Analysis of Requirements and Technologies to Migrate Software Development to the PaaS Model

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***Abstract*—Software development has been evolving during the last years and, more and more, the software architecture to support this development has become increasingly complex to meet the new requirements and new technologies. With the new Cloud Computing architecture and models, Information Technology (IT) departments and Independent Software Vendors (ISVs) are developing new applications and moving the traditional software architecture to the cloud. In this context, the Platform as a Service (PaaS) model can provide software development services and components within a new architecture for building a new generation of software with all benefits of the cloud, like scalability and elasticity. We look at the requirements and technologies for developing software with the PaaS architecture and present a migration model for PaaS, based on the main software architectures and information system types, validated by specialists from software development and Cloud Computing areas. The results show the feasibility of our approach and the possibility to have an initial blueprint for software development in PaaS.**

Keywords-Cloud Computing; PaaS; Software Development; Software Architecture; Migration.

I. INTRODUCTION

Cloud Computing, one of the latest IT innovations, is still taking shape and gaining maturity, and at this stage, different people, from the technology area to the sales area, have divergent views and concepts about it, based on their interests and how to apply and use Cloud Computing in their daily lives [1]. Also, Cloud Computing has been modifying software development and traditional IT and business, introducing new ways to develop software, with more scalability and agility with lower costs, allowing companies, from startups to big corporations, to create new business models or improve existing ones.

Due to the growth of Cloud Computing adoption, Platform as a Service (PaaS) has become an important part of the cloud economy and has been showing the potential of a service model, with a platform that supports the entire lifecycle of an application, from development, testing, deployment and operations, with components, tools and integrated services [2]. Many organizations are planning and migrating their on-premise software to the cloud [3], starting with the Infrastructure as a Service (IaaS) and Software as a Service (SaaS) models. Nonetheless, they are facing some challenges and difficulties, mainly in the PaaS model, related to the complexity in integrating the legacy and internal systems, from their IT area to the new PaaS architecture model and services on the cloud.

The remainder of the paper is structured as follows. In Section 2, we present the background and problem identification. Section 3 presents the details of the PaaS service model. Section 4 presents the details of our proposed migration model. Section 5 discusses existing limitations and future works. Finally, Section 6 summarizes the discussion and conclusions of the paper.

II. BACKGROUND AND PROBLEM IDENTIFICATION

PaaS is a cloud service model that provides capabilities to deploy applications onto the cloud created with languages and tools supported by the provider and uses and integrates application infrastructure services in the application to cloud consumers.

In the PaaS model, the cloud provider manages the foundational infrastructure (network, servers, operating systems, storage, etc.), but the cloud consumer has control over the deployed applications, configurations and lifecycle [4].

PaaS delivers application infrastructure capabilities (middleware) to the software development process, such as runtime and development components, as cloud services like:

- Application Development, Data, Workflow, etc.
- Security Services (Single Sign-On, Authentication, etc.).
- Database Management Systems (DBMSs).
- Directory Services.
- Integration middleware.
- Business process management (BPM) platforms.
- Rules engine.
- Complex-event processing (CEP).
- In-memory computing (IMC) platforms.

Cloud Computing and PaaS model architecture bring new requirements and complexity to the software development process. These contingencies include the new technologies, services and tools available in PaaS, to the adaptation of the traditional software engineering and

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development process to use new techniques like DevOps, native cloud application models and hybrid cloud deployment (on-premise to cloud integration), until new methodologies, like Agile, used in this new software development scenario to be considered in the traditional software project management practices.

In this hypersonic-growth scenario, the ISVs and IT department of companies need to be able to evaluate the PaaS model and architecture to adapt their software development and architecture, usually complex with countless legacy systems, many integrations and different technologies to this new software development scenario.

III. PAAS SERVICE MODEL

Considered as the next level of abstraction of the cloud stack, after IaaS, which targets the basic IT infrastructure, PaaS provides the functions from the application stack as services, allowing developers to design and build solutions using platform services for caching, asynchronous messaging, database, and much more. In this way, developers do not need to reinvent the wheel implementing these "commodity" requirements from scratch and can focus on the business logic from the system [5].

However, PaaS is the hardest service model to characterize due to the many ways of building services and the wide range of offerings of PaaS providers. An additional layer of services related to development frameworks, middleware, databases, messaging and queuing is added to PaaS as an integration layer, so the applications can be built to the platform with the supported development languages and tools [6].

