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CLOUD COMPUTING ECOSYSTEM MODEL: REFINEMENT AND EVALUATION

Sebastian Floerecke
University of Passau, sebastian.floerecke@uni-passau.de

Franz Lehner
University of Passau, franz.lehner@uni-passau.de

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Complete Research

Floerecke, Sebastian, University of Passau, Germany, sebastian.floerecke@uni-passau.de

Lehner, Franz, University of Passau, Germany, franz.lehner@uni-passau.de

Abstract

A business ecosystem has evolved in the field of cloud computing whereby new types of market actors have emerged breaking up the traditional value chain of IT service provision. In order to create a profound understanding of this ecosystem, several scholars tried to capture it in a model. However, these models differ considerably from each other. The goal of this paper, therefore, is to develop a revised and comprehensive cloud computing ecosystem model according to the design science paradigm. For this purpose, the recently published ***Pa****ssau* ***C****loud Computing* ***E****cosystem Model (PaCE Model) is developed significantly further by integrating the insights of an analysis of the existing cloud ecosystem models regarding ten criteria and by considering findings from the general cloud and business ecosystem literature. To ensure the integrity of the enhanced PaCE Model, the Internet is manually searched for companies occupying the roles of the model. As a result, the model comprises 26 roles and includes the basic service flows. Since the missing market transparency is regarded as one of the main reasons for the low cloud adoption, the intended contribution is to foster a better understanding of the cloud ecosystem and to provide a conceptual framework for further research.*

Keywords: Cloud Computing, Ecosystem, Ecosystem Models and Roles, Value Chain, Design Science.

1 Introduction

Cloud computing is not a new technology, but rather a new operations model that combines a set of existing technologies such as virtualization, autonomic computing, grid computing and utility-based pricing (Zhang et al., 2010). Around this new operations model, a business ecosystem has evolved whereby new types of market players have emerged breaking up the traditional value chain of IT service provision: Besides the basic vendors of infrastructure, platforms and applications, providers have entered the market, generating new services, combining or integrating existing services into one or more adapted services, but also integrating cloud solutions into the customer's existing IT infrastructure or offering consulting services (Bitkom, 2009, Böhm et al., 2011).

Generally, each actor within the cloud computing ecosystem primarily provides paid services for his customers. Taken as a whole, the actors of the ecosystem jointly create services in a loosely coupled manner through service refinement that fulfil the end customers' needs by still concentrating on their core competences and maintaining corporate focus (Leimeister et al., 2010, Simons et al., 2014). From the end customer's viewpoint, the traditional model of a single provider one-stop provision of outsourcing is, thus, replaced by a web of different vendors (Böhm et al., 2011). As the classical division between customers and providers is blurring, the cloud computing market is characterised by a high degree of interdependence among the different actors which leads to a lack of transparency (Keller and König, 2014). This lack of transparency is seen as one of the main reasons why the adoption of cloud computing services has failed to meet the high expectations so far (Repschläger and Zarnekow, 2011, Sunyaev and Schneider, 2013).

In order to create a profound understanding of the business ecosystem in the context of cloud computing, several attempts have been made to describe it by a model (e.g., Hogan et al., 2011, Pelzl et al., 2013). However, these models differ considerably from each other with respect to their containing constructs and their form of presentation. The goal of this research paper, thus, is to develop a revised and more comprehensive cloud computing ecosystem model according to the design science paradigm. For this purpose, the existing cloud computing ecosystem models are firstly analysed based on ten evaluation criteria derived from the cloud ecosystem and the general business ecosystem literature: *(1) Aim of the Model*, *(2) Practical Use of the Model*, *(3) Model Derivation*, *(4) Form of Notation*, *(5) Role Definition*, *(6) Number of Roles*, *(7) Types of Relationships*, *(8) Model Labelling*, *(9) Scope of the Model* and *(10) Scientific Evaluation*. As a basis for the model creation process serves the recently published **Pa**ssau **C**loud Computing **E**cosystem Model (PaCE Model) which was the outcome of a comparative analysis regarding the roles of the existing cloud computing ecosystem models (Floerecke and Lehner, 2015). This model is developed significantly further by integrating the analysis results, as well as considering findings from the general cloud computing and the business ecosystem literature. To ensure the validity of the enhanced PaCE Model, it is tested within an Internet search whether all roles of the model are covered by real market actors. As a result, the enhanced PaCE Model comprises 26 different roles of market actors, grouped into five categories, and shows the basic service flows.

Since the existing ecosystem models differ considerably from one another and the missing market transparency is regarded as one of the key reasons for the low cloud computing adoption rate, the main contribution of the enhanced PaCE Model is to provide a conceptual framework offering a common view and supporting further research. By using this model, customers gain a deeper understanding of the cloud market mechanisms that might encourage them to obtain cloud services. Researchers can utilise the enhanced PaCE Model as an analytical framework to investigate the cloud computing field. Service providers will be able, amongst other things, to reflect their role or a role cluster, to identify possible business opportunities, to anticipate potential alliances, to strategically position their service offerings and to create new service provisioning opportunities.

