SEOUL NATIONAL UNIVERSITY
College of Engineering
Technology Management, Economics, and Policy Program

Technology Management, Economics, and Policy Discussion Paper Series

Business Support Service Platform for Providers in Open Cloud Computing Markets

Jörn Altmann, Matthias Hovestadt, Odej Kao

TEMEP Discussion Paper No. 2011:79

서 울 대 학 교
공 과 대 학, 기술경영경제정책 대학원과정
151-742 서울시 관악구 관악로 599

Technology Management, Economics, and Policy Program
College of Engineering, Seoul National University
599 Gwanak-Ro, Gwanak-Gu, Seoul 151-742, South-Korea
Phone: ++82-2-880-9140, Fax: ++82-2-880-8389

The *Technology Management, Economics, and Policy Program (TEMEP)* is a graduate program at Seoul National University. It includes both M.Sc. and Ph.D. programs, which are integrated into the graduate programs at the College of Engineering.

The *TEMEP Discussion Paper Series* is intended to serve as an outlet for publishing research about theoretical, methodological, and applied aspects of industrial economics, especially those related to the institute's areas of specialization, namely management of technology, information and communication technology, telecommunication, services, health industries, energy industries, as well as infrastructures for development. In particular, paper submissions are welcome, which analyze current technology and industry related issues, discuss their implications, and suggest possible alternative policies. The objective is to gain insights into important policy issues and to acquire a balanced viewpoint of policy making, technology management, and economics. It will enable us to identify the problems in industries accurately and to come up with optimal and effective guidelines. In addition, another important aim of this series is to facilitate communication with external research institutes, individual researchers, and policy makers worldwide.

Research results disseminated by TEMEP may include views on policies for information and communication technologies, technology management, telecommunication, energy, health, and development economics, but the institute itself takes no institutional policy position. If appropriate, the policy views of the institute are disseminated in separate policy briefs. Thus, any opinion expressed in the TEMEP Discussion Paper Series is those of the author(s) and not necessarily the opinion of the institute.

Finally, the current editor of this series would like to thank Prof. Dr. Almas Heshmati for establishing this working paper series in January 2009 and for guiding its development during the course of the first 55 issues. In particular, Prof. Heshmati provided invaluable contributions for setting up the local IT infrastructure, registering the series with RePEc, disseminating the working papers, and setting the quality requirements.

Jörn Altmann, Editor

Office: 37-305
Technology Management, Economics, and Policy Program
College of Engineering
Seoul National University
599 Gwanak-Ro, Gwanak-Gu
Seoul 151-742
South-Korea

Phone: +82-70-7678-6676
Fax: +1-501-641-5384
E-mail: jorn.altmann@acm.org

Business Support Service Platform for Providers in Open Cloud Computing Markets

Jörn Altmann[1], Matthias Hovestadt[2], Odej Kao[2]

[1] Department of Industrial Engineering
College of Engineering, Seoul National University
Seoul, South-Korea
jorn.altmann@acm.org

[2] Technische Universität Berlin
Berlin, Germany
matthias.hovestadt@tu-berlin.de, odej.kao@tu-berlin.de

September 2011

Abstract: Cloud computing faces two business-related issues. First, the management of clouds requires not only technical skills but also the understanding of the business side of these systems. Traditional distributed systems research did not require this understanding, simply assuming that all components involved are willing to cooperate according to the resource allocation algorithm prescribed. This cooperation assumption is not valid anymore if clouds are commercial. Secondly, the demand of cloud customers can cause demand spikes at any time, raising the questions on how to allocate the limited resources. Consequently, a real-time view of the provider's business with respect to revenue streams and costs becomes essential for cloud providers. Such a system helps them to respond in an economically efficient way. From the user perspective, the understanding of the different offerings of clouds is also becoming none-trivial, requiring a support in selecting the best-fitting cloud service. A solution to these two issues is the use of business economics. The objective of this work is to lay out a concept and design of a business support service platform, which is called Cloud Management Cockpit (CMC), which uses business economics for giving decision support to providers for managing clouds and for using clouds. The applications of the CMC are laid out in three scenarios. They highlight the usefulness of the CMC business support models and demonstrate how CMC enables platform interoperability, service composition, and reduces complexity of clouds.

Keywords: Cloud architecture, cloud economics, business economics, optimization, cloud markets.

JEL Classification Numbers: C61, C63, C80, L86, M15, M21.

1. Introduction

Numerous research initiatives resulted in a solid technical foundation on distributed systems, ranging from middleware systems (Grid middleware), resource allocation schemes (matching of resources and jobs), to scheduling. This foundation allows accessing resources that are geographically distributed around the world. Virtualization in combination with these distributed system technologies extends this foundation by allowing greater flexibility in the use of hardware resources and by making them substitutable for performing tasks independently of the geographic location. Consequently, virtualization contributes to consolidation of server data centres, reduced asset costs, and simplified administration. However, the access to these virtualized systems has not yet been standardized, so that providers currently provide proprietary interfaces to their systems only.

Until now, several providers of virtualized resources have emerged, offering Amazons EC2 (Elastic Compute Cloud), Sun Cloud, and Googles Apps. However, their solutions are not interoperable and their business models do not encourage provider switching. This means that providers do not support their customers in interconnecting to other clouds, even though this would provide their customers a higher level service. If customers want to use resources of multiple providers, the customer himself has to implement the interface of the other provider. In addition, since the interfaces to clouds are not standardized, it is rather complex for users to effectively use this technology and avoid lock-in effects through high switching costs. This lock-in results in limited competition between providers, thus allowing the provider to set prices almost at will. With increased interoperability, however, an open cloud market could lead to lower resource costs and higher resource utilization of existing computing resources.

