2011 Third IEEE International Conference on Coud Computing Technology and Science

A Business Resolution Engine for Cloud Marketplaces

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Abstract—**Nowadays cloud computing can be considered as a key element of modern ICT systems, changing the technological and architectural aspects that these systems are designed and managed. The number and variety of applications, exploiting the advantages of this new computing paradigm, is increasing, emerging a new market of services and resources. Modern applications, from enterprise software to mobile and social networking apps are adapted and become available through the Cloud, allowing wider adoption and advanced functionality. Besides the numerous technical and technological advancements, cloud computing also leverages new business models and value networks. To this direction more entities are involved in the service delivery process and marketplaces are created to ease the development of applications through reusability and aggregation of services and resources. In this paper we present an innovative mechanism for the resolution of the customers' requirements which enhances the process of selecting cloud services from the business point of view.**

Keywords: Cloud Computing; Marketplace; Business Models; Pricing Models; Service Selection; Service Level Agreement

I. INTRODUCTION

Although cloud computing [20] as another distributed computing paradigm is not something new, nowadays it seems that the number of people and organizations exploiting the cloud computing capabilities is increasing and the research interest in cloud technologies is expanding. The new cloud ecosystems are changing the way computing, storage and networking resources are purchased and consumed, creating new business models and value chains. According to the Hype Cycle of Gartner Research [11], as cloud computing passed the "Peak of Inflated Expectations" and is moving towards the "Plateau of Productivity", the business aspects of cloud computing are considered of high importance for the wide adoption and the commercial success of the applications exploiting this technology.

Following the SPI (Service, Platform, and Infrastructure) cloud model [18], cloud computing products are categorized in the three main layers of *Infrastructure as a Service (IaaS), Platform as a Service (PaaS)* and *Software as a Service (SaaS)*. Lately more and more "buzzwords" for cloud products appear describing IT assets that are offered as services though the Cloud such as *Database as a Service (DaaS)*, *Context as a Service (CaaS)* and other; all wrapped under the term *Everything as a Service (XaaS, EaaS or *aaS)* [1]. What all these products have in common is the need for marketplaces capable to support the technical and business requirements of providers and consumers, allowing them to exploit the technological advantages of Clouds expanding their businesses.

The existing cloud solutions come with several limitations regarding the involvement of players with competitive applications in the cloud ecosystem because of the various, often complex and contradicting, business and technical requirements. In addition, the process for third parties to deploy their applications on cloud infrastructures, create new business models and establish synergies is very complicated since their requirements cannot be fulfilled from a single provider. In the mobile telephone paradigm there are several approaches addressing this problem, with most known and successful the iPhone App Store [14] and the Android Market [2]. Developers and providers join these marketplaces selling their applications and services using various business and revenue models. These solutions have led many developers and providers to be involved, extending their businesses in the mobile market, while end users are now able to discover hundreds of services and applications that satisfy their needs.

In the cloud computing paradigm, the marketplace concept is expected to minimize the business complexities for providing and consuming all types of services by supporting all phases of the service lifecycle (knowledge, intentions, contract and settlement). The marketplaces offer the providers the ability to publish services and applications in a managed

978-0-7695-4622-3/11 $26.00 © 2011 IEEE
DOI 10.1109/CloudCom.2011.68

environment, which controls the business terms and conditions (price, revenue sharing, promotion, etc.), including integrated rating and billing capabilities. Selection of appropriate products based on customers' needs is another important aspect of the marketplaces in order to allow the elasticity that is required in business level. Cloud marketplaces should be capable of supporting product compositions, spanning the cloud stack layers, and provide mechanisms and tools to the developers for reusing existing products. This requires automated selection processes not only for products but also of pricing models and SLAs (Service Level Agreements) through which these products are provisioned. In that sense, the selection becomes a very complicated process, especially if we consider that cloud marketplaces are capable to offer any kind of product (XaaS), each of which can be merchandised through different pricing schemas and SLAs.