The remainder of this research paper is organised as follows: Section 2 explains the cloud computing phenomenon in conjunction with its market and value creation. In section 3, the research design used in this contribution is presented. Section 4 explains the criteria catalogue for the model analysis and the results of this analysis process. In section 5, the enhanced PaCE Model is introduced and described. Section 6 evaluates the developed model and discusses its main characteristics and the results of the model analysis. Section 7 provides a summary, limitations and an outlook for future work.

2 Related Work

2.1 Cloud Computing

Cloud computing in general represents an example for the paradigm shift from selling products to providing customer-focused, integrated bundles of products and services (so-called product-service systems) that deliver value in use (Floerecke et al., 2015, Sultan, 2014). However, cloud computing by itself is not a new technology. Instead, it is a new operations model that combines a set of existing technologies such as virtualization, autonomic computing, grid computing and utility-based pricing (Zhang et al., 2010). In literature, there is still no generally accepted definition of the term cloud computing (Vaquero et al., 2008, Weinhardt et al., 2009). This can be explained according to Madhavaiah et al. (2012) by the fact that different scientists define cloud computing with respect to its key components and conceptualisations as they personally perceive it. Based on the frequently cited definition of the National Institute of Standards and Technology (NIST) (Mell and Grance, 2009, 6), "*[c]loud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*". However, in this paper, the definition suggested by Marston et al. (2011) is used as the focus is, in contrast to the NIST definition, on the business aspects of the cloud computing phenomenon. Based on a content analysis study by Madhavaiah et al. (2012), the proposed definition of Marston et al. (2011) is considered as the most comprehensive business related definition:

"*Cloud computing is an information technology service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location. The resources required to provide the requisite quality-of-service levels are shared, dynamically scalable, rapidly provisioned, virtualized and released with minimal service provider interaction. Users pay for the service as an operating expense without incurring any significant initial capital expenditure, with the cloud services employing a metering system that divides the computing resource in appropriate blocks*" (Marston et al., 2011, 176 f.).

In the field of cloud computing, three service models can be distinguished, namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). A further differentiation is made between four deployment models – public, private, hybrid and community. IaaS stands for the needs-based provisioning of infrastructural resources, such as storage and computing power. PaaS allows users to develop their own applications by offering them operating system support and a software development environment with programming languages, libraries and tools. SaaS refers to providing on-demand applications via data networks. These three service models form layers which are interrelated, each building on the former. Whereas in public clouds service providers offer their resources to the general public, private clouds are designed for exclusive use by a single organisation. Hybrid clouds are a combination of public and private clouds where a part of the infrastructure is located in a private cloud and the remaining part in a public cloud. The community cloud, a particular private cloud, provides an infrastructure which is shared by several organisations with common interests (Mell and Grance, 2009, Zhang et al., 2010).

2.2 Concepts Explaining the Value Creation in the Cloud Business

In order to characterise the nature of value creation in the cloud computing business, two main concepts named "*value network*" and "*business ecosystem*" are dominating the discussion. Despite of their partly overlapping meaning, both concepts differ significantly as the results of a comparative analysis conducted by Lehto et al. (2013) show (Figure 1).

	Purpose	Value Transfer	Structure	Governance	Competition, Collaboration	Evolution
Business Ecosystem	innovation / novelty / renewal	rather value creation than capture	loosely coupled, emergent structure	inherent / evolving	competition / collaboration within the ecosystem and against others	common, constant flow, flux self-renewal
Value Network	efficiency / service	rather value capture than creation	tightly coupled, purposefully structured	agreed / set / defined	competition against other networks, collaboration within	stagnation, maintaining the status quo

Figure 1. Differences between Business Ecosystems and Value Networks (Lehto et al., 2013)

A first substantial difference relates to the structure of both concepts: While business ecosystems are loosely coupled and emergent, value networks are tightly coupled and purposefully structured. Another major distinction is that business ecosystems allow competition both among different business ecosystems and within the system itself. Value networks, in contrast, only compete against other value networks without real competition within the network (Lehto et al., 2013). Considering these and the further differences presented in Figure 1, the business ecosystem perspective is used in this research paper because it is more appropriate to describe the special nature of the cloud computing market.

The discussion on "*business ecosystems*" was initiated by Moore (1993) in analogy to biological ecosystems in which "*[…] companies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations*" (Moore, 1993, 76). Several scholars picked up this idea subsequently and enhanced it, what unfortunately undermined a precise and general accepted definition (Anggraeni et al., 2007). Nevertheless, there is a consensus that a business ecosystem consists of a large number of participants that can be firms acting as partners, subcontractors, complementors, competitors, but also other organisations like public bodies, investors and research institutes (Heikkilä and Kuivaniemi, 2012). The participants are interconnected and, thus, have an effect on each other so that failures of one firm can lead to failures of the other firms (Peltoniemi, 2006). These interactions can be competitive, as well as cooperative (Peltoniemi and Elisa, 2004).

Business ecosystems are self-organised and the decision-making processes are decentralised due to their modular structure. Hence, no single organisation can control the entire system, but there can be several major players dominating the ecosystem (Iansiti and Levien, 2004). The single members aim at innovations and commercial success and try to take advantage of the other members and their capabilities. This is challenging as a business ecosystem is coupled to its environment, which may change rapidly and unpredictably (Peltoniemi, 2006). The environment comprises legal, political, cultural and social aspects. These aspects significantly influence the ecosystem and are external drivers of its evolution (Zhang et al., 2010). A business ecosystem as a whole, therefore, is a dynamic structure that evolves and develops in time (Peltoniemi, 2006).

