is a standardised flowchart based notation for defining BPs (Group, 2011). The notation aims to be comprehensible for managers, business analysts as well as developers. BPMN models may be defined on a variable level of detail: from high-level process landscapes down to a detail level allowing the transformation into an executable language.

The Decision Model and Notation (DMN) (Group, 2015) standard supports mod-

Table 1: Business process cloudification.

CeBP level	Cloud Characteristics (NIST)									
	On-demand self-service		Broad network access		Resource pooling		Rapid elasticity		Measured service	
	def	exec	def	exec	def	exec	def	exec	def	exec
I: Business Process	**0**	**0**	**!**	**0**	**0**	**0**	**!**	**0**	**!**	**0**
II: Technical Workflow	**0**	**0**	**!**	**0**	**!**	**0**	**!**	**!**	**!**	**!**
III: Executable Workflow	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**!**	**0**
IV: Production Workflow	**0**	**!**	**0**	**!**	**0**	**!**	**0**	**!**	**0**	**!**
V: Workflow Instance	**0**	**!**	**0**	**!**	**0**	**!**	**0**	**!**	**0**	**!**

elling and automating of business decisions and is understood by business experts and technical experts.

Several web-based tools exist to apply the presented technologies and create business process models such as Adonis[1], ADOxx[2] or Bonita BPM[3]. Tools such as ADOxx or the Camunda modeler[4] support creating DMN models.

4.2 Technical Workflow

The BPMN standard (Group, 2011) of the prior level can be exploited on this level as well. Further technologies are commonly exploited to integrate services into executable workflows. The Service Modeling Language (SML) is used to model complex services and systems, including their structure, constraints, policies, and best practices (W3C, 2009). Mapping services to task and integrating them into a technical WF, the service interfaces have to be described, *e.g.* with WSDL (Christensen et al., 2001). Standards to describe the execution of WFs of BPs, *e.g.* BPEL (Alves et al., 2007) reside on this level. They are used for an automatic execution of WFs.

There are a plethora of WFEs available that run BPMN processes. The Activiti Platform[5] is an example of an open-source tool that is able to create BPMN with concrete services and also run/instantiate them.

There are no established tools that support the mapping of tasks to services.

4.3 Executable Workflow

Various modelling languages exist for describing an application and its deployment configuration, *e.g.* hardware requirements and installation scripts with respect to cloud resources. Such technologies cater for the automation of the deployment and management process in the sense of the DevOps paradigm. Furthermore repositories hosting those models for flexibility and reusage are beneficial for the support of the cloud characteristics. Because those can be used to assemble new technical WF descriptions.

Configuration management tools, widely known as DevOps tools, come with languages to describe the configuration of a software component and a system to ensure the correct installment of the component in a local scope (*i.e.* mostly in the view of a single node). They ease the description of application installation and dependencies.

Cloud modelling approaches such as CloudML[6], CAMEL[7], CAMP (Durand et al., 2014) or TOSCA (Palma and Spatzier, 2013) are results of research efforts. They aim to cater for the reusability and flexibility needed for the descriptions of cloud applications. Repositories for cloud-enabled application descriptions are emerging, such as the Vinothek for TOSCA or the social network for the CAMEL language.[8] A web-based tool for the model-based description of cloud applications is juju[9] that also provides a service catalogue.

4.4 Deployed Workflow

COTs (Baur et al., 2015) are managing the holistic life-cycle of the cloud application, *i.e.* the topology of the software components, providing application-wide self-service and care for the accessibility of services. Resource pooling is done in respect to the management of connected cloud providers. COTs gather monitoring data, which can be exploited for rapid elasticity in terms of adaptation actions and to a certain degree for measured services.

[1]http://en.adonis-community.com/
[2]https://www.adoxx.org/live/home
[3]http://www.bonitasoft.com/
[4]https://camunda.org/dmn/simulator/
[5]https://www.activiti.org/
[6]http://cloudml.org/
[7]http://camel-dsl.org/
[8]http://www.paasage.eu/training-materials/the-paasage-social-network
[9]https://www.ubuntu.com/cloud/juju

The models@runtime paradigm (Ferry et al., 2014) can be applied to synchronise the cloud application model and the real world model by correlating actual monitoring data with the cloud model.