Due to the evolution of the Cloud Computing industry and increased cloud customer adoption, new Cloud Computing "as a service" models known as XaaS have emerged, that refer to "anything" or "everything" as a service. These new service models related with the three original cloud service models are being deployed by public cloud providers and into the enterprise private cloud [7].

The PaaS market is growing and becoming segmented with new extended service models for PaaS, as reported by Gartner [8], in 2016 there were 20 specialized PaaS categories from vendors with paying customers, and some new categories will emerge and others will be integrated into new PaaS suites in the next years. This growing market of PaaS solutions reflects the evolution of Cloud Computing and the search for new solutions in the cloud for software development. The main PaaS categories reported by Gartner [8] in 2016 are:

- *Application Platform Services (**aPaaS**):* a cloud service focused on general-purpose business applications development, deployment, execution, supporting business logic and data handling for back-end services, web, and mobile.

- *Business Analytics Platform Services (**baPaaS**):* cloud-based business analytics platforms offering capabilities to ingest data from different data sources, prepare data for analysis, visualize and analyze data, develop and publish dashboards or other Business Intelligence (BI) outputs.

- *Business Process Management Services (**bpmPaaS**):* The delivery of Business Process Management (BPM) capabilities as a cloud service including a graphical business process and rule modeling capabilities, a process registry and repository to handle the modeling metadata, a process execution environment, and rule engine.

- *Business Rule Platform Services (**brPaaS**):* also referred to as decision management PaaS (dmPaaS), a cloud-based service that aims to support decision making by the business rules management.

- *Communications Platform Services (**cPaaS**)*: cloud-based solutions that enable applications to integrate or improve communications functionalities, like telephony calling, SMS, MMS, Speech recognition, Mobile browsing, Video services, and Conferencing.

- *Database Platform Services (**dbPaaS**):* a cloud service that provides any database management system (DBMS) or data storage engineered as a scalable, elastic and multitenant subscription.

- *Function Platform Services (**fPaaS**):* cloud-based service that provides a serverless execution environment for small and event-triggered functions, where it is possible to run code without provisioning or managing servers with support to automatically scale processes to support increasing and decreasing load.

- *Enterprise Horizontal Portal Services (**Portal PaaS**):* cloud-based service that provides an Enterprise Portal with core portal features like security, personalization, integration, content aggregation and presentation, with the ability to run in shared, multitenant environments, including private and public cloud deployments.

- *Integration Platform Services (**iPaaS**):* provides a platform in the cloud to support application, data and system-to-system integrations, using a mix of cloud services, mobile apps, on-premises systems and Internet of Things (IoT) integrations.

- *Message-Oriented Middleware Services (**momPaaS**):* cloud-based services focused on provide communication between one part of an application to another or between different applications through the internet, in the case of public cloud momPaaS, and between components in the same LAN with the private cloud model.

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IV. MIGRATION MODEL

The proposal and migration model are based on the concepts and fundamentals related to the following assumptions:

- There are different PaaS service models specialized in attending to the different needs of software development and migration to the cloud.
- Although there are several types of software, systems, and applications, the migration model was focused on the main types of information systems that have business content relevance.
- There are a variety of software architectures to use in software development, and each one has specific requirements and characteristics that should be evaluated according to the needs and requirements of the system.
- Although software development for PaaS uses the traditional Software Development Life Cycle (SDLC), it is critical to consider the characteristics of Cloud Computing to adapt software development to PaaS.
- Migration software development to PaaS needs to have a defined roadmap and process to allow the migration in phases, although the migration process may be the same for all software development migration to the cloud.

Design Science Research (DSR) is one of the methodologies that allows producing knowledge in a structured way, focusing on a real problem resolution, ensuring the attainment of scientific results. The authors used DSR as a scientific methodology to produce this academic contribution and the migration model. The approach involved an analysis of current software development processes and PaaS software development requirements. We proposed recommendations based on the study and interviewed specialists validated the recommendations. The authors documented the results and discussions.

The migration model for developing and migrating the software development to the PaaS cloud model, described in Table I, was constructed based on two dimensions: the software architecture style and the type of information system that the software was built or will be built using one or more PaaS specialized categories.

The software architectures used in the model were selected based on the relevance and importance in the software engineering and in the current technologies used in software development. Also, the types of information systems [9] were selected based on the focus on business systems and in most of the legacy software implemented. For a specific software architecture and type of information system relation, one or more PaaS specialized models were recommended based on main PaaS categories and should be evaluated whether it will be necessary to use a PaaS specialized model or more than one combined to use PaaS in software development migration projects.