In the case of cloud computing, each single actor within the ecosystem offer services (liable to costs) and, thereby, provides a value for customers. Taking the ecosystem as a whole, all actors jointly create services in a loosely coupled manner through service refinement that fulfil the end customers' needs (Leimeister et al., 2010). From the end customer's perspective, the traditional model of a single provider one-stop provision of outsourcing is, thus, replaced by a web of different vendors (Böhm et al., 2011). The classical distinction between customers and providers is, therefore, blurring. One main reason for this development is the multi-layered architecture of cloud services. This change is further driven and facilitated by the special cloud computing characteristic "*on-demand self-service*" which means that services "*[…] can be rapidly provisioned and released with minimal management effort or service provider interaction*" (Mell and Grance, 2009, 6). It can further be obeyed that some actors within the cloud market exclusively offer various compositions of existing services from other players, without adding any own functionality (Simons et al., 2014). Hence, it is not uncommon that end customers do not even know which component of a service package is provided by which specific actor.

In practice, it can be observed that many companies being part of the cloud computing ecosystem offer a broad range of services. Therefore, it makes sense for the analysis of the ecosystem to abstract from concrete actors and to use the concept of roles. According to Böhm et al. (2010, 133), a role is a "*[…] set of similar services offered by market players to similar customers*". Salesforce, for instance, fulfils on the one hand the role of an Application Provider with their own customer relationship management solution, and on the other hand, the role of an Application Market Place Operator with their portal named AppExchange offering external applications.

3 Research Design

The main goal of this work is to develop a revised and comprehensive cloud computing ecosystem model according to the design science paradigm. Design science research generally aims at producing a viable artifact in the form of a construct, a model, a method or an instantiation which solves an important and relevant business problem (Hevner et al., 2004). Takeda et al. (1990) describe the design science research process as a circle consisting of five phases: (1) Identification of the research problem (*Awareness*); (2) Suggestion of the key concepts needed to solve the research problem (*Suggestion*); (3) Implementation of a solution to the problem (*Development*); (4) Evaluation of the solution artifact (*Evaluation*) and (5) Decision on whether to adopt the artifact or to start a new design cycle (*Conclu-*

sion). These five phases are reflected in the structure of the underlying research whereby the entire research process consists of the steps shown in Figure 2.

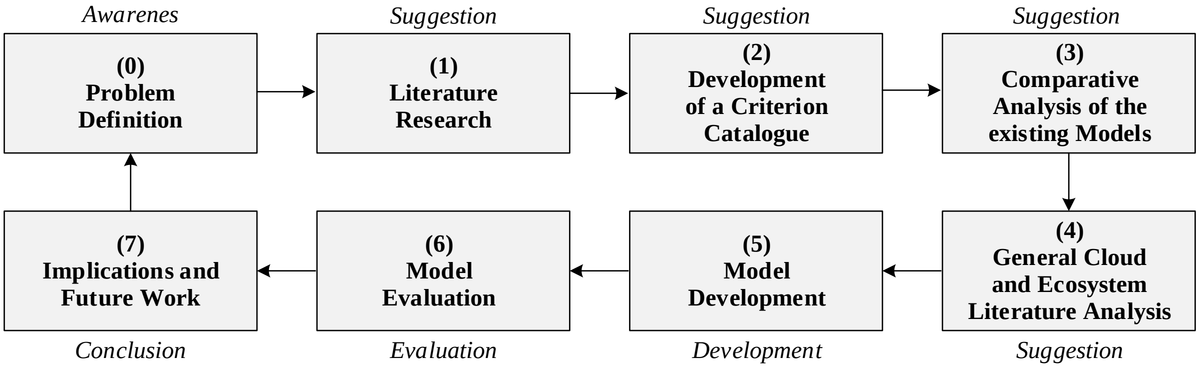

Figure 2. Research Process

The main research problem is, as explained in the introduction, that the existing cloud computing ecosystem models differ considerably from each other. Consequently, there is a need for a comprehensive model in order to create a common understanding of the cloud computing ecosystem (Step zero).

The first step was to identify the existing cloud computing ecosystem models. For this purpose, a systematic literature research was conducted according to the guidelines of Webster and Watson (2002). Thereby, the literature databases ACM Digital Library, AIS eLibrary, Emerald Insight, Google Scholar, IEEE Xplore and Springer Link were searched for the keywords "*Actors*", "*Ecosystem*", "*Framework*", "*Market*", "*Roles*", "*Value Chain*", "*Value Creation*" and "*Value Network*" in conjunction with "*Cloud Computing*", as well as the German equivalents of these words. Initially, the abstract of each of the 500 most cited publications was screened to examine its relevance for this research paper. After a positive assessment, the publication was read completely. To avoid overlooking relevant literature, the bibliography of the selected articles was examined (backward search). Simultaneously, a forward search was conducted to identify contributions that were missed by the keyword search as they are newer and, thus, less often cited. Publications on ecosystems from related fields like grid computing (e.g., Altmann and Mohammed, 2007) or software (e.g., Hanssen, 2012) have been found to be not close enough to the cloud computing topic and have, therefore, been omitted. As a result, seventeen models were selected as the basis for this research paper (Table 1).

