

Architecting the Recommendation Layer of a Platform-as-a-Service e-Marketplace

Fatemeh AhmadiZeleti, Islam Hassan, Sonya Abbas, Adegboyega Ojo and Lukasz Porwol
Insight Centre for Data Analytics, National University of Ireland, Lower Dangan, Galway, Ireland

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Abstract: This paper addresses the problem of how to architect aspects of an Electronic Marketplace (e-Marketplace) to enable Software SMEs (Small and Medium Scale Enterprises) Engineers to easily discover the most appropriate Platform-as-a-Service (PaaS) offerings available in a marketplace. While there are existing architectural models for e-Marketplaces, these models largely ignore the semantic aspects of the descriptions of offerings in the marketplace. In addition, they provide little support for recommendations and decision making for consumers in the marketplace. These shortcomings make the reuse of existing e-Marketplace architectures inadequate for some categories of services such as PaaS services which are characterised by relatively complex technical specifications. We address this problem by integrating a Semantic Recommendation Layer into a PaaS e-Marketplace architecture. Requirements for this layer were obtained from a series of interviews with Software SME engineers and PaaS providers within the context of a Three-year EU Project. We describe the major components of the Layer and the underpinning recommendation and decision model. Results from this work should contribute to domain-specific architecture for e-Marketplaces.

1 INTRODUCTION

Architectures for Cloud e-Marketplace are receiving growing attention from researchers, demonstrated by scholarly works such as (Kamateri et al. 2013). However, published e-marketplace architectures in literature are far from maturity. Most of the implementations of these e-Marketplaces architectures are below level 4 of the Technology Readiness (TRL 4 – technology validated in the lab). Besides this limitation, these models largely ignore the semantic aspects of the descriptions of offerings in the marketplace. In addition, they provide little support for recommendations and decision making for consumers in the marketplace.

These shortcomings make the reuse of existing e-Marketplace architectures inadequate for categories of services such as PaaS services which are characterised by relatively complex technical specifications. A notable earlier attempt at addressing this problem is presented in (Kamateri et al. 2013) as part of the Cloud4SOA project. However, the architecture was only intended to support a demonstrator – typically, TRL 4.

This research carried out as part of a follow-up project designed to address the some of the limitations of the Cloud4SOA project aims to develop the Semantic Recommendation Layer for a viable PaaS e-Marketplaces in collaboration with Cloud SMEs in Europe. The Recommendation Layer is also expected to support the decision making of the Consumer Engineers in selecting the most appropriate offering satisfying their needs from the list of recommendations. We describe the major components of the Layer and the underpinning recommendation and decision model.

The rest of the paper is structured as follows: Section 2 describes some background to existing Cloud e-Marketplaces. In Section 3, we address the research question and describe our approach to the research. The details of the architectural framework for the PaaS e-Marketplace Recommender Layer is presented in Section 4. We end with concluding remarks in Section 5.

2 BACKGROUND

In this section, we summarize recommender systems of three broker-based Cloud architectures derived from related EU projects that aim to address Cloud interoperability mainly in the PaaS layer as well as open and proprietary offerings targeting PaaS interoperability.

2.1 Cloud4SOA

Cloud4SOA is a completed FP7 project that focused on resolving the interoperability and portability issues that exist in current Clouds infrastructures and on introducing a user-centric approach for applications which are built upon and deployed using Cloud resources. The project architecture consists of five layers, three horizontal and two vertical, outlined below. The three horizontal layers include Front-End Layer, Repository Layer, and Harmonized API. The two vertical layers include Semantic Layer and Governance Layer. Cloud4SOA PaaS Recommendation is an individual component of the SOA Layer. In Cloud4SOA, the PaaS Recommendation component offers suggestions for the best matches of PaaS offerings. The degree of relation between a PaaS offering and an application is computed based on the similarity of their semantic profiles. Moreover, this module offers a rating mechanism that enables the user rating and the system automatic rating (based on SLA violations) of PaaS offerings (Kamateri et al. 2013).

2.2 MODACloud

MODAClouds is an EU FP7 project aiming to provide the followings: Decision Support System; an Integrated Development Environment; a run-time environment for the high-level design, early prototyping, semi-automatic code generation, and; automatic deployment of applications on Multi-Clouds with guaranteed Quality of Service (QoS). In particular, MODAClouds uses a Model-Driven Engineering approach for Clouds for semi-automatic code deployment using decision support systems on multiple Cloud providers hiding the proprietary technology stack (Almeida et al. 2014).

MODAClouds Architecture consists of two distinct software levels: the MODAClouds IDE and the Runtime platform. The Runtime platform includes Monitoring Platform, the Self-Adaptation Reasoner, the Models@runtime engine, the Execution Platform and the Filling the Gap component. MODAClouds IDE includes Decision

Support System, MODACloudML Functional Modelling Environment, QoS modelling and analysis tool, Data Mapping Component, MODACloudML Deployment and Provisioning Component, and Filling the Gap Design-Time Manager (Almeida et al. 2014).