At this time, cloud users are the driving force for interconnecting clouds. By using cloud configuration tools by a handful of small technology providers (e.g., fluid Operations [1] and CohesiveFT [2], it will be simple for cloud users to switch cloud providers. These configuration tools enable cloud users to dynamically select providers and to combine services of multiple providers simultaneously for running their applications. This new demand will force cloud providers to interconnect in the same way as ISPs in the Internet, and offer compatible interfaces to customers for important functions like accounting and monitoring, dynamic resource adaptation, and VPNs for the inter-cloud communication needs.

However, management of commercial clouds is even more challenging than managing large-scale systems, since it requires not only highly technical skills but also the understanding of the business side and the resulting economic incentives. Traditional distributed systems research did not require this understanding, simply assuming that all components involved are willing to cooperatively operate the various pieces of the resource allocation algorithm prescribed.

In addition, since cloud users can come from anywhere in the world and demand spikes can happen anytime, a real-time view of the provider business with respect to revenue streams and cost becomes essential for any cloud provider for being successful. From the users perspective, the understanding of the different offerings of clouds is also becoming complex due to the large variety of resource offerings and different pricing models. The latter is making price comparisons particularly difficult. This complexity implies that cloud users require some form of support when selecting the best-fitting resource service.

Provider selection (from the customer perspective) and accepting customer requests during a service negotiation (from the provider perspective) are two major decision processes. By moving to world wide open cloud markets where multiple commercial cloud providers are competing for customers, such decisions are strongly impacted by business related questions. Since humans are rarely involved in internal system management processes, scheduling algorithms at provider and customer side have to decide. However, current schedulers are typically focusing on technical aspects solely, e. g., whether the quality of service requirements of an incoming customer request may be fulfilled in the current system situation.

In the light of the business dimension in scheduling, the scheduler however should better not decide if the request can be fulfilled but if it should be fulfilled. Even though it might be technically possible to fulfill all quality of service requirements of an incoming job request, the provider might better not accept the job request, thus having resources available for accepting more valuable job requests at a later point of time. Business dependent scheduling decisions are well-known from other domains, e. g., yield management applied to flight ticket sales in the airline industry.

Although worldwide research in business economics resulted in verified and widely accepted economic models that addressed the issues involved in supporting users and providers in reducing the complexity through decision support systems, business economic models have not been used in the cloud domain yet. The use of business economics will not only contribute to reducing the complexity of understanding service offerings but also provide the framework to study and enhance cloud competition by analyzing prices, demand, cost of interconnection, and cost of unused resources. By studying competition and gathering the appropriate information from a decision support system for the cloud market, a cloud provider may decide to offer a standard interface to a service which is in high demand and compete for the same customers as his competitors.

The objective of this paper is to introduce such a decision support system, which is called cloud Management Cockpit (CMC). In particular, we present the concepts and design of CMC as well as three application scenarios of the CMC. This contributions will help providers as well as users to implement such a system. The remainder of this paper is organized as follows: After presenting related work in section 2, we introduce a business economics layer in the systems management. Section 4 introduces the concept of the Cloud Management Cockpit, supporting the respective cloud providers and users in their particular decision making processes, where also an exemplary application scenario is given. The paper will conclude with brief summary.

2. Related Work

Business Economics (synonymous with industrial economics, managerial economics) is a part of economic theory, focusing on defining business strategies for enterprises. In particular, business economics is concerned with economic issues and problems related to business organization, management, market strategy, and the interactions between companies, and the business environment. Especially, it is concerned with the application of economic methods in the managerial decision-making process [3].

Future systems have to support decision making aligned to business strategies, as these decisions may affect revenue and cost. For example, the understanding of the effects of outsourcing of service requests to a competing provider is essential, as it impacts the price setting of services and the service negotiation with customers. Major economic models that can support these decision processes are [6] [9] [11] [16].

The provider does not only have to be supported in common scheduling procedures where an incoming job request has to be accepted or rejected [17] [18], the provider also has to be supported in long-term decisions like infrastructure management. Here, decision support models from business economics can help in aligning the cloud infrastructure investments to the particular business strategy, or making the infrastructure sustainable at the desired degree. The following economic models may be applied in this context [5] [7] [8] [19].

Due to an increasing importance of green IT, i. e. IT infrastructures considering the ecological impact of system management, models from business economics even have to support the provider in this aspect. A focal question here related to the question whether scheduling decisions can support the overall energy saving of the compute center. By applying regulative governmental actions like inclusion of CO_2 emission rights, the ecological footprint of compute centers get a very concrete impact on business related system management decisions. Models of Hedwig et al. may be applied in this context [4].

Since cloud computing also has a huge impact on the existing business models, the understanding of the value chains is essential for cloud providers. Helpful insight can be given by models of Bany et al. and Courcoubetis et al. [10] [12]. Furthermore, there are business model analyses performed in [13] [14] [15].

3. Business Economics Layer

Two major stakeholders can be distinguished in cloud computing markets. A cloud provider is an entity, which owns computing resources, software resources, or data resources, representing his cloud. A cloud provider sells use of these resources as services. In order to achieve his business goals (e. g. profit maximization, energy conservation), cloud providers have to pay attention to the optimization of the configuration of their IT infrastructure.