Identified Cloud Computing Ecosystem Models from Literature
(1) **Bitkom 2009**: Cloud Computing – Evolution in der Technik, Revolution im Business
(2) **Böhm et al. 2010**: Towards a Generic Value Network for Cloud Computing
(3) **Böhm et al. 2011**: Cloud Computing – Outsourcing 2.0 or a new Business Model for IT Provisioning?
(4) **Fang et al. 2010**: Cloud Computing Business Model based on Value Net Theory
(5) **Fortis et al. 2012**: Towards a Service Friendly Cloud Ecosystem
(6) **Hogan et al. 2011**: Nist Cloud Computing Standards Roadmap
(7) **Keller and König 2014**: A Reference Model to Support Risk Identification in Cloud Networks
(8) **Kushida et al. 2012**: The Gathering Storm: Analyzing the Cloud Computing Ecosystem and Implications for Public
(9) **Leimeister et al. 2010**: The Business Perspective of Cloud Computing: Actors, Roles and Value Networks
(10) **Mohammed et al. 2010**: Understanding Businesses and Value Creation in the Cloud
(11) **Pelzl et al. 2013**: Wertschöpfungsnetzwerke deutscher Cloud-Anbieter
(12) **Petkovics and Petkovics 2014**: ICT Ecosystem for advanced higher Education
(13) **Quian et al. 2009**: Cloud Computing: An Overview
(14) **Repschläger et al. 2010**: Cloud Computing: Definitionen, Geschäftsmodelle und Entwicklungspotenziale
(15) **Venkatraman and Wadhwa 2012**: Cloud Computing – A Research Roadmap in Coalescence with Soft. Engineering
(16) **Walterbusch et al. 2014**: Hybride Wertschöpfung durch Cloud Computing
(17) **Walterbusch and Teuteberg 2012**: Vertrauen im Cloud Computing

Table 1. Identified Cloud Computing Ecosystem Models from Literature

In order to analyse the identified cloud computing ecosystem models, a set of ten important evaluation criteria was derived from the cloud ecosystem and the general business ecosystem literature: *(1) Aim of the Model*, *(2) Practical Use of the Model*, *(3) Model Derivation*, *(4) Form of Notation*, *(5) Role Definition*, *(6) Number of Roles*, *(7) Types of Relationships*, *(8) Model Labelling*, *(9) Scope of the Model* and *(10) Scientific Evaluation*. The actual model analysis was conducted in step three. Subsequently, the general cloud computing and business ecosystem literature was studied to identify further potential model improvements (Step four). The new cloud computing ecosystem model was developed in step five. The model creation process was based on a first version of the PaCE Model. This model was developed significantly further by integrating the analysis results above, as well as by considering the findings from the general cloud computing and the business ecosystem literature. To ensure the validity of the enhanced PaCE Model, it was examined within a manual Internet search whether all roles in the model can be assigned to real actors (Step six).

Once the roles and the generic relationships within the cloud computing ecosystem are known, the model can serve as a basis for further investigations. Nevertheless, the cloud computing market is highly dynamic and, therefore, also the enhanced PaCE Model needs continuous adaptions and improvements in order to keep its usability, which leads to a new design cycle (Step seven).

4 Systematic Analysis of the existing Cloud Ecosystem Models

In order to analyse the existing cloud computing ecosystem models, a catalogue of evaluation criteria was derived from literature. This catalogue comprises the ten criteria summarized in Table 2.

Criterion	Explanation
(1) Aim of the Model	Aim the Authors want to reach with their Model Development
(2) Practical Use of the Model	Specified Use of the Model for Theory and Practice
(3) Model Derivation	Research Methods which the Model Development is based on
(4) Form of Notation	Mode of Graphical Representation
(5) Role Definition	Understanding and Application of the Role Roncept
(6) Number of Roles	Number of Roles being Part of the Model
(7) Types of Relationships	Nature of Relationships between the Roles
(8) Model Labeling	Chosen Network Concept to represent the Market Structure
(9) Scope of the Model	Inclusion of the Environment or Focus on Core Elements
(10) Scientific Evaluation	Scientific Method for the Model Evaluation

Table 2. Criteria Catalogue for the Cloud Computing Ecosystem Model Analysis

(1) Aim of the Model: In most cases the purpose is to describe the roles and the relationships between the roles to reach a broader understanding of the cloud computing market (e.g., Böhm et al., 2010, Leimeister et al., 2010, Walterbusch et al., 2014). Petkovics and Petkovics (2014) propose an ecosystem for a special domain – supporting the work of university and college education. In three publications, the model creation is just a means to an end: Keller and König (2014) developed their model primarily to study causalities between risks in the ecosystem. The cloud computing network of Pelzl et al. (2013) serves as the basis for the investigation of role clusters in the German market. Fortiş et al. (2012) propose a cloud governance model which contains several roles. In the publications of Bitkom (2009), Böhm et al. (2011), Qian et al. (2009) and Repschläger et al. (2010) no explicit intention of the models can be found.