This paper proposes an innovative solution, as part of the cloud marketplaces, to efficiently resolve the customer requirements from the business perspective and select appropriate pricing models for services, allowing combined models and end-to-end SLAs. While existing marketplaces focus on trading standalone services, our approach will support, among other features, dynamic business terms and conditions for both simple services and composite products. The proposed solution follows a pluggable approach for the selection algorithms and techniques deploying ad-hoc the appropriate solving methodology for a given selection problem.

The rest of the paper is structured as follows. Chapter 2 presents the related work concerning service selection in cloud and other electronic marketplaces. The role of the marketplaces in the cloud ecosystems as well as the main entities involved in the service delivery process are analysed in chapter 3. Chapter 4 describes the Business Resolution Engine including the motivation and extensive analysis of the resolution process and system architecture. The innovative aspects of the proposed solution are highlighted in chapter 5. Finally, chapter 6 concludes our work and presents issues that need to be addressed in the forthcoming period.

II. RELATED WORK

A marketplace in the cloud ecosystem has the role of managing the relationships and transactions among the different parties (providers and consumers), enhancing the product discovery and cash transactions. A market-oriented approach promotes QoS-based activities (resource allocation, service selection etc.) depending on the experienced utility values [10]. In these marketplaces the same technology being composed / distributed differently can be commercialized according to several pricing models, resulting in multiple product instances serving the same or similar purposes (e.g. different QoS level). As the number of products and instances increases, the solution complexity also increases, making the optimal service selection of a multi-level product almost unfeasible to be reached in a non-automatic way.

There have been various approaches and selection mechanism propositions, concerning optimal service selection and provision in distributed and service oriented systems, from users', service providers' and overall performance scope. As the resolution of customers' QoS parameters at requested levels, plays a significant role, the performed selection mechanism must be able to ensure that the selected set of service providers will meet the required QoS thresholds, ensure fault tolerance and reliance to avoid possible SLA violations.

In the service oriented infrastructures, services are regarded as reusable components, representing business or operational tasks. A service can be composed of various, independent or linked, web services. This approach may offer a higher degree of standardization and interoperability and also may expose reusable application functionality that can easily be accessed, customized (in order to meet different QoS parameters and cost levels) and consumed by different end users [3]. On this basis, a selection algorithm that converges to the optimal solution, by means of properly selecting the set of service providers who satisfy the requested QoS parameters under the given cost and execution time constraints of a business process, without having to explore the entire solution space, has been proposed by Menasce et al. [6]. In this paper, optimized service selection is formulated as a nonlinear programming optimization problem, with objective to select a service, from the solution space, that minimizes the average execution time under given cost constraints. A heuristic search algorithm that performs very close to the optimal, examining though only a small percent of the solution space, is also presented. Both the abovementioned service selection approaches aim at minimizing total execution time or cost, while taking into account only two QoS constraints, namely cost and execution time.

On the other hand, the service selection scheme which optimizes the delivered QoS, is modelled as a linear programming problem, optimizing a suitable objective function under threshold values of some attributes of interest (expected response time, execution cost, availability etc.) by Cardellini et al. [22]. In this mechanism, the selection process is carried out per groups rather than per request, to avoid and more effectively manage potential requests' overload. Also a statistical guarantee on the requested QoS parameters is provided. The proposed by Dubey et al. [23] service selection mechanism is based on the maximization of users' utility function, subject to its cost constraints. Utility functions, derived from distributed autonomic self-optimization systems, are used to measure the level of customer satisfaction, in terms of a set of attributes (response time, availability etc.), as a result of a service selection set. Nevertheless these solutions do not take into consideration stakeholder relationships.

A supplier selection mechanism in a B2B marketplace environment is proposed by Chamodrakas et al. [12]. The service suppliers' selection is performed in two stages, in order to reduce the information overload effect and reduce the computational complexity. The first stage reduces the initial set of possible solutions according to user hard constraints and the remaining are evaluated and rated in the second stage. This solution respects the existence of a large number of quality criteria but not the execution relationships. A two phase selection algorithm is also described by Trummer et al. [13]. In the first phase enumerates all possibilities of partitioning the requested service and in the second part determines the optimal solution by transforming the problem into a constraint optimization problem, aiming to minimize the total running

cost. This mechanism takes into account possible dependencies and/or combinations and constraints, between different components of the given service/application, but focuses only on total cost minimization.

