The Rise of Cloud Brokerage: Business Model, Profit Making and Cost Savings

Evangelia Filiopoulou(✉), Persefoni Mitropoulou, Christos Michalakelis, and Mara Nikolaidou

Department of Informatics and Telematics, Harokopio University of Athens, 9 Omirou Street, Tavros, Athens, Greece
{Evangelf, Persam, Michalak, mara}@hua.gr

Abstract. Cloud computing has succeeded in transforming the ICT industry, making computing services more accessible to businesses. Nowadays, many cost effective solutions are available to users. However, searching for the best provider or the best bundle is not always an easy decision for the client. The cloud broker is a widely known business model derived from this necessity. It is a third-party business which assists clients to make the best decision in choosing the most suitable cloud provider and the most effective service bundle for their needs, in terms of performance and price. Into that context, this paper describes the cloud broker business model and its promising future. It highlights the broker's vital role and the benefits that arise from the use of its services, explores on the same time the drawbacks that derive from the intermediation of cloud broker. The economic context of the cloud broker model is also examined by reviewing the contemporary literature for the pricing methods that can be adopted by a cloud broker in order to achieve cost savings.

Keywords: Cloud broker · Cloud computing · Brokering models · Intermediary · Pricing models

1 Introduction

The cloud has succeeded in transforming the ICT industry, making software and hardware services even more accessible to businesses and offering no upfront capital investments for clients, leading to a faster market to market time in many businesses [1]. From a provider's standpoint, it offers a plethora of different features to adopt, while on the demand side, users benefit by choosing the appropriate services or combinations of them according to their needs. The task of finding the best service and best pricing at the same time, raises new challenges on how to make this selection.

As a consequence, the necessity of cloud brokerage was realized and the business model of cloud broker was developed. The broker acts as an intermediary between users and providers, assisting the former to choose the services that meet their requirements and the latter to schedule resources and apply effective pricing schemes. The broker's role is very important for reaching a point where both the demand and the supply side agree with a price set, settling the best financial agreement, making a profit out of this service [2]. The future of cloud broker is unquestionable and is considered to

J.Á. Bañares et al. (Eds.): GECON 2016, LNCS 10382, pp. 19–32, 2017.
DOI: 10.1007/978-3-319-61920-0_2

be the single largest cloud service in 2015 [3]. According to Gartner [4], cloud broker is identified as one of the top ten technology trends of 2014 and it is expected that by year 2015, 40% of cloud services will be delivered via brokers [5]. In addition, cloud brokerage market is predicted to grow from $1.57 billion in 2013 to $10.5 billion by 2018, as illustrated in Fig. 1, which represents a compound annual growth rate of 46.2% between these years [6]. This growth of cloud broker changes constantly the cloud environment and the cloud broker model seems to hold the key of these reforms.

Fig. 1. The expected cloud brokerage growth (2013–2018).

The rest of the paper highlights the cloud broker's vital role and is structured as follows. Section 2 provides a description of the cloud broker business model and its services, while Sect. 3 highlights the beneficial role of the broker, exploring at the same time its drawbacks. The financial context and a comparative review of the contemporary literature on the pricing models of a cloud broker are described in Sect. 4. Finally, Sect. 5 concludes, providing directions for future research.

2 Cloud Broker and Services

A cloud broker aims at building a secure cloud management model in order to ease the delivery of cloud services to cloud clients, while it presents them the services a cloud provider can offer [7]. It mediates between clients, such as SMEs or larger scale businesses, and providers, by buying resources from providers and sub-leasing them to clients [8]. It is an entity that manages the use, performance and delivery of cloud services, and negotiates relationships between cloud providers and consumers [9].

Cloud broker plays a dual role in the context of cloud computing. When it interacts with a provider, acts as a client and it behaves as a provider when interacting with a customer [10]. Cloud brokers are considered to be the key for managing hybrid IT environments [11]. Enterprises, brokers and providers agree at a Service Level Agreement (SLA) that specifies the details of the service, according to their requirements. The SLA is agreed by all parties; it determines details about the provided services and contains penalties for violating the expectations of all parties [8].

A cloud broker manages multiple cloud services and offers technical services to businesses, focusing on managing interoperability issues among providers.