(2) Practical Use of the Model: The models can be used by providers, customers and scientists. Providers can strategically position themselves or their service offerings (Walterbusch et al., 2014), identify possible business opportunities (Böhm et al., 2010), create new service provisioning scenarios (Mohammed et al., 2010), anticipate potential alliances (Mohammed et al., 2010), allocate themselves to a role or a role cluster (Pelzl et al., 2013) or identify options for reconfiguration (Pelzl et al., 2013). Especially new market entrants can get an understanding of potential markets, formulate their value model based on the market needs and fully utilize existing services (Mohammed et al., 2010). Customers are able to identify the different potential costs for using and customizing a cloud solution based on their business needs, to anticipate various service scenarios from a strategic point of view (Mohammed et al., 2010) and to generally understand the complexity of the cloud computing market (Walterbusch et al., 2014). Scientists can use the cloud computing ecosystem models as an analytical framework to guide their research (Böhm et al., 2010). However, nine of the models do not provide any potential application scenario.

(3) Model Derivation: The models which provide a description of their origin are either based on studies on market actors in various domains (e.g., Böhm et al., 2010, Keller and König, 2014) or in the cloud computing field (e.g., Pelzl et al., 2013, Walterbusch et al., 2014). Thus, most of the authors developed a synthesis of existing models. It is remarkable that the model of Böhm et al. (2010) often serves as a basis model which is extended using the results from other authors. Five models (e.g., Bitkom, 2009, Qian et al., 2009) do not make any statement regarding the derivation of the model.

(4) Form of Notation: In order to illustrate the various models, the e³-value method (Gordijn et al., 2006) was used several times (Böhm et al., 2010, Leimeister et al., 2010, Petkovics and Petkovics, 2014, Walterbusch and Teuteberg, 2012, Walterbusch et al., 2014). The e³-value method has been designed to show how economic value is created and exchanged within a network of actors and roles (Gordijn et al., 2006). Besides that, non-standardised graph-based models (e.g., Fang et al., 2010, Repschläger et al., 2010), process models (e.g., Bitkom, 2009, Mohammed et al., 2010) and one model with a simplified version of the Unified Modeling Language (Keller and König, 2014) can be found.

(5) Role Definition: Only four papers provide a definition for "*role*" (Böhm et al., 2010, Pelzl et al., 2013) respective "*actor*" (Hogan et al., 2011, Petkovics and Petkovics, 2014). The most formal role definition is given by Böhm et al. (2010, 133), explaining roles as a "*[...] set of similar services offered by market players to similar customers*". Even if the majority of the models speak of "*actors*", there is no clear differentiation between the terms actor and role and both are often used as synonyms.

*(***6) Number of Roles**: The compared models differ considerably regarding the number and types of roles. The number of roles reaches from five (Hogan et al., 2011) to 13 (Bitkom, 2009).

(7) Types of Relationships: Nine of the models contain service, as well as financial flows (e.g., Böhm et al., 2010, Leimeister et al., 2010, Walterbusch et al., 2014) between the roles. Whereas several remaining models concentrate on the service flows (e.g., Bitkom, 2009, Qian et al., 2009, Repschläger et al., 2010), two models omit any relationships (Fortiş et al., 2012, Velamuri et al., 2011).

(8) Model Labeling: While nine models use the value network as the suitable structure concept (e.g., Böhm et al., 2010, Leimeister et al., 2010), only three models relate to the business ecosystem perspective (Bitkom, 2009, Kushida et al., 2012, Repschläger et al., 2010). The remaining models are named value chain (Mohammed et al., 2010, Qian et al., 2009) or architecture (Fortiş et al., 2012, Hogan et al., 2011, Venkatraman and Wadhwa, 2012).

(9) Scope of the Model: None of the analysed models takes the environment surrounding the cloud computing ecosystem explicitly into consideration. Instead, the focus is on the core of the ecosystem.

(10) Scientific Evaluation: For seven models, a scientific evaluation is mentioned: Interviews with domain experts (Böhm et al., 2010, Walterbusch et al., 2014), allocation of real market actors to their suggested model roles (Kushida et al., 2012, Pelzl et al., 2013), a combination of both approaches (Keller and König, 2014), testing a limited number of hypothetical business scenarios (Mohammed et al., 2010) and use cases (Fortiş et al., 2012).

5 The enhanced PaCE Model

The enhanced PaCE Model (Figure 3) comprises 26 roles and includes the basic service flows between the roles. In comparison with the previous model version, nine additional roles were integrated: Certification Authority (Sunyaev and Schneider, 2013), Private Cloud Vendor (Hu et al., 2011), Service Bundler (Simons et al., 2014), Service Customizer (Simons et al., 2014), Service Integrator (Simons et al., 2014) and Training Provider (Walterbusch et al., 2014), as well as three environmental roles, namely Legislator, Research Institute and Standard Developer (Moore, 1996). The role Aggregator/ Reseller is a generalisation of the three roles Service Bundler, Service Customizer and Service Integrator and is, therefore, not included in the total role count.