Rehman et al. [24] have proposed and formalized a multi-criteria service selection methodology, which leads to the selection of the services' set that best matches a user's requirements, according to performance criteria, measurement functions and user priority weights. However, this approach is effective only for service selection among service instances of similar specifications and without regarding execution relationships among them.

A business operating environment, to support services from the service consumer's perspective, is introduced by Graupner et al. [21]. Based on the current trend of delivering XaaS, this business environment provides capabilities for the definition, selection, contracting, integration and operation of services which can be connected and/or transformed into higher abstractions. Additionally, a component based QoS negotiation mechanism, with broker and service provider software components, is described by Menasce et al. [7]. The presented solution is characterized of QoS based service registration and discovery ability, along with a secure protocol for QoS negotiation and a control mechanism. This solution eliminates as possible the involvement of the service provider in the negotiation, but does not take into account the costs of delivering different QoS levels.

III. MARKETPLACES IN THE CLOUD ECOSYSTEM

The adoption of clouds as technologies and solutions for developing, providing and consuming services and applications for IT is continuously increasing. Similarly, more and more organizations, enterprises, SMEs as well as individuals, are involved in this computing paradigm exploiting its benefits and extending its functionality in all layers. As already mentioned, the concept of cloud computing extents from the hardware resources layer to the delivery of complete applications, thus several types of actors participate in the processes taking place in each layer. In that sense, the service delivery process becomes more complicated and spans in different administrative domains, which leads to multi-part value chains and more complex lifecycles for applications and services.

The simplified model of provider-consumer trading resources or services is not applicable in modern clouds where any kind of IT assets can be offered either independently or through compositions. The modern and future clouds can be better characterized by the notion of XaaS which is covering more perspectives of the cloud computing services. In business level, the functionality of exchanging of XaaS assets is offered by cloud marketplaces. The marketplaces play the role of a broker between providers and consumers, allowing also the service aggregators to participate in the value chain by developing new products. Based on the SPI cloud model the key entities in the service delivery value chain are the following:

Infrastructure Provider an entity that operates and manages IaaS cloud layer i.e. the hardware (computational, storage and network) resources offering them as services to the other layers using virtualization techniques. This layer encompasses capabilities for service resilience, scalability and high availability.

Platform Provider realizes the PaaS cloud layer offering an environment with monitoring and management mechanism, as well as application programming interfaces (APIs) for the development, testing and operation of applications in the Cloud. At this layer, the developers are interested in the adaptation of the application using native cloud technologies such as Cloud enabled databases rather that the amount of low level resources that are needed for the execution of the application. In that sense, Platform Providers offer toolkits for effective adaptation of applications to a particular cloud environment.

Application Provider offers software applications, hosted in cloud platform(s), as services to the customers. Application Providers focus on the application internal parameters such as the number of concurrent users in an eLearning session, so as to guarantee the smooth operation of the application on the required QoS level. This role incorporates tasks (SaaS layer) such as application and performance modelling, enactment and monitoring of application execution, evaluation of events and triggering of corrective actions. In order to guarantee the effective description and integration of the application in the Cloud, Application Providers make use of platform specific tools and APIs offered by the Platform Providers.

Consumer is the end user of the applications that are provided as services in the Cloud, requesting the use of a service on a specific QoS level and configuration, paying for the service use based on the pricing model of the Application Provider.

Marketplace Operator is responsible for realizing and providing the cloud marketplace concept by bringing together all cloud entities. As in all marketplaces, the operators ease the communication between providers and consumers and also offer extended capabilities for search, selection, accounting and billing of services and resources. Although marketplaces and marketplace operators, as brokers, are not essential elements in the service delivery, given the complexity of the modern cloud systems and the need for inclusive access and usage of services, they can be considered as necessary.

Service Aggregator The role of the service aggregators is to create new products, combining existing applications/services. These new products may be something totally different from the combined services, products that have added value compared to the aggregated services or even products that satisfy particular requirements (e.g. high availability, QoS) coming from the market or specific customers. The role of service aggregators is not new, however the realization of service aggregations can become very difficult due to the fact that the services have increased complexity and vary in business and technical requirements. In addition aggregators require functionality for searching and reserving services and resources, which is typically provided by the marketplace.