Furthermore, it negotiates contracts with cloud providers on behalf of the businesses [9]. A graphical depiction of the above is given in Fig. 2.

A cloud broker provides services in three categories:

1. Intermediation: A cloud broker acts as an intermediary between clients wishing to adopt cloud services and cloud providers [9, 12].
2. Aggregation: A cloud broker can customize and combine multiple cloud services into one or more services. An aggregation service establishes the secure data movement between businesses and multiple cloud providers and includes data integration [9, 12].
3. Arbitrage: A cloud broker assists customers to select several cloud providers according to requirements, such as cost or performance. Service arbitrage is similar to service aggregation, except that the services are being combined and are not fixed [9, 12].

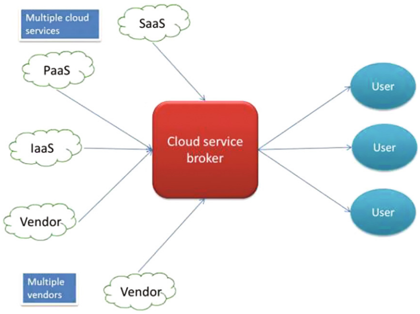

Fig. 2. Cloud service broker model

3 Cloud Broker Benefits

Businesses usually face difficulties in choosing the best provider based on service cost and other specified requirements, mainly due to lack of knowledge and time. It is also hard for clients to select services offered directly by providers, because there are no standards that can measure performance of different service providers. Every provider has its own standards, which are not necessarily widely acceptable [8]. Thus, they grant the authorization to a broker to decide on behalf of them [12].

The benefit of cloud broker for an enterprise can be realized by assisting a provider to choose the best framework, so that an enterprise can focus on its core business rather than being concerned about task deployment strategies, meeting its functional or non-functional requirements. Cloud broker offers not only the best provider but also integrates disparate services across multiple hybrid approaches. Furthermore, it helps providers adapt directly to market conditions and offer more efficient services [12]. It pioneers the integration of the entire cloud ecosystem, connecting hardware players such as IBM, HP, Dell; software players such as Microsoft, Citrix; PaaS, IaaS, SaaS providers such as Google, Salesforce, Amazon, and Rackspace, among many other prominent players in the IT and Telecom industry [3].

Cloud broker is a trusted and reliable advisor for businesses, as organizations mistakenly think that the choice of cloud services is similar to the selection of web services. However, this choice is in fact different, because there is no standardized representation of cloud providers' properties. The broker is bound to provide the guaranteed resources [8] and it also forms Service Level Agreements with the providers because the SLAs of the providers often vary in format and content, causing confusion to the non-aware clients [2].

The model of cloud broker also provides budget guidance to businesses and assists them to adopt a cost effective solution, satisfying budget requirements. It usually achieves better discounts, reduces capital costs and accesses more information from providers [12].

Some of the world's largest technology companies offer cloud services, including Google, Amazon and Microsoft. Since cloud providers deliver many services it is almost impossible to manage each customer individually, therefore providers need the intermediate cloud broker in order to promote their services to the clients [13]. They cooperate with independent cloud brokers in order to empower their relationship with enterprise customers, because customers seek for credible brokers [14].

4 Overview of Brokering Methods

A cloud broker functions in the cloud computing market the same way as it does in real-world markets, matching users demands with providers supplies [8]. It aims to succeed in settling the best financial agreement between the consumer and the provider [15]. In the next paragraphs, the most common cloud brokers pricing methods are presented, according to the contemporary corresponding literature.

4.1 Financial Brokering Method Based on Derivative Contracts

This brokering method was initially developed by HP Labs by Wu, Zhang, and Huberman (WZH). It describes the financial method of a cloud broker based on derivative contracts.

A derivative contract is a contract that derives its value from the performance of an underlying entity. Options contracts, are common types of derivatives contracts which give buyers the legal right, but not an obligation, to purchase a resource for an agreed price on some later delivery date [16]. Derivative contracts are used by the broker as a strategy to avoid the risk for uncertainty over future demand and supply [2].