The Data Mapping Component allows the user to decide upon the best cloud-specific data representation formats and tools that fulfil the application requirements. A cloud developer must consider the possibility of migrating and replicating data on different data storages possibly located in different clouds. This component offers different kinds of Cloud data storage services. As clouds offer different kinds of storage services, a first issue to address is to select the type of service to exploit according to the characteristics of data to be stored the way they are going to be used. A second important concern is about the way data have to be mapped on the data schema offered by the selected storage service. Finally, a cloud developer must consider the possibility of migrating and replicating data on different data storages possibly located in different clouds (Almeida et al. 2014).

2.3 4CaaSt

4CaaSt is a FP7 EU project that aims at introducing a broker-based architecture which decouples the development and specification of applications from their actual deployment, leaving the underlying complexity of infrastructure and platforms out of users' concerns (Garcia-Gomez & Jimenez-Ganan 2012). 4CaaSt introduces the concept of the blueprint, a technical description of an application or a service that decouples the various dependencies it has along the Cloud layers. For PaaS deployments, using 4CaaSt blueprints, application providers can choose from different platform layers and services to run their applications, including different infrastructure, middleware, and applications components/services. Once the selection is done, 4CaaSt generates automatically the deployment designs and automatically provision the necessary resources required for the deployment. In addition, 4CaaSt offers resource provisioning by considering based on the deployment designs the required resources needed for the deployment for instance the QoS levels, scalability requirements, the configuration of virtual machines (Gómez 2013) (Momm 2013).

The recommendation is performed in Marketplace section which includes a number of sub-components. The marketplace allows any of its

stakeholders to search and check the constituting components of a particular service and product before he purchases it. Ideally, it should support as many different search methods as possible. 4CaaS uses the following types (Gómez 2013) (Momm 2013): Free text search, Search by formal specification, Search by browsing, History based search, and User profile based search. The marketplace gets a list of the most relevant products for a customer and it allows service consumer or any stakeholder to compare two or more products in terms of capabilities, price model or conditions. The marketplace enables the selection of the most appropriate product among those offered (Slabeva & Hoyer 2013) (Momm 2013).

2.4 Comparing Cloud E-Marketplaces

A simple comparison between open source related projects shows that Cloud4SOA, ModaClouds, and 4CaaS are the projects that implement recommendation layer either in one module or combination of modules for their offerings.

Other Cloud e-Marketplace or brokers without recommender system are listed in Table 1.

Table 1: Analysis of recommender systems for cloud marketplaces.

Platforms	Adaptive Front-ends	Semantic Models	Offering Recommendation Layer	Monitoring and SLA Enforcement Layer	Persistence and Execution Layer
Cloud4SOA		✓	✓	✓	✓
mOSAIC		✓		✓	✓
SpringCloud					✓
ModaClouds			✓	✓	
REMICS and ARTIST		✓			✓
4CaaS			✓	✓	✓

3 RESEARCH QUESTION AND APPROACH

3.1 Research Question

The research question addressed in our work includes: What kind of architectural framework and decision model is required to recommend the best PaaS Offerings to DevOps?

To answer the above problem, we carried out an extensive review of the literature and designed questionnaires for eliciting requirements from SME Clouds service provider and the SME engineers for the recommendation layer (and other layers) of the

PaaS e-Marketplace architecture.

3.2 PaaS Project Contexts

The research was carried out as part of the PaaS project which aims to create a marketplace where on the one hand, different PaaS providers can advertise their cloud offerings and, on the other hand, developers can benefit from a PaaS abstraction layer in order to avoid the vendor lock-in problem. Moreover, PaaS project focuses on resolving the data and application portability issues that exist in the Cloud PaaS market through a flexible and efficient deployment and migration approach. The vision of the PaaS project is to enable Cloud vendors to roll out semantically interoperable PaaS offerings while benefiting European Software SMEs by allowing them to deploy or migrate business applications on the best-matching Cloud PaaS offerings.