A cloud user in contrast is an entity, which can own computing resources, software resources, or data resources but uses them only internally. A cloud user buys cloud services and integrates them into his IT infrastructure. The simplicity of integration of additional resources into the existing infrastructure depends on the degree of service-orientation that the cloud users IT infrastructure has. That means, if the IT infrastructure is completely based on a service-oriented architecture, the cloud user can dynamically configure his own IT infrastructure, in the same way as a cloud provider.

The use of business economics will allow us to understand the key issues in obtaining a more competitive market for cloud services worldwide, and the additional complementary services, which, if available, will increase total user demand. It will guide us in designing and implementing a technology, which will enable cloud SMEs to compete successfully on the market against large cloud providers (e. g. Amazon, Google, Microsoft). Finally, a more efficient and economically sustainable cloud market will emerge since customers and providers will share more information and avoid market failure due to information asymmetry.

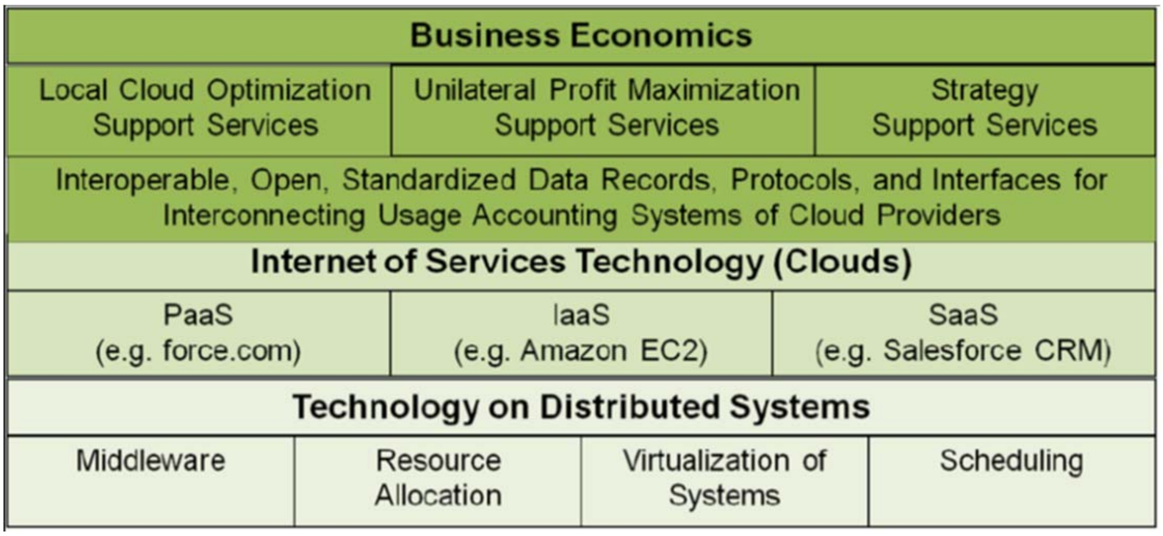

Figure 1. The business economics layer on top of cloud computing architecture layers.

Cloud computing architecture currently only focuses on purely technical aspects, distinguishing infrastructure-as-aservice (IaaS), platform-as-a-service (PaaS), and software-asa-service (SaaS). Since none of these layers targets questions related to business impact of decision making, we propose adding an additional layer on top of the currently defined technical layers. Figure 1 depicts how this novel layer enhances cloud systems by business knowledge. It supports local optimization procedures (e. g. improvement of infrastructure), profit maximization services (e. g. supporting negotiation processes) and general strategy support (e. g. improving the business model itself). In addition it will introduce uniform data models that these process domains reside on.

As described above, the aspect of business economics will be of focal importance, once an ecosystem of interoperable commercial cloud providers has been realized. Questions on business economics do not only affect scheduling decisions but all system components and decision making processes. Therefore, business economics represents a horizontal topic across all system components. Consequently, a decision support system is needed, enabling stakeholders to make informed decisions about economically efficient service sales, resource purchases, or configuration of their clouds. The decision support system comprises local cloud optimization support services, unilateral profit maximization support services, and strategy support services.

3.1. Local Cloud Optimization Support Services

The first major domain that is considered here is the support in optimizing the local infrastructure that is used for realizing the cloud system. The type, quality, and amount of resources does not only determine the type of services that the provider is able to offer his customers, it also determines the service quality level the provider can offer and the price he can request for his services.

For example, For being able to request higher prices, a provider may decide to improve his infrastructure situation. By spending money on additional or on replacing resources or fault tolerance mechanisms, the provider is able to turn these added values into higher prices.

Since this investment decision is primarily related to business models, traditional cloud management systems do not support the provider in any way in this decision process. Neither do they analyse the status quo with respect to relation between the achieved performance and prices at the market, nor do they predict future performance in any way, forecasting how selecting infrastructure investments would turn into an increasing cloud business revenue or market position.

This decision support aspects have be performed offline, taking available logfiles or user accounting records from various sources as foundation for the analysis methods. Thus, executing these methods is not bound to any time constrains, since results of this decision support mechanisms do not interfere directly with regular business activities, e. g. the negotiation procedure with a new customer on accepting a specific job. Moreover, these decision support mechanisms have full information, because they are executed only in specific intervals (e. g. each night or once per week), analyzing the past performance of the provider and how modifications on infrastructure or business strategy would have helped to increase this performance.