Reserved instances are committed by the broker through derivatives contracts. As soon as the contract matures, the resources are delivered to clients by the broker. The broker makes a long-term reservation of resources, in fact the broker purchases obligations on resources for the next 3 years. Then the cloud broker repacks the reserved instances as one month options contracts [17]. Each month the broker accepts the resource requirements from clients. The requirements are expressed as a probability that reveals the utilization of an instance in the next month. The broker sums these probabilities that correspond to the prediction of how many instances will be required in the following period. Consequently, the broker sells to clients options contracts and decides whether or not to purchase resources [2, 17, 18].

The broker compares the performance of a reserved instance during the previous 36 month time period, $P = \{P_{t-36}, \ldots, P_t\}$, with the future resource capacity, such as the number of reserved instances that the broker has currently available $F = \{f_t, .., f_{t+36}\}$ during the following 3 years. The deficit profile D is estimated for each forthcoming month, by subtracting historical demand from future expected demand.

$$D = F - P \tag{1}$$

Margin Resource Utilization (MRU) describes the possible utilization of an additional reserved resource and it is the proportion of item in $D > 0$. In addition, the broker uses another metric variable, which is called threshold and is denoted by θ. Threshold advices the broker whether it is in its interest to purchase reserved instances in advance or it is better to buy on demand resources later on [2, 17, 18].

MRU and θ are combined in the following way:

1. If MRU > θ, then the broker is advised to purchase additional reserved instances, which will very probably be utilized in the following months and this decision is expected to be profitable.
2. If MRU <= θ, then the broker should purchase new instances on demand, estimating that it will be more profitable than purchasing reserved instances in advance.
3. The next month clients can demand instances from the broker by exercising their options contracts. If the broker has available capacity to satisfy the demand of the client, instances are sold to clients at a higher value than the purchased one. Otherwise, the broker has to buy on demand instances and provide them to the client in order to fulfill its obligation [2, 17].

The simulation was programmed in Python. Simulations were implemented with a pool of 1000 clients submitting probabilities. The drawback of this method is that if clients reveal a mistaken possibility, the broker will inaccurately forecast the reservation of the resources.

4.2 A Cloud Computing Broker Model for IaaS Resources

This brokering method is based on provider tariffs instead of providers. Tariff options constitute an open contract between the cloud provider and the client which outlines the terms and conditions of providing cloud computing services to consumers and includes rates, fees and charges [19].

Infrastructure as a Service includes control of fundamental computing resources, such as memory, computing power and storage capacity [20]. The instances of IaaS are presented by virtual machines (VMs) here. The resource (VM) is denoted as a vector r = (#vCPU, RAM, HDD) which depicts a virtual machine that includes a number of virtual CPUs (#VCPU), an amount of virtual random access memory in Gigabytes (RAM) and an amount of storage capacity in Gigabytes (HDD).

The consumer-resource demand is expressed by the following number of factors and criteria: (a) Qualitative criteria (C), such as constraints for CPU, RAM, HDD (upper and lower bound, customer service, location and legislation), (b) Load profile (L) that contains the consumer's performance priorities for CPU, RAM, HDD, (c) Time T: The total deployment time in hour of the VM, (d) ton: The number of hours the VM is running ("on-time)", (e) *s:* the HDD capacity required by the VM.

This brokering method can be described by 4 steps. In the first step consumers send resource requests as mentioned above. Thereafter, the model filters provider tariffs for consumer constraints, for example location, upper and lower bound and excludes tariffs which do not meet the requirements. In the third step the cost-performance ratio of each tariff is computed. The lowest cost-performance indicates the most cost-efficient solution for the consumer. In the final step the broker ranks and returns the results.

The cost-performance ratio of an IaaS instance is estimated by a benchmarking suite called UnixBench [21]. For every provider tariff, an instance (CPU, RAM, HDD) is ordered and UnixBench runs benchmarks on the system, calculating the benchmark points of the VM. The benchmark results (benchmark points BP, $\bar{X}$), the announced price of the provider (P) and L are the three factors that estimate the cost performance ratio. Especially L is a factor that can either attribute to the calculation of the ratio or not. If it is independent of the process then the performance rate (Price per BP) is calculated by the equation:

$$\text{Price per BP} = \text{P}/\bar{X} \tag{2}$$

Therefore the lowest price per BP indicates the highest performance for the given price and it is considered to be the most appropriate solution for the consumer.