A. Product Resolution

The contemporary cloud ecosystems should be able to offer any kind of IT products in the frame of XaaS notion. This implies the need for advanced resolution capabilities in order to identify how the customers' requirements are mapped to each cloud layer with respect to both technical and business aspects of the offered products. Each product, from the hardware resources to the composite services, can be offered in several different variations based on the QoS levels, the additional features and of course the pricing models that is associated with.

In Figure 1 we analyse a simple web application, such as an e-shop, focusing on the way that the application requirements are resolved as cloud products mapped to specific cloud layers. In SaaS layer, the e-shop requires initially two services, the e-shop framework (S_1) and the product catalogue (S_2). However, assuming that the e-shop owner requires "single sign-on" for its customers, another service (S_{1a}) is needed which will provide this feature. In PaaS layer, the e-shop framework and the "single sign-on" service can be deployed on the same application server (P_1) while the product catalogue will be deployed on a database server (P_2). The application server though requires a specific technology platform, such as J2EE or .NET, which will be provided by P_{1a}. Finally in IaaS layer, the technology platform and the application server will be instantiated in a VM1, while the database will be deployed on VM2 and VM3 due to the high number of stored data and the increased transactions rate.

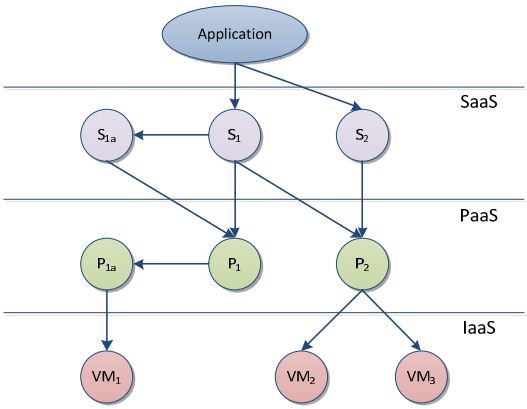

Figure 1. Resolution of a simple application in the cloud stack

At this point several issues related with the selection of appropriate products arise from the various stakeholders involved in the delivery of the particular application. The business and pricing aspects should be also taken into consideration selecting appropriate pricing models for each product as well as for the overall application. In addition, the operators of the various layers have the options either to deploy new products or should utilize existing ones under the multi-tenancy cloud concept. How does this decision affect the resolution outcomes of the layers above or below and the selected pricing models? These issues, even with the simplest case of buying a service, affect considerably the lifecycle of each product in the overall value chain and the operational and business policies for provisioning this product. If we also take into account the business constraints from all stakeholders, the overall lifecycle and the decisions in each step become much more completed, making the role of marketplace, as a key decision point and resolver of the user requirements, essential.

B. Business and Pricing Aspects

It is always possible that any product could deliver an already existing functionality by a different, more innovative and efficient way, so as to achieve high growth and wide acceptance, overcome competitive pressures and become successful. This requires appropriate business and pricing models, according to its functionality and target segment. Service instances that deliver the same functionality when distributed and charged differently may lead to different final products. As defined by Faber et al. [8], a business model describes the rationale of how a business creates, delivers and captures value. Business models, used and supported in a marketplace, play a crucial role in products' lifecycle and their innovation is vital to sustain competitive advantage during the dramatic change of environment [16]. In that sense, a successful business model consists of the following components:

- *Customer value proposition*: the way a business creates value to its customers. Depends on the customer target group, its addressed problem and the offered solution.
- *Profit formula*: the way a business creates value, by providing a customer value. It depends on the revenue model, the cost structure, the margin model and the resource velocity.
- *Key resources*: the assets that are required to deliver the expected value proposition to the customers, like people, technology, products, equipment, information, channels, partnerships, alliances and brand.
- *Key processes*: the processes, norms, rules and metrics that allow the profitable delivery of the created value in a scalable and easily repeatable way.