3.3 The PaaS Architectural Framework

PaaS Marketplace constitutes a thin, non-intrusive broker that mediates between PaaS offerings and PaaS users. It relies on open standards and introduces a scalable, reusable, modular, extendable and transferable approach for facilitating the deployment and execution of resource-intensive business services on top of semantically-enhanced Cloud PaaS offerings. PaaS Marketplace comprises of five layers (Figure 1). The major layers of the architecture are explained below:

- The PaaS Semantic Models: this layer serves as the conceptual and modelling pillars of the marketplace infrastructure, for the annotation of the registered PaaS offerings and the deployed applications profiles;
- The PaaS Offering Recommendation Layer: this layer implements the core functionalities offered by the PaaS Marketplace Infrastructure, such as PaaS offering discovery, recommendation and rating;
- The Monitoring and SLA Enforcement Layer: this layer realizes the monitoring of the deployed business applications and the corresponding Service Level agreement;
- The Persistency, Execution and Coordination Layer: this layer puts in place the technical infrastructure, e.g. repositories, on top of which the PaaS marketplace is built. It also includes the PaaS Unified PaaS API that is a common API exploited in order to uniformly interact with the heterogeneous PaaS offerings and, in

addition, it realizes the lifecycle management of the deployed applications;

- The Adaptive Front-ends: this layer support seamless interaction between the users and the PaaS functionalities, through a set of configurable utilities that are adapted to the user’s context.

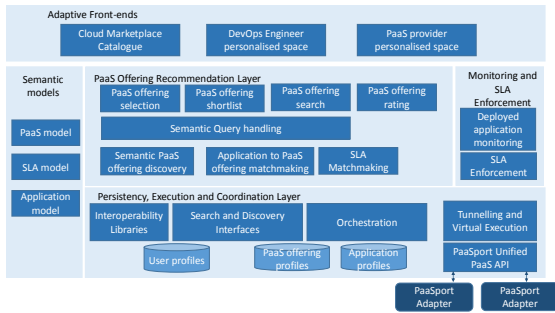


Figure 1: PaaS high-level architecture.

4 RECOMMENDATION LAYER

Recommendation layer offers a toolbox that software SMEs can use through their personalized front-end in order to find the PaaS offering that best matches the requirements of the application that they want to deploy in the cloud. The offering recommendation is based on the degree of similarity between the applications deployment profiles and the available PaaS characteristics, which is computed based on the similarity of their semantic descriptions. Recommendation Layer has been developed as part of the PaaSSport Cloud-broker Architecture specification.

4.1 Core Components

This section presents the eight core components of the Recommendation Layer of PaaSSport Reference Architecture, shown in Figure 2.

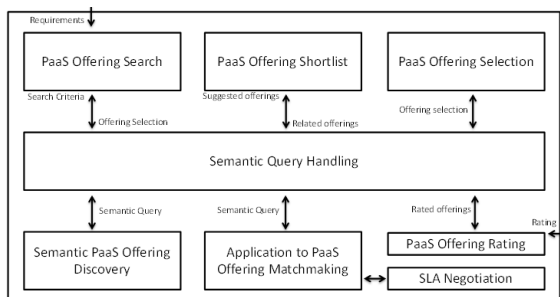


Figure 2: Recommendation layer of the PaaSSport Reference Architecture.

- **PaaS Offering Search:** PaaS offering Search component receives software SMEs application requirements and sends the requirement to the Semantic Query Handling component.
- **Semantic PaaS Offering Discovery:** The PaaS Offering Discovery component capitalizes on the search mechanisms offered by the Distributed Repository Layer and employs lightweight semantic models and techniques in order to find among the available PaaS offerings these which meet best the user’s requirements. It also negotiates with those PaaS Offerings to get SLA agreements.
- **Application to PaaS Offering Matchmaking:** Application to PaaS offering Matchmaking implements the semantic matchmaking between the semantic profile of an application and those of the available PaaS offerings. The matchmaking criteria will be flexible and configurable thus allowing the Software SMEs Engineer to decide in a range between exact (full) match and partial matches.
- **PaaS Offering Shortlist:** PaaS offering shortlists provides to Software SMEs Engineers suggestions of PaaS offerings related to/suitable for the application that they want to deploy. The degree of relation between an application and the available PaaS offerings is computed based on the similarity of their semantic profiles.
- **PaaS Offering Selection:** PaaS offering selection utilizes lightweight semantic models and multiple parameters in order to support Software SMEs Engineers to make their final decision and selection with regards to the most suitable PaaS offering recommended by the PaaS Offering Shortlist Component, by simply prioritizing and adjusting the multi-parametric characteristics of the service deployment and configuration requirements.
- **SLA Matchmaking:** The SLA Matchmaking Component allows the SLA matchmaking based on the application requirements and the multi-parametric characteristics of the service deployment and configuration requirements of the provider.
- **PaaS Offering Rating:** PaaS offering rating facilitates the rating of a particular PaaS offering by a Software SMEs Engineer. Each engineer can leave a comment and rate a particular PaaS, thus offering to express their satisfaction or dissatisfaction with regards to quality, usability, reliability and user-friendliness of the offering.
- **Semantic Query Handling:** Semantic (SPARQL) query handling component is the core component of the layer as it controls all the interaction between all the other components.