TABLE I. RECOMMENDATIONS FOR SOFTWARE DEVELOPMENT AND MIGRATION TO PAAS

Software Architectures	**Types of Information Systems**					
	Transaction Processing Systems (TPS)	***Business Intelligence (BI)***	***Enterprise Applications***			
			Enterprise Resource Planning (ERP)	***Supply Chain Management (SCM)***	***Customer Relationship Management (CRM)***	***Knowledge Management Systems (KMS)***
Monolithic	aPaaS *iPaaS* (1)	aPaaS baPaaS *iPaaS* (2)	aPaaS *iPaaS* (1)	aPaaS *iPaaS* (1)	aPaaS *iPaaS* (1)	aPaaS *iPaaS* (1)
Client-Server	dbPaaS *iPaaS* (3)	dbPaaS *iPaaS* (3)	dbPaaS *iPaaS* (3)	dbPaaS *iPaaS* (3)	dbPaaS *iPaaS* (3)	dbPaaS *iPaaS* (3)
N-Tier	aPaaS dbPaaS *iPaaS* (4)	aPaaS dbPaaS *iPaaS* (4)	aPaaS bpmPaaS dbPaaS *iPaaS* (5)	aPaaS dbPaaS Portal PaaS *iPaaS* (6)	aPaaS cPaaS dbPaaS Portal PaaS *iPaaS* (7)	aPaaS dbPaaS Portal PaaS *iPaaS* (6)
Microservices	aPaaS dbPaaS fPaaS *iPaaS* *momPaaS* (8)	aPaaS baPaaS dbPaaS *iPaaS* *momPaaS* (9)	aPaaS bpmPaaS brPaaS dbPaaS *iPaaS* *momPaaS* (10)	aPaaS brPaaS Portal PaaS dbPaaS *iPaaS* *momPaaS* (11)	aPaaS brPaaS cPaaS Portal PaaS dbPaaS *iPaaS* *momPaaS* (12)	aPaaS Portal PaaS dbPaaS *iPaaS* *momPaaS* (13)

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The recommendations from the migration model in Table I, resulted from the relation of software architecture style and the type of information system, can be summarized as follows:

- **Monolithic architecture [10] and TPS, ERP, SCM, CRM and KMS information systems [11]:** as a monolithic application is built in a single unit, these types of information systems can use the Application Platform Services (aPaaS) model to implement and deploy the system in the cloud, using an embedded database and one or more programming language runtimes to implement the application (UI, business logic and data access layer) *(Recommendation 1)*.

- **Monolithic architecture [10] and BI information system [11]:** To implement BI information systems in the cloud as a monolithic application, Application Platform Services (aPaaS) can be used to build an application with BI capabilities from scratch or the Business Analytics Platform Services (baPaaS) model can be used to prepare data for analysis, visualize and analyze data, develop and publish dashboards or other Business Intelligence (BI) outputs *(Recommendation 2)*.

- **Client-server architecture [10] and TPS, BI, ERP, SCM, CRM and KMS information systems [11]:** Database Platform Services (dbPaaS) can be used to host the server logic and data for client-server applications and the respective information systems types, but as the application logic is implemented with database stored procedures and database triggers, the dbPaaS vendors and products offer needs to be analyzed and evaluated, before any implementation or migration, to attend these requirements *(Recommendation 3)*.

- **N-tier architecture [10] and TPS/BI information systems [11]:** Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) can be used to implement an n-tier application for TPS and BI information systems, where the data layer can be hosted in dbPaaS and the presentation and business logic layer (and other layers if needed) can be implemented and deployed in an aPaaS as separated applications/modules *(Recommendation 4)*.

- **N-tier architecture [10] and ERP information system [11]:** Like recommendation 4, Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) can be used to implement an ERP information system. Additionally, Business Process Management Services (bpmPaaS) can be used to model and execute the business process related with the functional areas in ERP, such as manufacturing and production, finance and accounting, sales and marketing, and human resources *(Recommendation 5)*.

- **N-tier architecture [10] and SCM/KMS information systems [11]:** Like recommendation 4, Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) can be used to implement an SCM and KMS information systems. Also, an Enterprise Horizontal Portal Services (Portal PaaS) can be used to provide a corporate portal with the enterprise knowledge base for KMS systems and a Business-to-Business (B2B) portal for the interaction between the company and the suppliers, purchasing firms, distributors and logistics companies *(Recommendation 6)*.