All computed usage data is related to revenue, profit, and cost. The unilateral profit maximization support services analyze data and support the cloud user or cloud provider in their decision making process by providing different revenue management models and letting them set model parameters and view the results as the model is subject to different inputs.

3.2. Unilateral Profit Maximization Support Services

The provider also has to be supported with online services. These support services are designed to support decisions that have to be made in due time and that directly effect the business operation of the provider. A major field of support services is the realization of business-aware negotiation mechanisms. Here, a customer has contacted the provider and started negotiating on a specific service that should be provided. Aspects of this negotiation are type, quality, and quantity of the service to be provided, the price that the customer will be charged, as well as the penalty fee that the provider has to pay in case he fails to deliver the service as negotiated.

In this online decision situation, decision support systems neither have complete information (i. e. the system as only knowledge about jobs that are currently in the system, but does not know which jobs will arrive in the future) nor unlimited time for decision taking. In particular, these timing aspects put hard constraints on the algorithms to be developed, because a decision has to be made within a given time frame. If the decision process takes longer than this given time span, timeouts would occur in the negotiation process, forcing the negotiation procedure between customer and provider to fail.

These timing aspects underline the need for business-aware, online decision support mechanisms, since the provider has no chance of making informed decisions using conventional offline systems. By bridging selected models from business economics to these decision support systems, the decision making of providers can be actively supported, achieving the provider's business goals.

3.3. Strategy Support Services

In addition to these offline and online decision support services, the cloud stakeholders also have to be supported in optimizing their currently applied business models. Here, business-model-aware decision support systems can provide the most significant added value in contrast to conventional systems, because such a system allows the cloud provider to understand the implications of its business model, its performance, and the achieved revenue.

Cloud providers are experts in their domain from the technical perspective. Since optimizing a business strategy requires in-depth knowledge in business economics, many providers stick to a single business strategy, knowing neither their performance nor if this strategy is optimal in their specific context at all. Strategy support services help cloud providers understanding their business strategies in the context of the cloud market (e. g. collaboration through cloud usage information exchange, market movements through competition). Thus, these strategy support services focus on supporting the cloud provider in finding answers to strategic questions which relate to collaboration or competing with other cloud providers.

3.4. Data Exchange and Method Invocation

The three domains described above allow both cloud customer and cloud provider to consider the business dimension of their activities during system planning, management, and operation. As common in layered architectures, architecture elements shall have standardized interfaces making it possible to exchange particular services offered by these elements.

In this context the exchange of services implies the exchange of business economic knowledge that has been coded into these services. By exchanging these services, the behavior of the business is changing. Research on the business economics layer will result in modules with increasing functionality and improving quality, resp. novel and advanced business models. Hence, standardized interfaces between the technological focused cloud middleware layer and the business economics layer will allow to exchange services without having to change the respective cloud middleware element.

Moreover, methods in the business economics layer depend on having required information available for executing business economics algorithms. Since the majority of data is stored at the level of the cloud middleware, the business economics layer has to be enabled to access this data. For making the modules in the business economics layer applicable in a wide range of cloud middleware systems, the interface for data access has to be standardized as well. This way, the methods in the business economics layer are able to access all required information for computing their models without putting any restraints to the installed cloud middleware system.

We propose a specification of a usage record for cloud services, an open protocol to exchange those records, and a standardized interface for interconnecting accounting systems across cloud providers. These innovations will be extensions to an existing, open-source accounting system, such as GASA (2006), DGAS (2008), or SGAS (2008) ?? ?? ??. An accounting system, which is highly customized for business economics, is important in order to get the appropriate usage data needed to run the different decision support services.

Both definition of standardized interfaces and data exchange formats resp. protocols are important tasks that have to be focused in the realization of this concept.

4. Cloud Management Cockpit

Having the proposed business economics layer available, cloud middleware systems are able to use the services of this layer by integrating them into internal processes. For example, when a job request has been received from a consumer, the cloud middleware can drive the negotiation procedure. Depending on the result of this procedure, the job request is either accepted or rejected by the cloud middleware.

It has to be underlined that the negotiation procedure is driven by the cloud middleware. If services of the business economics layer are used, these functions complement the services of the regular negotiation procedures, not replacing them. The cloud middleware executes functions of the business economics layer in order to consider the economic implications of the job in question during the negotiation process.

The internal configuration of the business economics layer is a black box for the cloud management layer. It is accessing specific functions, not looking inside or even understanding the internals. Hence, the available configuration and management tools for the cloud middleware system do not apply to the business economics layer.

For supporting the user in managing this layer, we propose the introduction of a portal named Cloud Management Cockpit (CMC) to this layer, allowing both configuration and analysis. This way, an administrator could connect to the CMC using his regular web browser for configuring the details of the particular business goals or for analyzing past events with regard to optimality of business achievements.

The CMC could even provide added value to the cloud middleware system. Since services of the business economics layer are regularly invoked by the cloud middleware layer, CMC is saving information about these invocations in its internal database system. The granularity of this information is very fine compared to the data that has been returned to the invoking procedure at the cloud middleware. Consequently, it can be used to provide information about confidence level for recommended decisions or additional information about potential alternatives.