One of these "key" components, the profit formula depends heavily on the pricing models used. The main pricing models identified in electronic marketplaces to charge users and generate revenue are admission/registration fees, fees per term (subscription), fees per use (transaction), advertisements, shared revenue, charge for additional services and discounts. After the successful deployment and service execution, the user is accounted according to the contracted pricing model depending also on the monitored attributes' amount. The total revenue is then distributed, by the marketplace, among the execution participant parts, based on the predefined revenue agreement. Attention must be also paid to the relationships and flows among key resources and processes, as well as in understanding the most common obstacles in a job's execution, sometimes more than to the specific components, in order to support competitive advantage creation.

As the internet and communication technologies evolve, the marketplaces based on them also evolve and thus will the corresponding business models. Prior research on electronic market business models has categorized them by different ways, mainly around two streams, describing generic e-

business models and typologies and focusing on the e-business model components, respectively [4]. One classification based on Rappa et al. [15] is presented in Figure 2, together with key subcategories:

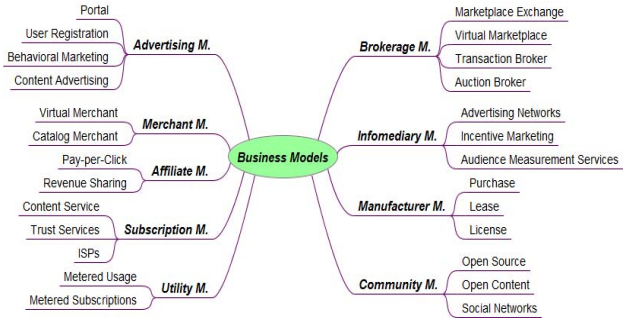

Figure 2. Business Models in Electronic Markets

IV. BUSINESS RESOLUTION ENGINE

In this paper we propose a solution for addressing these issues named *Business Resolution Engine*. The Business Resolution Engine is a service-oriented mechanism that can be used as a key element of existing or future cloud marketplaces, allowing selection of flexible pricing models and automated service composition based on the business requirements of each particular customer.

A. Motivation

Clouds can be regarded from both technical and business perspectives. There has been done significant work considering the technical aspect, which has led to the evolution and establishment of a large number of cloud service providers allowing the development of advanced applications. On the other hand, the business aspect with focus on the business lifecycle, management and selection of products, faces a slower evolution, and until recently, the existing cloud ecosystems almost neglected this aspect.

An increasing number of service consumers, moves their business operations into cloud environments in order to ensure their sustainability and optimization to reduce their IT investment, management and operation costs without scarifying the desired QoS levels of their services. According to C. Weinhardt et al. [5], this trend has led to a shift from regarding cloud computing simply as a virtualized distributed system, or a pool of services with a common set of capabilities, to a service-oriented market solution.

As a result, there is an emerging necessity of creating marketplace environments that allow enterprises and individuals to create businesses in the Cloud, using existing cloud IT assets in a highly efficient manner. These environments, unlike to the most of the currently used cloud ecosystems, should provide users (enterprises or individuals) the ability to express their needs, in terms of product characteristics, define their QoS requirements, search for possible candidates and choose or compose the appropriate ones. As most of the business users are not IT experts, it is necessary for marketplaces to provide automatic search and selection and/or composition of services with predefined characteristics and quality constraints, among a high and increasing number of possible solutions.

Most of the commonly used cloud ecosystems, until recently, did not exchange and support XaaS. In addition they did not support, neither complex business processes nor service resolution from a business perspective. In that sense there is a need of supporting various and complex business processes, possibly based on different business models. Additionally, the marketplace environments must be cost efficient, so as to be considered as real business paradigms. Flexibility to support various business models and specifications for every type of cloud products as well as dynamic pricing schemas becomes a necessity. Moreover the number of products hosted in a cloud environment capable to provide a requested functionality grows, making the value network more like a graph than a chain and to this direction the complexity of a business process increases, placing more emphasis on dynamic and flexible search and automatic, optimized selection of cloud products.