- **N-tier architecture [10] and CRM information system [11]:** Like recommendation 6, Application Platform Services (aPaaS), Database Platform Services (dbPaaS) and Enterprise Horizontal Portal Services (Portal PaaS) can be used to implement a CRM information system. Besides, a Communications Platform Services (cPaaS) can be used to provide communications functionalities to enhance the communication and interaction with customers *(Recommendation 7)*.

- **Microservices architecture [12]-[14] and TPS information system [11]:** In the case of a TPS information system, it can be implemented in microservices architecture using: Application Platform Services (aPaaS) to implement each microservice application, Database Platform Services (dbPaaS) to be used by each microservice and encapsulate the business data domain, and Function Platform Services (fPaaS) to implement small functions and procedures to be executed as a microservice by the system *(Recommendation 8)*.

- **Microservices architecture [12]-[14] and BI information system [11]:** Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) can be used to implement each microservice of BI information systems and a Business Analytics Platform Services (baPaaS) can be used together with the

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microservices to provide analytical reports and dashboards *(Recommendation 9)*.

- **Microservices architecture [12]-[14] and ERP information system [11]:** Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) can be used to implement each ERP information system microservice, and can additionally use a Business Process Management Services (bpmPaaS) for modeling and executing the business process and Business Rule Platform Services (brPaaS) to encapsulate some business rules to be executed by the microservices in the system *(Recommendation 10)*.

- **Microservices [12]-[14] architecture and SCM information system [11]:** Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) can be used to implement each SCM information system microservice and Business Rule Platform Services (brPaaS) to encapsulate the business rules that can be consumed by the microservices. Additionally, Enterprise Horizontal Portal Services (Portal PaaS) can be used to provide a B2B portal that is integrated with the microservices layer *(Recommendation 11)*.

- **Microservices architecture [12]-[14] and CRM information system [11]:** Like recommendation 11, a CRM information system can be implemented in microservices architecture using Application Platform Services (aPaaS), Database Platform Services (dbPaaS), Business Rule Platform Services (brPaaS) and Enterprise Horizontal Portal Services (Portal PaaS). Also, Communications Platform Services (cPaaS) can be used by the microservices to provide communications functionalities to customers *(Recommendation 12)*.

- **Microservices architecture [12]-[14] and KMS information system [11]:** KMS Information system types can be implemented in a microservice architecture using Application Platform Services (aPaaS) and Database Platform Services (dbPaaS) to build each system microservice, and Enterprise Horizontal Portal Services (Portal PaaS) can be used to provide a knowledge base portal that is integrated with the microservices layer *(Recommendation 13)*.

For all the recommended scenarios in the migration model (Table I), Integration Platform Services (iPaaS) was recommended for situations when the integration and exchange of information between cloud applications and on-premise and legacy applications are required.

In the recommendations related to Microservices Architecture (8, 9, 10, 11, 12 and 13), a Message-Oriented Middleware Services (momPaaS) was proposed to support the communication and integration between the different microservices implemented in the respective system, thus supporting the message exchange with different protocols.

The proposed migration model and respective recommendations were validated through interviews, where the objective of the interviews was to validate the migration model with specialists in Cloud Computing and Software Development from academic institutions and IT companies.

The following three questions and the identification of each interviewee were considered fundamental in the interview step and aim to validate the study, validate and improve the model and the work.

1. Does it make sense to propose a model that systematizes the different specializations of PaaS for software development?

2. Do you agree with the strategy followed in the presented migration model (Software Architecture/Information System Type/Recommendations)?

3. Do you have suggestions to improve the migration model proposed?

Based on the interview answers collected from the specialists, it was possible to verify that the migration model proposed in this work is valid and the recommendations presented in the model can be applied in software development scenarios with PaaS, according to what has been proposed in the migration model.

Regarding question 1, which aimed to validate if it makes sense to propose the model presented, all interviewees agreed that the proposed model makes sense and the importance of having precise definitions of PaaS specialized models was highlighted, thus avoiding overlaps of concepts.

The strategy followed in the model was agreed by all interviewees, according to the answers from question 2, and it was suggested that some examples of the application of recommendations to enrich the work should be described.

In question 3 answers, the interviewees collaborated with interesting suggestions for improvements in the model, but there did not agree on how to evolve the model, since one interviewee suggested keeping it as simple as possible and not include new types of information systems and new software architectures, while another interviewee suggested exactly the opposite, evolving the model to consider new types of information systems and new software architectures.

Thus, analyzing the results of the validation of the proposed model by the specialists through interviews, it was clear that it can add value to the software development process for PaaS and thus support decision makers, managers and technical specialists in trying to choose the most

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appropriate PaaS models for the needs and requirements of their projects.