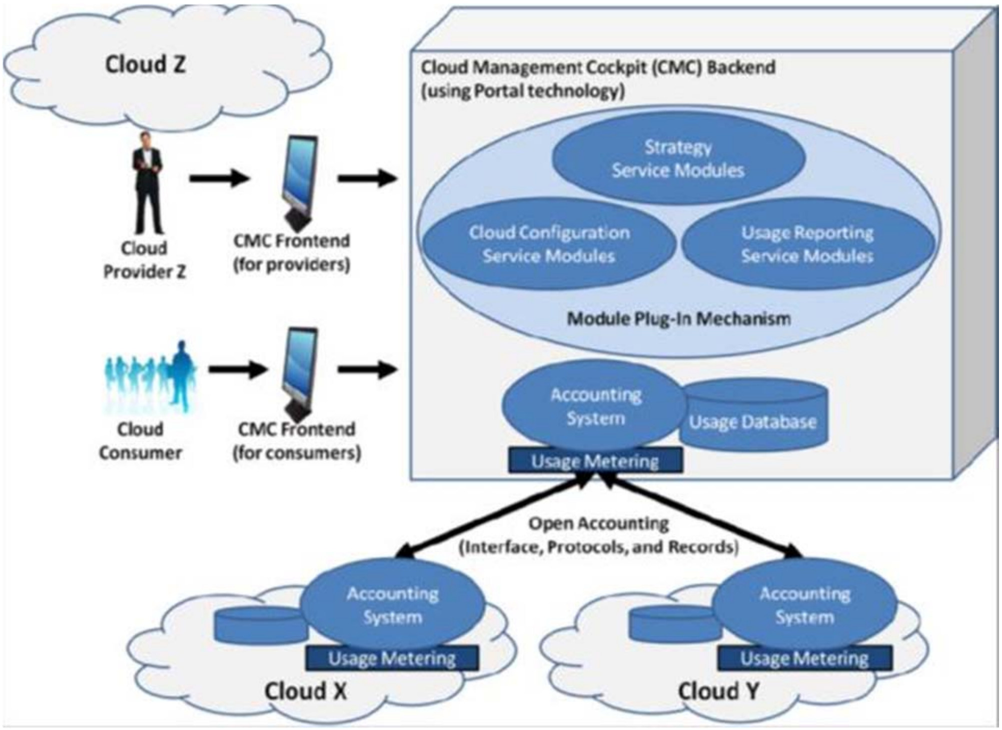

Figure 2. Architecture of the Cloud Management Cockpit (CMC).

Both cloud consumer and cloud provider could interact with the CMC since stored information is relevant for both parties. The CMC can even be installed between multiple clouds, as depicted in Figure 2. In this case the clouds interconnected by the CMC establish a common market following a predefined and common set of business rules, e. g. a given set of price building functions.

4.1. Deployment Issues

At the moment the presented concept of the business economics layer in cloud computing as well as the CMC are theoretical concepts only. For turning this concept into real and widely accepted software, the CMC has to comply with three fundamental requirements. Firstly, the Cloud Management Cockpit must support interfaces to relevant cloud systems (e.g. Amazon EC2, Microsoft Azure) in order to be usable in testpilot installations of early adaptors. Here, open source middleware stacks like Eucalyptus are of particular interest since these stacks can be modified, integrating methods of the business economics layer into the particular decision making processes.

Secondly, the development of interfaces and protocol standards as well as benchmark sets for evaluating the performance of business economic services should be performed in the international context, e. g. in the scope of a working group in the Open Grid Forum (OGF) [23]. This way both public awareness and broad acceptance can be achieved. Thirdly, the various sources of information have to be considered. Depending on the use of the CMC, different sources of performance information about clouds are used. If the CMC provides support services to cloud providers or can be customized to the needs of one provider, then compiling information, which can be gathered locally within one cloud, can be done and is already beneficial. However, some support services might work even better if they exchange some anonymized usage information with other cloud providers. The challenge here is that the incentives for exchanging this usage information are not clear and have not been investigated. Assuming that a cloud user is willing to reveal more detailed usage information in return for lower prices from its cloud providers, then its CMC might provide some internal usage data to other cloud providers. This assumption is realistic since it is common standard in many fields of commercial application.

4.2. Exemplary Scenario

For making the concept of the business economics layer and the CMC more concrete, an exemplary usage scenario is presented in this section. Without elaborating on any details of used protocols or interfaces, the basic information exchange between the cloud stakeholders is presented.

In this scenario, which is depicted in Figure 3, a cloud computing customer plans to execute a software system within the cloud. Since multiple cloud providers are active on the market, all supporting open cloud markets by offering standardized services, the customer is able to negotiate with those providers on executing his software.

During this negotiation a service level agreement (SLA) as to be agreed on by both parties, which is a contractually binding statement of all expectations and obligations in the business relationship between customer and provider. In this context, an SLA holds information about type, quality and quantity of services to be provided as well as non-technical information like the price for resource consumption or penalty fees. Standards for defining and negotiating such SLAs have been defined [24] and implemented in software stacks for various middleware systems.

However, these stacks are limited to negotiation of system aspects that can be managed and evaluated by available resource management systems. Hence, in practice SLA negotiation exclusively focuses on technical aspects of job execution, e. g. availability of sufficient computing resources. If systems negotiate on prices, applied price building models are flat and far from what is known from real-world business environments.

At this place, the presented concepts are able to extend the capabilities of the user's negotiation engine. By giving the services at the business economics layer access to available information (step 1 in Figure 3), services can start supporting the customer in the bidding procedure as well as in general provider selection (step 2). Whereas currently available methods solely focus on technical aspects, the customer is now able to make an educated decision regarding the best provider according to his particular business strategy.