Common COTs are Brooklyn[10], Scalr[11] or Cloudiator[12]. As their properties and abilities towards their intended usage varies heavily we recommend (Baur et al., 2015) for more technical details.

Monitoring data can be gathered and processed by tools such as InfluxDB[13], yet there exist a plethora of applicable options. The synchronisation of the actual and the ideal application model of a running deployment is currently still a research target. One example is CloudMF (Ferry et al., 2014) for the CloudML modelling language.

4.5 Workflow Instance

The tools on this level have the same significance on the cloud-enabling as the previous level. From the execution view of the BPaaS, Level V must support all cloud characteristics, which should be the case as the deployed services of Level IV are used.

5 RELATED WORK

There are well adopted classifications for the common cloud service models (Mell and Grance, 2009) as well as more fine grained classifications, *e.g.* for Data-as-a-Service (DaaS) or Storage-as-a-Service (STaaS) (Rimal et al., 2009; Kachele et al., 2013).

Yet, the term BPaaS is not considered in these classifications. While the BPaaS term came up in 2011 and has gained a growing interest since 2013 (Barton and Seel, 2014), the term BPaaS not yet standardised (Mell and Grance, 2009) nor exist a common classifications or taxonomy for BPaaS.

In 2011, (Papazoglou and van den Heuvel, 2011) introduce the concept of BPaaS with respect to the cloud service levels, by introducing the BPaaS layer on top of the common cloud service levels IaaS, PaaS and SaaS. In their concept the BPaaS level is defined via blueprints, mapping business processes and workflows to cloud services. In introducing the BPaaS concept, this approach focuses on the modelling aspects while our presented classification considers the full BPaaS lifecycle including definition and execution.

Focusing on cloud integration an extended concept of the previously described BPaaS approach is presented by (Papazoglou, 2012). Here the BPaaS paradigm is expressed via an extended blueprint modelling language, combining different cloud services into one common view without focusing the BP and WF specific levels as our classification does.

A conceptual framework for categorising cloud services as BPaaS is presented in (Lynn et al., 2014). This framework aims at identifying potential value of adopting the BPaaS model and its implications for the realisation of business values from cloud computing. With the need to clarify the term BPaaS, the basic terms from business process management and cloud computing are set in relation and possible challenges are derived. This framework follows a similar approach in placing BPaaS into the cloud context as our classification does, while the framework only builds upon a theoretical bases and our classification builds upon an technical BPaaS implementation.

A first approach to implement BPaaS happens in the CloudSocket project (Woitsch and Utz, 2015b). This approach introduces a first step into defining different levels in the BPaaS paradigm and outlines an architecture for implementing these levels. While this work focuses on the business-IT alignment with respect to BPaaS, a cloud-centric classification of the overall BPaaS paradigm is not in its focus.

6 CONCLUSIONS

The evolution of cloud computing moves from the traditional cloud service models to multi-dimensional services models, which focus on technical aspects as well as on business aspects. In this context an upcoming service model is Business Process as a Service (BPaaS), which has gained attention but is not yet classified in the common terms of the cloud service models (Mell and Grance, 2009). We present a novel classification for BPaaS with respect to the well adopted cloud service models, defining a hierarchy of five levels of business processes with an increasing technical specification. We argue that at its core any BPaaS offering has to enable support for the lowest of the five layers which can be achieved by proving a distributed and multi-tenant capable workflow engine. Yet, only support for higher layers in the hierarchy support leveraging the flexibility and dynamic that is a main property of cloud offerings. Finally, we discussed available tools and technologies that can be used for realising support for each of the five layers in a prototype implementation of a BPaaS platform.

Future work targets the completion of a reference implementation for a BPaaS platform in the Cloud-

[10]https://brooklyn.apache.org/

[11]http://www.scalr.com/

[12]http://cloudiator.org/

[13]https://www.influxdata.com/

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Socket project[14]. Other work will encompass a validation of our classification based on advanced BPaaS implementations. Further, the classification will include human actors and roles, and extend the existing levels by more fine-grained sub-levels.

ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Community's Framework Programme for Research and Innovation HORIZON 2020 (ICT-07-2014) under grant agreement number 644690 (CloudSocket).