B. Resolution Cases

Based on the description of the various entities of a cloud ecosystem and the resolution case, it becomes clear that the delivery of a simple IT asset may include the interaction of several stakeholders and the need for mapping the user requirements (business constraints, QoS, functional) to operational parameters for more than one layer in the cloud stack. This introduces considerable complexity for adapting and developing applications for Clouds, counterbalancing, or even abolishing, their great advantages for scalability, reliability and low (entry and operational) cost. Cloud marketplaces try to bypass these limitations and transform clouds into real business ecosystems. As presented in the following figure, marketplaces can act as a single point of access, hiding the complexity of the cloud systems and allowing the efficient collaboration of all stakeholders.

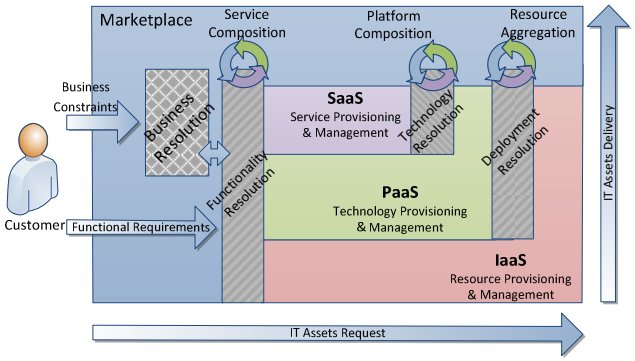

Figure 3. The resolution process of customers' requirements

The fulfilment of a customer's request for using an application includes several steps. Initially, the request can be separated to business and technical constraints' parts. The business constraints refer mainly to the pricing aspects of using the application while the technical requirements describe the QoS levels that the application will provide for the particular use and its specific needs (e.g. response time, capacity). The resolution of these requirements to deployment parameters of service and resource instances is a very complex problem and

depends heavily on the type of application, especially in cases of composite or multitenant applications where the building elements are also utilized by other consumers. Following this analysis, we have identified three different types of resolution that are required:

Technical Resolution: Selection of appropriate services / technologies / resources that fulfil the needs of the end user. In this process the requirements are mapped to the aforementioned products available in the marketplace from an abstract point of view. We consider the resolution as an iterative process starting from the application layer to the resource layer identifying a) dependencies between services (SaaS), b) dependencies between services and technologies (SaaS to Pass - Technology Resolution), c) dependencies between technologies (PaaS) and d) dependencies between technologies and resources (Pass to IaaS). Since the marketplaces provide products of XaaS, there may also be cases where the customer's request is directly for PaaS or IaaS products, bypassing respectively the SaaS and PaaS layers and the related resolution steps. The outcome of this process are multiple abstract trees describing the required products without though references to the specific instances that will be deployed and used (part of the deployment resolution) or details about the pricing models for the overall application (business resolution).

Business Resolution: The business resolution addresses the business constraints of the request. The products offered through the marketplace are associated with multiple pricing models and a set of SLA terms for QoS levels that the product will be provisioned, and in that sense the fulfilment of the user request also need to address these aspects. This process is fundamental for any marketplace environment in order to enhance the business potentials of all involved stakeholders leveraging new value networks for existing services and enhancing the overall service delivery process. Business resolution has as inputs the business constraints of the user and the outcome of the technical resolution. The possible technical resolutions are compared against the business constraints from user to find the optimal pricing model for the specific products and produce a pricing model for the overall application. The resulting final products are then evaluated based on the predefined (by the user) business characteristics, which in our example are price, availability and security. The default resolution algorithm concludes to a solution after ranking the available products based on these characteristics placing a greater impact on the pricing aspect. In case that the user wishes to choose another way of selection this is also possible by loading another resolution function.

Part of the process is the decision of SLAs for each product, using the SLA Resolution Service, describing the obligations between the providers and customers for providing and using the IT assets.

Deployment Resolution: The deployment resolution defines the exact instances that will be used for the deployment of the product based on the outcomes of the technical and business resolution. The selected instances do not necessarily need to be deployed, since the multi-tenancy features of the cloud infrastructures allow existing instances to be also used if there is enough capacity. Part of this resolution is the selection of appropriate scalability and management rules/policies for the provisioning of the product based on the SLA terms that the product is associated with.