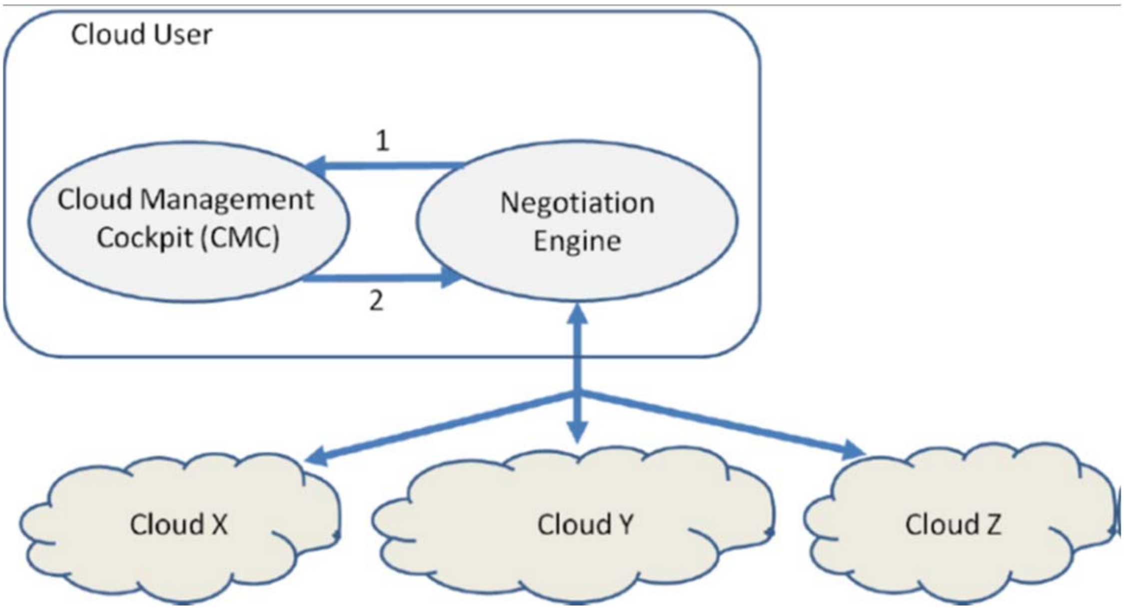

Figure 3. Cloud Provider Selection Scenario.

It has to be pointed out that this support action is not only restricted to the negotiation phase. In fact, exchange of information between the customer's cloud computing software and the services in the business economics layer is a continuous process which constantly reevaluates whether the chosen provider still is the optimal choice for the customer. This process might result in the decision to switch the cloud provider, which has been the goal of creating open cloud markets in the first place.

5. Conclusion

During the recent years, cloud computing emerged as a novel paradigm on using and providing IT services. Following the idea of service computing, customers are enabled to request and consume services on-demand, being charged for consumed services only. At this, cloud consumer and cloud provider negotiate on Service Level Agreements, specifying type, quality and quantity of services to be provided as well as all other expectations and obligations within the business relationship.

Cloud computing already impacted numerous usage domains, both in academia and business. However, negotiation mechanisms still focus on technical aspects of how the service has to be provided. Aspects related to business economic implications are not yet considered thoroughly.

Within this paper, we described how providers and users can be supported in their decision making in this regard. For filling the gap, we introduced a business economic layer as well as the Cloud Management Cockpit (CMC), which provides real-time snap shots about the business situation of providers and users. This information is used for making decision that are economically efficient.

In particular, we introduced the detailed architecture of the CMC and described the workings of the CMC with the help of an exemplary usage scenario.

Our current work comprises the implementation of the CMC, allowing us to plug in different resource allocation algorithms. The CMC is intended to be used for managing the resource allocation in the university data center.

References

[1] FluidOps, http://www.fluidops.com, 2011.

[2] CohesiveFT, http://www.cohesiveft.com, 2011.

[3] Samuelson W. F. and Marks S. G., Managerial Economics, 6th ed. Wiley 2008.

[4] Hedwig M, Bodenstein C, Neumann D: Datacenter Investment Support System (DAISY), Proceedings of the 43rd Annual Hawaii International Conference on System Sciences (HICSS-43), January 5-8, Computer Society Press, 2010.

[5] Hedwig M, Malkowski S, Neumann D: Taming Energy Costs of Large Enterprise Systems through Adaptive Provisioning, International Conference on Information Systems (ICIS 2009), Phoenix, Arizona, 15-18. December 2009.

[6] Pschel T, Anandasivam A, Buschek S, Neumann D: Making money with clouds Revenue optimization through automated policy decisions 17th European Conference on Information Systems (ECIS 2009).

[7] Risch M., Altmann J., Capacity Planning in Economic Grid Markets, GPC 2009, 4th International Conference on Grid and Pervasive Computing, Geneva, Switzerland, May 2009.

[8] Quan D. M., Altmann J., Grid Business Models for Brokers Executing SLA-Based Workflows, in Rajkumar Buyya, Kris Bubendorfer, Market-Oriented Grid and Utility Computing, Wiley, New York, USA, August 2009.

[9] Risch M., Altmann J., Cost Analysis of Current Grids and its Implications for Future Grid Markets, GECON 2008, Workshop on Grid Economics and Business Models, Springer LNCS, Las Palmas, Spain, August 2008.

[10] Bany Mohammed A., Altmann J., Hwang J., Cloud Computing Value Chains: Understanding Business and Value Creation in the Cloud, presented at EMDS 2008, Workshop on Economic Models for Distributed Systems, Baton Rouge, USA, January 2008, published in Economic Models and Algorithms for Distributed Systems, Autonomic Systems book series, Birkhuser, Springer, Heidelberg, July 2009.