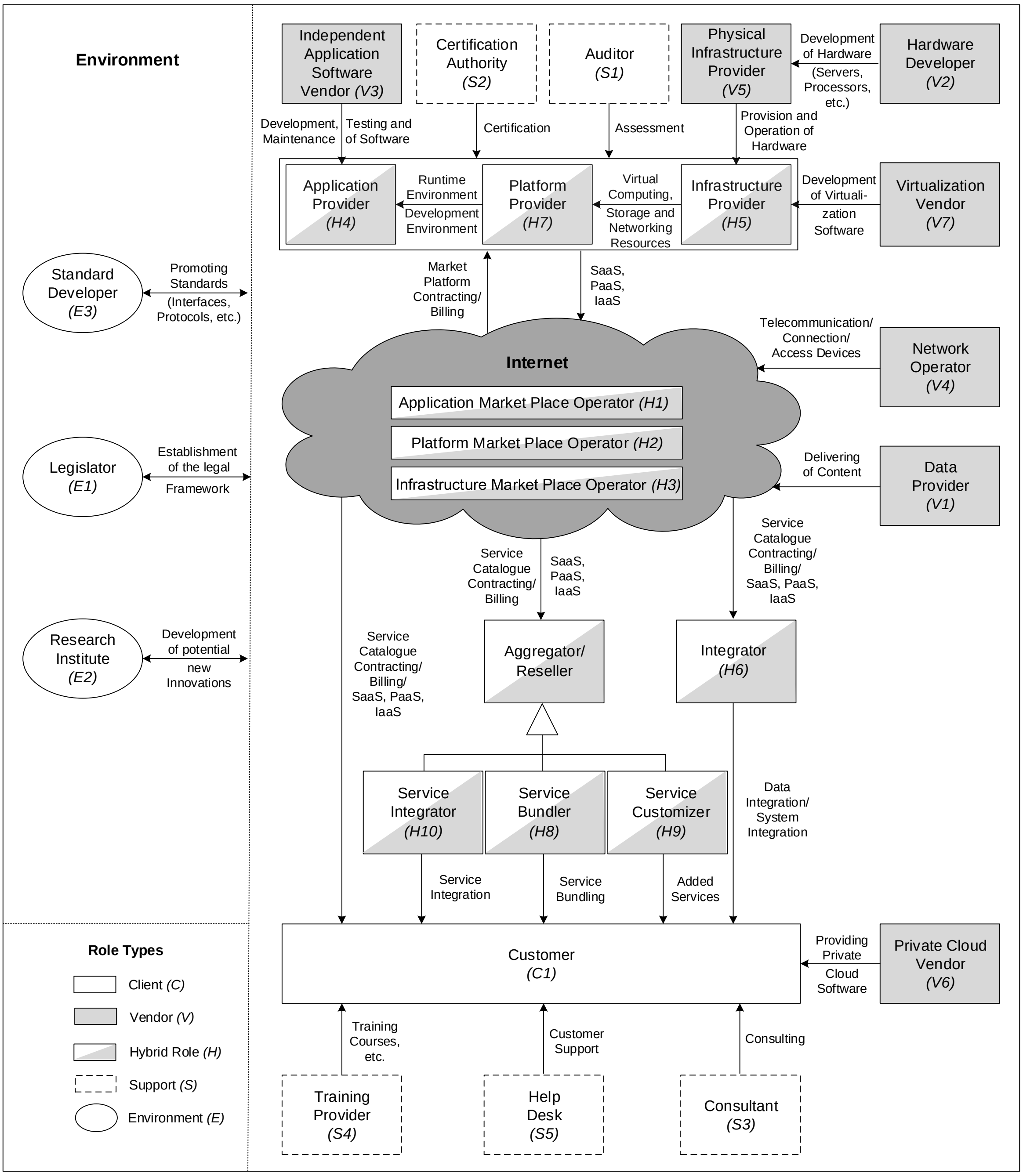

Figure 3. Enhanced PaCE Model

The roles of the enhanced PaCE Model can be grouped into the five categories **(1) Client**, **(2) Vendor**, **(3) Hybrid Role**, **(4) Support** and **(5) Environment**. A vendor provides specific services or products for his clients. Often, both the customer and the vendor role can be found in one organisation. This so-called hybrid role is illustrated by split nodes. The Customer (Client) is the only role that does not deliver services to any other unit. Supporters are third party players offering non-technological services like certification, training or consulting. The category environment contains roles which are located outside the core ecosystem, but have a significant impact on the ecosystem as a whole and vice versa. Probably, the list of these environmental roles is not exhaustive as the focus of this model is on the core of the cloud computing ecosystem.

Despite of the fact that several authors use the e^3-value method to illustrate their model, a simplified representation with nodes for roles and edges for relationships is applied for the enhanced PaCE Model. The relationships represent only service flows. The labeling of the directed edges explains which main services are assigned to an individual role. The roles are explained briefly below (with examples for real world representatives in angular brackets):

(1) Client

The **Customer** *(C1)* – a person or an organisation – is the starting point of any service request and the end point of the service delivery and directly or indirectly pays for all value adding activities in the ecosystem (Böhm et al., 2010). Customers can either buy services directly from a service provider, from one of the Market Place Operators or from Aggregators/Resellers (Walterbusch and Teuteberg, 2012). [*Netflix*, *Expedia*]

(2) Vendor

A **Data Provider** *(V1)* is responsible for generating, aggregating and delivering data and information for other entities in the ecosystem (Böhm et al., 2010). [*Searchmetrics*, *Upside Digital*]

A **Hardware Developer** *(V2)* develops and sells dedicated hardware, such as servers and processors, which is needed for providing IaaS (Repschläger et al., 2010, Bitkom, 2009). [*Dell*, *HP*]