V. LIMITATIONS AND FUTURE WORK

Although Cloud Computing is not a recent technology, Platform as a Service has been gaining attention in the IT market in the last years, and consequently, the platform has been evolving. Even though the migration model presented tries to address the main aspects of PaaS, there are still open challenges remaining which can be worked on in future projects and studies.

An exhaustive investigation was necessary in different sources of information, like research and advisory companies in IT, academic papers and theses, books related with Cloud Computing and software development, producing this scientific contribution with more impartiality and objectivity and contributing to the scientific community. Gathering experts in the Cloud Computing area and getting an agenda for the interviews was difficult too, so the focus was on selecting at least one specialist from the university, one from a software consulting company and one from a software technology company, thus allowing to validate the migration model with different perspectives and experiences.

Currently, we can notice that Cloud Computing has been revolutionizing the IT market and the way we build applications and solutions, and if we analyze the conclusions of this study, it is evident that there is a need to study and explore the PaaS cloud model and its specializations further, also the changes and adaptations required in the software development arising from this "new way" to build software.

VI. DISCUSSION AND CONCLUSIONS

Every day, agility and innovation have become key factors for organizations to continue to grow and be competitive in the local and globalized market. Cloud Computing is increasingly playing a key role to support IT departments and ISV to drive organizations to achieve these goals, supporting new software and hardware technologies, and new software development methodologies and software architectures. More and more users are deploying strategical business applications in IaaS, PaaS, and SaaS, thus making platform capabilities the center of the cloud innovation. PaaS has been evolving and specializing in specific platforms to attend the different software development needs and the IT market trends, like Big Data, Internet of Things, Mobility, Cloud Native and others.

However, with continuous PaaS specialization and new software development technologies that come up every day, migrating legacy systems or developing new systems in the cloud becomes complex and challenging in some situations. The migration model presented originated because of the previously mentioned scenarios and built based on the study of the concepts and technologies related to PaaS. We tried to give recommendations and solutions, to help IT departments and ISV to start entering in PaaS software development with an initial blueprint. We validated our proposal with a model mediating to specialists in Cloud Computing and Software Development from academic institutions and IT companies.

REFERENCES

[1] N. B. Ruparelia, *Cloud Computing*, First Edit. MIT Press, 2016.

[2] D. Beimborn, T. Miletzki, and S. Wenzel, "Platform as a Service (PaaS)," *Bus. Inf. Syst. Eng.*, vol. 3, no. 6, pp. 381–384, 2011.

[3] C. Pahl and H. Xiong, "Migration to PaaS clouds - Migration process and architectural concerns," in *2013 IEEE 7th International Symposium on the Maintenance and Evolution of Service-Oriented and Cloud-Based Systems*, 2013, pp. 86–91.

[4] P. Mell and T. Grance, "The NIST Definition of Cloud Computing Recommendations of the National Institute of Standards and Technology," *Nist Spec. Publ.*, vol. 145, p. 7, 2011.

[5] M. J. Kavis, *Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, and IaaS)*. Wiley; 1 edition (January 28, 2014), 2014.

[6] R. Mogull *et al.*, "The Security Guidance for Critical Areas of Focus in Cloud Computing v4.0 ('Guidance v4.0')," *Cloud Secur. Alliance*, vol. 4.0, p. 152, 2017.

[7] J. Bond, *The Enterprise Cloud*, First Edit. O'Reilly Media, 2015.

[8] Y. V. Natis *et al.*, "Platform as a Service: Definition, Taxonomy and Vendor Landscape, 2016," *Gartner*, 2016. [Online]. Available: https://www.gartner.com/doc/3334517/platform-service-definition-taxonomy-vendor. [retrieved: Feb, 2018].

[9] J. O'Brien and G. Marakas, *Management Information Systems*, 10th Editi. McGraw-Hill Education, 2010.

[10] J. Ingeno, *Software Architect's Handbook Become a Successful Software Architect by Implementing Effective Architecture Concepts.* Packt Publishing Ltd, 2018.

[11] K. C. Laudon and J. P. Laudon, *Management information systems: Managing The Digital Firm*, 15th Editi. Pearson Education Limited, 2018.

[12] B. Burns, *Designing Distributed Systems - Patterns and Paradigms for Scalable, Reliable Services*. 2018.

[13] C. Posta, *Microservices for Java Developers*, First Edit. O'Reilly Media, Inc., 2016.

[14] Microsoft, "Cloud Application Architecture Guide," Microsoft Press, 2017.

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