[11] Robin Mason, Costas Courcoubetis and Natalia Miliou, " A Framework for Analyzing the Economics of a Market for Grid Services " , The 6th International Workshop on Grid Economics and Business Models, GECON 2009, Proceedings, pp. 28-45, Lecture Notes in Computer Science (LNCS 5745), Springer 2009.

[12] Courcoubetis C., Weber R.. "Economic Issues in Shared Infrastructures", VISA 2009 Workshop, Barcelona, Spain, August 2009. ACM. 2009.

[13] Katarina Stanoevska-Slabeva, Thomas Wozniak, George Thanos, Davide Maria Parrilli, Belen Serrabou, and Karita Luokkanen-Rabetino, "Turning Grid Research into Business - Identification of Commercialization Barriers"Proceedings of the First International ICST Conference on Digital Business-DIGIBIZ 2009-, London, June 2009.

[14] Katarina Stanoevska-Slabeva, Davide Maria Parilli, George A. Thanos, Defining Efficient Business Models for Grid-enabled Applications, eChallenges 2008, Stockholm October 2008.

[15] George Thanos, Eleni Agiatzidou, Costas Courcoubetis, George D.Stamoulis, "Grid Business Models", Book Chapter 5, Grid and Cloud Computing: A Business Perspective on Technology and Applications, Springer, November 2009.

[16] Omer F. Rana, Martijn Warnier, Thomas B. Quillinan, Frances M.T. Brazier: Monitoring and Reputation Mechanisms for Service LevelAgreements. GECON; 2008.

[17] Isaac Chao, Ramon Sangesa, Oscar Ardaiz, Liviu Joita, Omer F. Rana: Optimising decentralised grid markets through group selection. IJWGS; 2008.

[18] Dominic Battr´e, Matthias Hovestadt, Odej Kao, Axel Keller, Kerstin Voss: Enhancing SLA Provisioning by Utilizing Profit-Oriented Fault Tolerance; In: T. F. Gonzalez (Ed.), Proceedings of the 20th IASTEDInternational Conference on Parallel and Distributed Computing and Systems (PDCS 2008), ACTA Press, pp. 212-218, 2008.

[19] Dominic Battr´e, Georg Birkenheuer, Vikas Deora, Matthias Hovestadt, Omer Rana, Oliver Wldrich: Guarantee and Penalty Clauses for Service Level Agreements; In: The 8th Cracow Grid Workshop, Academic Computer Center CYFRONET AGH, 2008.

[20] Barmouta A. and Buyya R: GridBank: A Grid Accounting Services Architecture (GASA) for Distributed Systems Sharing and Integration. In IPDPS 03: Proceedings of the 17th International Symposium on Parallel and Distributed Processing, page 245.1, Washington, DC, USA, 2003.

[21] Piro R.M., Guarise A. and Werbrouck A: An Economy-based Accounting Infrastructure for the DataGrid; Proceedings of the 4th International Workshop on Grid Computing (GRID2003), held in conjunction with SuperComputing 2003, Phoenix, Arizona (USA), 2003.

[22] Peter Gardfjll, Erik Elmroth, Lennart Johnsson, Olle Mulmo, Thomas Sandholm: Scalable Grid-wide Capacity Allocation with the SweGrid.

TEMEP Discussion Papers

2009-34: Jungwoo Shin, Chang Seob Kim and Jongsu Lee, “Model for Studying Commodity Bundling with a Focus on Consumer Preference”

2009-35: Yuri Park, Hyunnam Kim and Jongsu Lee, “Empirical Analysis of Consumer Preferences for Mobile Phones and Mobile Contents in the Presence of Indirect Network Effects”

2009-36: Jörn Altmann and Juthasit Rohitratana, “Software Resource Management Considering the Interrelation between Explicit Cost, Energy Consumption, and Implicit Cost: A Decision Support Model for IT Managers”

2009-37: Marcel Risch, Ivona Brandic and Jörn Altmann, “Using SLA Mapping to Increase Market Liquidity”

2009-38: Amit K. Bhandari and Almas Heshmati, “Willingness to Pay for Biodiversity Conservation”

2010-39: Marcel Risch, Jörn Altmann, Li Guo, Alan Fleming and Costas Courcoubetis, “The GridEcon Platform: A Business Scenario Testbed for Commercial Cloud Services”

2010-40: Junseok Hwang, Jörn Altmann and Ashraf Bany Mohammed, “Determinants of Participation in Global Volunteer Grids: A Cross-Country Analysis”

2010-41: Ruzana Davoyan, Jörn Altmann and Wolfgang Effelsberg, “Intercarrier Compensation in Unilateral and Bilateral Arrangements”

2010-42: Ruzana Davoyan, Jörn Altmann and Wolfgang Effelsberg, “Exploring the Effect of Traffic Differentiation on Interconnection Cost Sharing”

2010-43: Ruzana Davoyan and Jörn Altmann, “Investigating the Role of a Transmission Initiator in Private Peering Arrangements”

2010-44: Ruzana Davoyan, Jörn Altmann and Wolfgang Effelsberg, “A New Bilateral Arrangement between Interconnected Providers”

2010-45: Marcel Risch and Jörn Altmann, “Capacity Planning in Economic Grid Markets”

2010-46: Dang Minh Quan and Jörn Altmann, “Grid Business Models for Brokers Executing SLA-Based Workflows”