An **Independent Application Software Vendor** *(V3)* develops, tests and maintains the software offered as SaaS. In contrast to the Application Provider, this role does not have any direct contact with the Customers (Pelzl et al., 2013, Fang et al., 2010). [*Adobe*, *Microsoft*]

A **Network Operator** *(V4)* offers connectivity and ubiquitous access of cloud services (Kushida et al., 2012, Qian et al., 2009). For instance, a cloud provider sets up the service level agreements (SLAs) with a network operator to provide services consistent with the SLAs negotiated with the customer (Hogan et al., 2011). [*Telekom*, *O2*]

A **Physical Infrastructure Provider** *(V5)* provisions and operates the physical infrastructure and, therefore, acts as supplier of an Infrastructure Provider (Pelzl et al., 2013). [*1 & 1*, *QSC*]

A **Private Cloud Vendor** *(V6)* develops and sells the software which is necessary to enrich a server with IaaS functions (Hu et al., 2011). [*ownCloud, Seafile*]

A **Virtualization Vendor** *(V7)* develops and sells virtualization software – the main prerequisite of the cloud computing concept (Bitkom, 2009). [*Citrix*, *VMware*]

(3) Hybrid Role

The three roles **Application** *(H1)*, **Platform** *(H2)* and **Infrastructure Market Place Operator** *(H3)* are responsible for market places where various cloud services are offered by different players. Customers can search for suitable cloud services and providers can advertise their services (Walterbusch et al., 2014). Additional services can be offered to both parties, like billing or SLA contracting (Böhm et al., 2010). [Application: *Salesforce*, *AppDirect*; Platform: *CloudForge*, *AppDirect*; Infrastructure: [*AppDirect*, *Deutsche Boerse Cloud Exchange*]

An **Application Provider** *(H4)* deploys, configures, maintains and updates applications on its own or outsourced cloud infrastructure. This role also performs additional tasks, such as monitoring, resource management and failure management (Böhm et al., 2010). [*Dropbox*, *Salesforce*]

An **Infrastructure Provider** *(H5)* provisions storage, computing capacity, network access and other resources. Customers deploy and run applications and have control over the hosting environment and operating systems, but do not control the underlying infrastructure (Hogan et al., 2011). [*Amazon*, *Fujitsu*]

An **Integrator** *(H6)* converts existing data and migrates it into the cloud but also integrates cloud computing solutions into the existing customer's IT infrastructure by developing interfaces to on-premise applications (Böhm et al., 2010). [*Booz Allen*, *CSS Corp*]

A **Platform Provider** *(H7)* is responsible for managing the cloud infrastructure assigned to a platform and provides tools and resources for customers to develop, test, deploy and administrate applications (Pelzl et al., 2013). [*CloudSigma*, *Microsoft*]

A **Service Bundler** *(H8)* offers simple bundling or a complex composition of cloud services without adding new functions, but in combination with a single point of access, billing and identity management (Simons et al., 2014). [*Bluewolf*, *Zapier*]

A **Service Customizer** *(H9)* enhances or adapts given external services by improving existing features and, therefore, provides added value to Customers (Hogan et al., 2011). [*Telestra*, *Netflix*]

A **Service Integrator** *(H10)* provisions a vertical connection of existing cloud services from various providers across the three layers of the cloud computing stack (Simons et al., 2014). [*MSG*, *T-Systems*]

(4) Support

An **Auditor** *(S1)* offers independent evaluation of cloud services, operations, as well as performance and security management of a cloud implementation (Hogan et al., 2011). [*Vigitrust*, *Protiviti*]

A **Certification Authority** *(S2)* assesses a service regarding the fulfilment of quality criteria including legal, security or functional requirements, as well as the business processes and the data centre infrastructure. A certificate is issued upon the fulfilment of the requirements for a predefined timeframe and is, contrary to the Auditor case, made available to the public. The offers of the various providers are, thus, easier to compare for Customers (Sunyaev and Schneider, 2013). [*MSP Alliance*, *TÜV*]

A **Consultant** *(S3)* provides fundamental knowledge about the cloud market and analyses the Customer's processes and requirements to identify and introduce suitable cloud services. Consulting services are also related to providers, for instance, to solve technical problems, evaluate service offerings or analyse customer needs (Walterbusch and Teuteberg, 2012). [*Accenture*, *Capgemini*]

A **Training Provider** *(S4)* offers different types of employee training programs (Walterbusch et al., 2014). [*Tutego*, *CloudAcademy*]

A **Help Desk** *(S5)* is responsible for professional customer support and acts as the primary contact point for Customers in case of problems (Bitkom, 2009, Pelzl et al., 2013). [*Dataprise*, *Camino Information Systems*]

(5) Environment

A **Legislator** *(E1)* establishes the legal framework for any business related activities (Moore, 1996). As cloud computing crosses national borders, heterogeneous national laws form an additional challenge (Marston et al., 2011). [*EU Parliament*, *US Congress*]

A **Research Institute** *(E2)* is, among others, a source for potential new innovations influencing the cloud computing ecosystem (Heikkilä and Kuivaniemi, 2012). [*University of Passau*, *Fraunhofer SIT*]

A **Standard Developer** *(E3)* promotes standards related to interfaces, protocols or SLAs and, hence, has an impact on the cloud computing ecosystem as a whole (Ortiz Jr, 2011). It is still challenging that different institutions define standards independent from each other (Fischer et al., 2013). [*ISO*, *IEEE*]

6 Evaluation and Discussion

In order to ensure the validity and the usability of the enhanced PaCE Model, all roles were verified by the activities of real market actors. For this purpose, the Internet was manually searched to identify companies occupying the roles described in the previous section – independently of the company's size or popularity. As a result, for all 26 roles of the enhanced PaCE Model, at least two market actors could be found. The enhanced PaCE Model, therefore, seems to be a reasonable model for mapping the cloud computing ecosystem as proposed.