If L that describes the relative importance of components (CPU, RAM, HDD) is taken into account then the brokering process is more complicated. The benchmark results are denoted by $\bar{X}_{\text{CPU}}$, $\bar{X}_{\text{RAM}}$, $\bar{X}_{\text{HDD}}$ for each component of the VM. L is considered to be (W_{CPU}, W_{RAM}, W_{HDD}). At first, P is divided into components (CPU, RAM, HDD) according to the weights of the load profile. By using the price to distribute weights, the need to make assumptions about the relation of benchmarking values between components is avoided. The performance weighed component price (PWC) for each component is presented below, as shown in Table 1.

Table 1. Performance weighed component price

CPU	RAM	HDD
WCPU*P	WRAM*P	WHDD*P

Afterwards and for each tariff, the performance weighed component price is divided by the component benchmark points, calculated by UnixBench and then the sum of them is used so that the Composed Total Weight tariff (CTW) is estimated:

$$\mathrm{CTW} = \left(\mathrm{PWC_{CPU}}/\overline{X_{CPU}}\right) + \left(\mathrm{PWC}_{RAM}/\overline{X_{RAM}}\right) + \left(\mathrm{PWC_{HDD}}/\overline{X_{HDD}}\right) \tag{3}$$

After the estimation of the cost-performance ratio the tariffs are enlisted. In previous step tariffs that do not fulfill qualitative criteria have been already excluded. The lowest price per performance unit is the most suitable solution for the consumer's task [19].

4.3 Dynamic Cloud Resource Reservation via Cloud Brokerage

As proposed in [22], the cloud brokerage service reserves a large pool of instances from cloud providers and serves users with price discounts. The broker optimally exploits both pricing benefits of long-term instance reservations and multiplexing gains, and makes instance reservations, based on dynamic strategies, with the objective of minimizing its service cost. The evaluation of the methodology was made by simulations driven by large-scale Google cluster-usage traces, revealing that the broker can achieve significant price discounts.

IaaS clouds provide users with multiple purchasing options, the most popular being "on-demand instances" and "reserved instances". On-demand instances allow users to pay a fixed rate in every billing cycle (e.g., an hour) with no commitment, paying for example $n*p$ monetary units, for n hours usage of an instance, which is charged at p monetary units per hour. Reserved instance allows users to pay a one-time fee, in order to reserve an instance for a certain amount of time. In most cases, the cost of a reserved instance is fixed. The cloud broker exploits the pricing difference between reserved and on-demand instances to reduce the expenses for the users.

The main problem to be satisfied in order to address the dynamic resource reservation corresponds to the decision regarding the number of instances the broker should reserve, the number of instances they should be launched on demand, as well as when to reserve, since the demand changes dynamically over time. The "Instance Reservation Problem" is an optimization problem, seeking to minimize the total cost of all the user demands, and can be formulated as:

$$\min \text{ cost} = \sum\nolimits_{t=1}^{T} r_t\gamma + \sum\nolimits_{t=1}^{T} (d_t - n_t)^+ p, \text{s. t. } n_t = \sum\nolimits_{i=t-r+1}^{t} r_i, \forall t = 1, \ldots, T \tag{4}$$

In the minimization formula, the first summation describes the total cost of reservations and the second the cost of all on-demand instances. In the above equation r_t is the number of reserved instances, d_t the aggregate demand and n_t the number of reserved instances that remain effective at time t = 1, 2 ,…, T. with the time in terms of billing cycle. The term $(d_t - n_t)^+$ describes the additional on-demand instances needed to be launched at time t. Moreover, r is the reservation period, γ the one time reservation fee for each reserved instance and p the price of running an on-demand instance per billing cycle.

The broker's problem is to make dynamic reservation decisions for r_t, t = 1,2 ,.., T to minimize its total cost, as described by the above equation, while accommodating all the demands. This problem is integer programming needing complex combinatorial methods to solve it. However, such kind of problems are described by the *curse of* *dimensionality*, the high number of possible combination and states which results into exponential time complexity seeking for solutions. In addition and in the cases of users who cannot predict their future demand, an online strategy is proposed which reserves instances based only on demand history.

The performance evaluation was based on simulations and on Google cluster-usage traces. The corresponding dataset contained 180 GB over a month's resource usage information of 933 users. According to their findings the broker can bring an aggregate cost saving at a level of 15%, when it aggregates all the user demands. The broker's benefit is different in different user groups, achieving a higher cost saving, at a level of 40% for users with medium demand fluctuation, than those with low demand fluctuation which amounts at a level of 5%.