- It triggers the Semantic PaaS offering discovery component to get all the offers according to the user preferences comes from the user profile.
- It sends the offers along with the application requirements to the Application to PaaS Offering Matchmaking component where the matchmaking happens based on the matching algorithm and returns list of the matched offers to the semantic query handling.
- It sends a list of the matched offers to the PaaS Offering Shortlist component where the offering scoring algorithm score the offers and returns the matched offers combined with scores.
- It sends the scored matched offers combined with the PaaS offering search component where a response will be generated to the SearchPaaSOfferingWidget.

4.2 Interaction between the Components

Figure 3 shows the interactions between the different components of Recommendation Layer. It also shows the flow of the implementation where the semantic query handling component plays a critical role in managing other components as detailed in the previous section. An essential component in architecture to start with is the PaaS offering search, it is one of the interfaces, which receives software SMEs application requirements with or without the user preference that might has valuable information to be used for providing a personalized semantic discovery. PaaS offering search component sends these query handler component continue with the rest of the process through interacting with the semantic PaaS offering discovery, Discovery component receives the semantic query from semantic query handling. It applies two different search methods in order to find among the available PaaS offerings these, which meet best the user’s requirements.

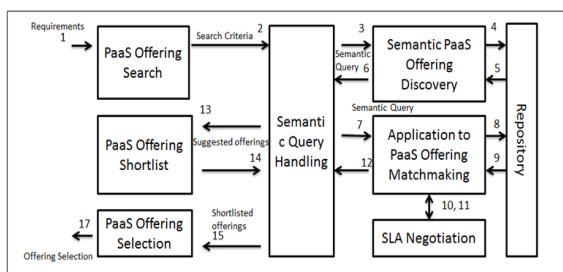


Figure 3: Interaction among components of the Recommendation Layer.

The PaaS Offering Discovery component search is based on the semantic profile of the application and also on manually inserted searching criteria. It is responsible for getting SLA offers through matchmaking with the PaaS Offerings that meet the user’s requirements. It interacts with the repository layer, SLA matchmaking component and semantic query-handling component in order to achieve the required functionality.

The PaaS offering matchmaking implements the semantic matchmaking between the application requirements and those of the available PaaS offerings. The matchmaking criteria will be flexible and configurable thus allowing the Software SMEs Engineer to decide in a range between exact (full) match and partial matches. It is invoked by the semantic query handling component and based on the matchmaking algorithm.

Then, Shortlisting component provides suggestions of PaaS offerings regarding the application that the Software SMEs Engineers want to deploy. It receives the results of the matchmaking component through semantic query handling component. It is evoked by the semantic query handling component and it’s mainly based on the offering scoring algorithm. The output of this component is a list of scored matched offers, which is sent back to semantic query handling component.

Finally, the selection component implements the multi-criteria decision-making algorithm, AHP over a list of PaaS offering results obtained from the PaaS Offering Shortlist component. The selection criteria are: 1) Quality of Service, 2) Quality of Support, 3) Maintenance Activity, 4) SLA Reliability and 5) Value For Money. The Software SMEs Engineer are allowed to specify their preferences for these criteria as a basis for PaaS Offering Shortlist component through semantic query handling component.

4.3 Elaborating the Decision Model

We frame the ranking of the matching offerings as a Multi-Criteria Decision (MCD) problem.

There are three different methods for Multi-Criteria Decision Making (Kousalya et al. 2012):

- Weighted Sum Method: common approach especially for single dimensional problems,
- Preference Ranking Organization Method for Enrichment Evaluation: uses pair-wise comparison of alternatives, and
- Analytical Hierarchy Process (AHP): decomposes complex problem into a hierarchy where the goal is on the top and criterions are at levels and sub-levels of it.

Despite the existence of aforementioned methods, we employed AHP for developing the Selection Component of the project as it is fairly simple to apply, and one of the most popular approaches used for multi-criteria decision-making. AHP sorts and recommends list of PaaS Offerings based on the following:

- Preferences/priorities (1, the lowest priority, 5, the highest priority) given by the Software SMEs Engineers on the following five selection criteria:
 - Quality of Service,
 - Quality of Support,
 - Maintenance Activity,
 - SLA Reliability and
 - Value for Money
- Overall score of each PaaS offering. The rating mechanisms are used to give an average rating to each PaaS Offerings. The average rating per Offering is stored in the Rating Repository and automatic update takes place every time a new rating is submitted.

In order to compare PaaS Offerings, a scale of numbers is required to indicate how dominant one element is over another element with respect to the set of criteria (Coyle 2004) (Adamcsek 2008) (Kousalya et al. 2012).

5 CONCLUSIONS

In this paper, we have developed an architectural framework to enable semantic recommendation and support decision-making of end-users in the PaaS e-Marketplace. We believe that our framework can be easily reused in another e-Marketplace architectural context. Our future work includes large-scale validation of the architecture with members of the SME Associations that is a member of the PaaSport project consortium.

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