2010-47: Dang Minh Quan, Jörn Altmann and Laurence T. Yang, “Error Recovery for SLA-Based Workflows within the Business Grid”

2010-48: Jörn Altmann, Alireza Abbasi and Junseok Hwang, “Evaluating the Productivity of Researchers and their Communities: The RP-Index and the CP-Index”

2010-49: Jörn Altmann and Zelalem Berhanu Bedane, "A P2P File Sharing Network Topology Formation Algorithm Based on Social Network Information"

2010-50: Tai-Yoo Kim, Seunghyun Kim and Jongsu Lee, "The Gene of an Accelerating Industrial Society: Expansive Reproduction"

2010-51: Almas Heshmati and Sangchoon Lee, "The Relationship between Globalization, Economic Growth and Income Inequality"

2010-52: Flávio Lenz-Cesar and Almas Heshmati, "Agent-based Simulation of Cooperative Innovation"

2010-53: Erkhemchimeg Byambasuren and Almas Heshmati, "Economic Development in Mongolia"

2010-54: Almas Heshmati and Subal C. Kumbhakar, "Technical Change and Total Factor Productivity Growth: The Case of Chinese Provinces"

2010-55: Bory Seng and Almas Heshmati, "Digital Divide and Its Variations Amongst OECD, NIE and ASEAN Countries"

2010-56: Kibae Kim, Jörn Altmann and Junseok Hwang, "The Impact of the Subgroup Structure on the Evolution of Networks: An Economic Model of Network Evolution"

2010-57: Kibae Kim, Jörn Altmann and Junseok Hwang, "Measuring and Analyzing the Openness of the Web2.0 Service Network for Improving the Innovation Capacity of the Web2.0 System through Collective Intelligence"

2010-58: Alireza Abbasi and Jörn Altmann, "A Social Network System for Analyzing Publication Activities of Researchers"

2010-59: Jörn Altmann, Costas Courcoubetis and Marcel Risch, "A Marketplace and its Market Mechanism for Trading Commoditized Computing Resources"

2010-60: Fatmawati Zifa and Jörn Altmann, "A empirically validated framework for limiting free-riding in P2P network through the use of social network"

2010-61: Ashraf Bany Mohammed, Jörn Altmann and Junseok Hwang, "Cloud Computing Value Chains-Understanding Business and Value Creation in the Cloud"

2010-62: Ashraf Bany Mohammed and Jörn Altmann, "A Funding and Governing Model for Achieving Sustainable Growth of Computing e-Infrastructures"

2010-63: Junseok Hwang, Jihyoun Park and Jörn Altmann, "Two Risk-Aware Resource Brokering Strategies in Grid Computing: Broker-driven vs. User-driven Methods"

2010-64: Juthasit Rohitratana and Jörn Altmann, "Agent-Based Simulations of the Software Market under Different Pricing Schemes for Software-as-a-Service and Perpetual Software"

2010-65: Radoslaw R. Okulski and Almas Heshmati, “Time Series Analysis of Global Airline Passengers Transportation Industry”

2010-66: Alireza Abbasi and Jörn Altmann, “On the Correlation between Research Performance and Social Network Analysis Measures Applied to Research Collaboration Networks”

2010-67: Kibae Kim, Jörn Altmann and Junseok Hwang, “An Analysis of the Openness of the Web2.0 Service Network Based on Two Sets of Indices for Measuring the Impact of Service Ownership”

2010-68: Bory Seng, “The Driving Forces Underlying the Growth of Total Factor Productivity in Cambodia, Quantitative and Qualitative Studies”

2010-69: Michael Maurer, Vincent C. Emeakaroha, Ivona Brandic, and Jörn Altmann, “Cost and Benefit of the SLA Mapping Approach for Defining Standardized Goods in Cloud Computing Markets”

2010-70: Khin Swe Latt and Jörn Altmann, “A Cost-Benefit-Based Analytical Model for Finding the Optimal Offering of Software Services”

2010-71: Jung Eun Lee, Younghoon Kim, Yeonbae Kim and Donghyuk Choi, “The Impact of Technology Licensing Payment Mechanisms on Firms’ Innovative Performance”

2010-72: Dongook Choi and Yeonbae Kim, “Effects of Piracy and Digital Rights Management on the Online Music Market in Korea”

2011-73: Tai-Yoo Kim, Jihyoun Park, Eungdo Kim and Junseok Hwang, “The Faster-Accelerating Digital Economy”

2011-74: Ivan Breskovic, Michael Maurer, Vincent C. Emeakaroha, Ivona Brandic and Jörn Altmann, “Towards Autonomic Market Management in Cloud Computing Infrastructures”

2011-75: Kiran Rupakhetee and Almas Heshmati, “Rhetorics vs. Realities in Implementation of e-Government Master Plan in Nepal”

2011-76: Alireza Abbasi, Jörn Altmann and Liaquat Hossain, “Identifying the Effects of Co-Authorship Networks on the Performance of Scholars: A Correlation and Regression Analysis of Performance Measures and Social Network Analysis Measures”

2011-77: Ivona Brandic, Michael Maurer and Vincent C. Emeakaroha and Jörn Altmann, “Cost-Benefit Analysis of the SLA Mapping Approach for Defining Standardized Cloud Computing Goods”

2011-78: Kibae Kim and Jörn Altmann, “A Complex Network Analysis of the Weighted Graph of the Web2.0 Service Network”

2011-79: Jörn Altmann, Matthias Hovestadt and Odej Kao, “Business Support Service Platform for Providers in Open Cloud Computing Markets”