The model analysis reveals several aspects that should be taken into account: Firstly, only a small number of authors discuss the benefits for scientists and practitioners originated by the use of their models. Secondly, more than half of the publications do not make any statement regarding their applied research method. A third point is that merely a minority of the ecosystem models are scientifically evaluated. These three analysis results stand in contrast to the guidelines of the design science paradigm (Hevner et al., 2004).

Considering the existing cloud computing ecosystem models themselves, it becomes apparent that only a few of them use a formal definition of the role construct and the terms "*actor*" and "*role*" are mixed or even used as synonyms. Although the e³-value method is widely applied to illustrate the cloud computing ecosystem, a standard notation has not yet been established. Furthermore, the majority of the analysed models consider the value network as an appropriate concept for the description of the cloud computing market. However, important aspects are not included or representable so that a need for this particular model which is even able to incorporate environmental aspects can be stated.

The enhanced PaCE Model can serve as an instrument for further investigations especially on structural aspects and relationships between relevant units. Referring to these demands, the enhanced PaCE Model resolves several limitations of the preceding model version. Firstly, by refining the Aggregator/ Reseller role and adding subtypes with respect to the specific activity types, the increasing importance of brokerage in the cloud computing business is taken into consideration. In this field, there are only a few big and global players, but a huge number of brokers grading up or integrating services and reselling them under their label. Previous cloud computing ecosystem models are not able to represent this aspect sufficiently.

Secondly, the enhanced PaCE Model was designed to cover all four cloud computing deployment models. This was also a shortcoming of the previous models where the role of a Private Cloud Vendor was missing. When a Customer chooses a private, community or hybrid cloud computing solution, he usually buys a private cloud software product and can, for instance, authorize an Integrator but also a Consultant to implement it, in case that assistance is needed. All preceding cloud computing ecosystem models were restricted to the public cloud without explicitly communicating this fact.

Finally, as already stated, the published cloud computing ecosystem models ignore the circumstance that an ecosystem is coupled to its complex environment. Therefore, a category with environment roles was added in order to integrate external forces that influence the cloud computing ecosystem.

7 Summary, Limitations and Outlook for Future Work

In this research paper, a revised and comprehensive cloud computing ecosystem model was developed based on the design science paradigm. This model comprises 26 roles, grouped into five role categories, and includes the basic service flows. As the basis for the model served the recently published PaCE Model, an analysis of the cloud computing ecosystem models based on ten important criteria derived from literature, as well as insights from the general cloud computing and business ecosystem literature. Particularly, the PaCE Model was enhanced by integrating the roles Certification Authority, Private Cloud Vendor, Service Bundler, Service Customizer, Service Integrator, Training Provider, as well as the three environmental roles Legislator, Research Institute and Standard Developer. In order to ensure the integrity of the enhanced PaCE Model, it was investigated within a manual Internet search whether all roles being part of the model are covered by real market actors. As a result, market actors fulfilling the roles' tasks could be identified for all 26 roles.

The enhanced PaCE Model can be useful both for researchers and practitioners. Since the existing models differ considerably from each other and the missing market transparency is regarded as one of the key reasons for the low cloud computing adoption rate, the enhanced PaCE Model provides a common view of the cloud computing ecosystem and a framework for further research. By using this model, practitioners will gain a deeper understanding of the cloud computing market's complexity that might encourage them to consider cloud applications in future. Researchers can use the enhanced PaCE Model as an analytical framework for investigations in the cloud computing field. For established providers and new market entrants, the enhanced PaCE Model covers all the possible applications stated in the individual research papers (Section 4 – Criterion 2: Practical Use of the Model).

However, this research is not without limitations. The main limiting factor is that the evaluation of the enhanced PaCE Model verified only the match between real market actors and conceptual roles. The relationships were not subject of the evaluation and are, therefore, fully based on the scientific literature. Hence, it would be useful, to evaluate the enhanced PaCE Model as a whole in practice.

After identifying the roles and the generic relationships within the cloud computing ecosystem, it is now possible to investigate the ecosystem in detail. Some interesting research questions in this context are: *What value streams generate most of the monetary value? Which roles are successful and how can the success be measured? Which business models and pricing models led to economic success? What are the risks combined with specific roles? Which typical role clusters can be found in practice? Does it make sense to break down the roles from a company to an employee level? How can the diffusion and the acceptance of ecosystem models in general be supported?*

However, beside the need for further research building on the enhanced PaCE Model, the model itself requires continuous adaption as the cloud computing market is highly dynamic and market structures might change during the next years.

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