C. System Architecture

The following figure depicts the position of the Business Resolution Engine in the cloud ecosystem and its high level architecture, consisting of three main components which are designed and developed as RESTful web services: the *Pricing Model Resolution Service*, the *SLA Resolution Service* and the *Search & Selection Service*.

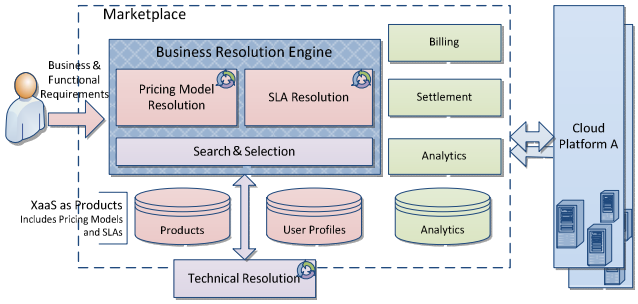

Figure 4. Business Resolution Engine Architecture

Pricing Model Resolution Service: This component collects the customer requirements and initiates the resolution process. The requirements may include both technical terms, such as response time and network bandwidth, and business constraints referring among others to usage, availability and pricing. As explained in a previous section the first step in the resolution process is to identify the possible product candidates that fulfil customers' technical requirements and for that reason Pricing Model Service communicates with the Search & Selection Service to acquire technical resolution trees. The input is examined against the business constraints and the service decides the best resolution for the particular request including pricing models for each individual product in the tree and for the overall application. In addition, appropriate SLAs are selected (with the support of SLA Resolution Service) that guarantee the QoS constraints (both business and technical) and include provisioning policies. In the selection process the user profiles are also taken into account allowing personalized selection of pricing models and SLAs without the need of defining requirements or constraints for each request. The resolution methodology is totally pluggable and dynamic allowing the usage of generic or problem specific algorithms and techniques.

SLA Resolution Service: The role of SLA Resolution Service is to identify appropriate SLAs for the products of the resolution tree, based on the customers QoS and/or business constraints (e.g. availability, security), the selected pricing models and the type of the product. It should be noted that (currently) this service will not produce new SLAs or provisioning policies but select existing templates that are created beforehand from the product developers or the platform and infrastructure providers. Therefore, the SLA negotiation and contracting processes are considerably simplified having as

input a consolidated SLA that already satisfies the contradictive requirements of all involved stakeholders.

Search & Selection Service: The resolution mechanism requires continuous interaction with the databases that maintain the product specifications (product dependencies, associated SLAs and pricing models). The role of Search & Selection Service is to simplify the communication with these databases and with the Technical Resolution Service returning appropriate products, models and SLAs to the resolution services. The service capabilities are not limited to search of the aforementioned elements including functionality for filtering and prioritizing the results so as to make the overall resolution process more efficient.

The design and implementation of these services followed a pluggable approach. In that sense, it is possible for each service to be customized or extended to address the future market needs and support new pricing models and provisioning policies. Similarly, the algorithms that are used for the selection and resolution of business aspects of the customers' requests can be updated with new ones that include enhanced functionality and produce better results. This approach decouples the mechanism implementation and operation from a specific marketplace, type of offered product or customer category allowing the providers, developers and operators to define advanced and focused methodologies for selection and resolution.

The results of the resolution process are propagated to the other elements of the marketplace to initialize the mechanisms for billing and settlement and to the other layers of the Cloud for deploying the required services, technologies and resources to provision the requested product. Another important aspect of the proposed mechanism is the capability to evaluate the performance of the previous resolutions exploiting past experiences for more efficient future resolutions. During the resolution and selection, this feature, supported by the analytics mechanism of the marketplace, will take into account the feedback of customers on the same or similar requests. Customer satisfaction is generally a very important aspect of the marketplaces and also countable in several ways such as "likes", number of downloads etc. Similarly, in a cloud marketplace, the Business Resolution Engine will propose to the customers' products, pricing models and SLAs considering the performance of the previous selections and the "market trends". The realization of this feature is an example of the advantages granted by the pluggable approach that is followed for the design of our mechanism but in order to be exploited effectively respective, product specific or not, selection methodologies and algorithms should be applied.