We thank the entire CloudSocket consortium for the valuable and constructive discussion on the matter and for feedback on earlier versions of this paper.

REFERENCES

Alves, A., Arkin, A., Askary, S., Barreto, C., Bloch, B., Curbera, F., Ford, M., Goland, Y., Guzar, A., Kartha, N., et al. (2007). Web services business process execution language version 2.0 (oasis standard). ws-bpel tc oasis.

Barton, T. and Seel, C. (2014). Business process as a service-status and architecture. In *EMISA*, pages 145–158.

Baur, D., Seybold, D., Griesinger, F., Tsitsipas, A., Hauser, C. B., and Domaschka, J. (2015). Cloud orchestration features: Are tools fit for purpose? In *2015 IEEE/ACM 8th International Conference on Utility and Cloud Computing (UCC)*, pages 95–101.

Christensen, E., Curbera, F., Meredith, G., Weerawarana, S., et al. (2001). Web services description language (wsdl) 1.1.

Durand, J., Otto, A., Pilz, G., and Rutt, T. (2014). Cloud Application Management for Platforms Version 1.1. OASIS Committee Specification.

Ferry, N., Song, H., Rossini, A., Chauvel, F., and Solberg, A. (2014). Cloudmf: Applying mde to tame the complexity of managing multi-cloud applications. In *UCC, 2014 IEEE/ACM 7th International Conference on*, pages 269–277.

Foster, I., Zhao, Y., Raicu, I., and Lu, S. (2008). Cloud computing and grid computing 360-degree compared. In *Grid Computing Environments Workshop, 2008. GCE'08*, pages 1–10. Ieee.

Group, O. M. (2011). Business process model and notation 2.0. Technical report, OMG, http://www.omg.org/spec/BPMN/2.0/PDF.

Group, O. M. (2015). Decision model and notation. Technical report, OMG, http://www.omg.org/spec/DMN/1.1/.

Kachele, S., Spann, C., Hauck, F. J., and Domaschka, J. (2013). Beyond iaas and paas: An extended cloud taxonomy for computation, storage and networking. In *UCC, 2013 IEEE/ACM 6th International Conference on*, pages 75–82. IEEE.

Lynn, T., OCarroll, N., Mooney, J., Helfert, M., Corcoran, D., Hunt, G., Van Der Werff, L., Morrison, J., and Healy, P. (2014). Towards a framework for defining and categorising business process-as-a-service (bpaas). In *Proceedings of the 21st International Product Development Management Conference*.

Mell, P. and Grance, T. (2009). The nist definition of cloud computing. *National Institute of Standards and Technology*, 53(6):50.

Palma, D. and Spatzier, T. (2013). Topology and Orchestration Specification for Cloud Applications Version 1.0. OASIS Standard.

Papazoglou, M. P. (2012). Cloud blueprints for integrating and managing cloud federations. In *Software Service and Application Engineering*, pages 102–119. Springer.

Papazoglou, M. P. and van den Heuvel, W.-J. (2011). Blueprinting the cloud. *IEEE Internet Computing*, 15(6):74–79.

Rimal, B. P., Choi, E., and Lumb, I. (2009). A taxonomy and survey of cloud computing systems. *INC, IMS and IDC*, pages 44–51.

Smith, D. M. (2012). Hype cycle for cloud computing, 2012. *Gartner Inc., Stamford*.

Van Der Aalst, W. M., Ter Hofstede, A. H., and Weske, M. (2003). Business process management: A survey. In *International conference on business process management*, pages 1–12. Springer.

W3C (2009). Service modelling language. Technical report, W3C, http://www.w3.org/TR/2009/REC-sml-20090512/.

Woitsch, R., Karagiannis, D., Plexousakis, D., and Hinkelmann, K. (2009). Business and it alignment: the it-socket. *e & i Elektrotechnik und Informationstechnik*, 126(7-8):308–321.

Woitsch, R. and Utz, W. (2015a). Business process as a service (bpaas). In *Conference on e-Business, e-Services and e-Society*, pages 435–440. Springer.

Woitsch, R. and Utz, W. (2015b). Business process as a service: Model based business and it cloud alignment as a cloud offering. In *Enterprise Systems (ES), 2015 International Conference on*, pages 121–130. IEEE.

[14]https://www.cloudsocket.eu/