V. INNOVATIVE ASPECTS

There are still many issues that need to be supported, extended and managed appropriately in order to provide a stable market-oriented cloud ecosystem. The current state of the art and identified research challenges in this area, presented by the authors in [9], [17] and [19], highlight the need for innovative business resolution solutions as key elements of the existing or future cloud computing environments.

Most of them can be efficiently handled by the Business Resolution Engine, in which the resolution and selection processes support dynamic and autonomous interpretation of customers' requirements by implementing innovative optimization techniques guaranteeing an optimal, or close to optimal, resolution in business level. The Business Resolution Engine provides an easy to use, highly available, open solution capable to balance the demand and supply at a (electronic) market equilibrium and to provide a more stable and competitive environment for business oriented Clouds. The requested products will be automatically selected and delivered, on demand based on different business models and criteria depending on the: type of service/application, user profile, business criteria, QoS parameters and constraints (specified via SLA), weighted factors, computational risks, functional limitations and also current workload, demand fluctuations, available resources and underlying technology.

As described before, the elasticity and flexibility aspects of the services are taken into consideration supporting a variety of requirements (application specific or not). The resolution mechanism is pluggable with new selection algorithms, decupling the selection methodology from the selection mechanism and thus being easily extensible. This approach supports competitiveness and interoperability, aspects of modern business ecosystems, by effectively evaluating business partnerships and strategic relationships among service providers, which may result in composing, selecting and distributing multi-level, economically affordable services, with improved quality. More emphasis has been placed on the fulfilment of various business requirements and the support to various types of business activities, promoting also the convergence of ICT assets.

The proposed mechanism can be also used in order to help an enterprise to inline its scope and strategic goals with the cloud infrastructure. Evaluating the compatibility of products and possible replacements among them, allows advanced composition of IT assets as well as reusability of services and applications providing higher performance levels and support to competitive advantage achievement. The resolution engine evaluates the current situation and autonomously adapts, when needed, to ensure that the requested levels of QoS parameters (such as performance, security, reliability, availability, scalability etc.) are met and current limitations do not leading to performance decrease, SLA violations and thus customer dissatisfaction. In addition, the monitoring information (feedback) and prediction models that are used can reduce the computational risk and improve the automatic selection scheme and SLA sustainability.

Since the main goal of the cloud marketplaces is the delivery of services that ensure customers' maximal satisfaction, more attention should be paid to parameters that influence the level of utility a user observes (ex: Security, 24/7 availability, technical support etc.) and a more personalized scheme should be established. A personal user profile is implemented in the Business Resolution Engine, in order to measure efficiently users' satisfaction, provide a more precise feedback and be able to leverage possible improvements in the resolution process.

VI. CONCLUSIONS AND FUTURE WORK

Cloud computing has become a mature technology in ICT domain allowing all involved entities to exploit a high number of advantages for developing and provisioning applications and services. As with all technologies, this paradigm is highly depended on its business capabilities and to this direction, cloud marketplaces play a very important role on its wide adoption. The proposed Business Resolution Engine, as part of the existing or future marketplaces, is capable to enhance functionality of Clouds and marketplaces simplifying the interaction with the customers by interpreting effectively their business requirements to cost efficient pricing models and to SLAs that support the provisioning of ICT assets in a personalized manner. A prototype of Business Resolution Engine is currently under validation and our effort is targeted on the performance evaluation of existing selection algorithms, e.g. weight function based on price and availability. Our future research will focus on enchasing the resolution processes with new algorithms for selection of pricing models and SLAs, which will improve the overall performance of the mechanism taking into consideration the customer profiles and analytics of previous resolutions. The notion of evaluating previous resolutions and exploiting the outcomes for future requests is a challenging research issue which will be investigated and it is expected to leverage new methodologies and algorithms for improving the cost effectiveness of the marketplaces and Clouds.

ACKNOWLEDGMENTS

This work has been supported by the 4CaaSt Project (http://www.4caast.eu) and has been partly funded by the European Commission's IST priority of the 7th Framework Programme under contract number 258862. This paper expresses the opinions of the authors and not necessarily those of the European Commission. The European Commission is not liable for any use that may be made of the information contained in this paper.

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