Evaluating the price discount in each individual user who can enjoy from the brokerage service it is found that over 70% of users can save more than 30%, while the broker can bring more than 25% price discounts to 70% of users if all users are aggregated.

4.4 Dynamic Pricing Based on Quantized Billing Cycles and the Ski-Rental Problem

Quantized Billing Cycles (QBC) is the situation according to which the user pays the same price for an on-demand instance, regardless if the time of usage is smaller than the whole Billing Cycle, i.e. paying the same price of using the VM for 1 min or 1 h [23]. Users with sporadic demand are facing QBC problems and the higher the sporadic nature, the greater the loss. When a cloud broker needs to buy VMs to serve the aggregate demand faces the risk of underutilization of the VM in the subsequent time slots. So, the broker has to decide without knowledge of future demand.

The pricing method presented in this section derives from the research performed in [23] and can be used to maximize the profit of the cloud broker under QBC, in both static pricing (the selling price remains constant at nominal rate) and dynamic pricing (price varies in response to the user's demand). The idea behind dynamic pricing is: "Suffer a small loss in one interval by decreasing the demand, rather than buying a VM and then suffering a major loss in the subsequent intervals due to low demand". This is realized by decreasing the demand and not increase the revenue, so the role of dynamic pricing is to regulate the demand. Dynamic pricing turns out to make more profit than static pricing, mainly due to the underutilization of the VMs met in the latter approach.

The mathematical formulation of the optimization problem described above, considering that the user pays the cloud broker based on per-request basis is:

$$maxP = \sum\nolimits_{t=1}^{T} (\gamma_t d_t - u_t)\; s.t. \sum\nolimits_{i=t-r+1}^{t} u_i \geq d_t ; d_t = f\, dt*, \gamma t; \quad \forall t = 1, 2, \ldots, T \tag{5}$$

P is the profit to be maximized, $(\gamma_t d_t - u_t)$ is the profit at t^{th} interval, γ_t is the selling price per VM per time slot, d_t is the number of VMs required to service the incoming request, u_t is the number of VMs bought at the t^{th} interval and d_t^* is the actual demand, at t.

The equivalent minimization problem to the above is:

$$minL = \sum_{t=1}^{T} \left[\left(\gamma^{*} d_t^{*} - \gamma_t d_t \right) + u_t \right] = f\left(d_t^{*}, \gamma_t \right);$$
$$\text{s.t.} \sum_{i=t-\tau+1}^{t} u_{i \geq} d_t; \forall t = 1, 2, \ldots, Td_t \tag{6}$$

In the above equation, $\left(\gamma^{*} d_t^{*} - \gamma_t d_t \right)$ and u_t correspond to the demand loss and VM loss, respectively and $f(d, \gamma)$ is the demand function. If there is an unexpected increase in demand d_t^{*} for a short time, then the optimization problem described by (6) will increase the selling price γ_t to reduce the demand. Thereby the cloud broker will suffer a small "Demand Loss". The option of buying enough VMs to support the demand hike is a good solution only if the hike in demand persists for a long time, otherwise the cloud broker may suffer a huge "VM Loss" in subsequent intervals due to underutilized VMs. Since it is not possible to know beforehand if an increase in demand will persist or decay soon, d_t^{*} is needed for all t. Hence, the next step is to design online algorithms which can make such decisions online based on present and past data.

The proposed algorithms are based on the *ski-rental problem*, according to which a player faces the decision of whether to buy or rent a resource, without the a priori knowledge of the period of usage. If the period of usage is short, then renting is preferable, while for a long period buying is cheaper. The concept of *breakeven point* is used for the construction of online algorithms, suggesting the point after which buying is cheaper than renting.

The evaluation of the proposed algorithms was based on simulations and on google cluster usage traces and the generation of the demand function, while conducting comparative studies regarding the effect of demand prediction and the demand threshold for switching between renting and buying. The results revealed the importance of demand prediction and indicated the appropriate breakeven points for the different threshold values considered.

The key points of the presented pricing methods, together with the evaluation results are presented in Table 2.

Table 2. Overview of common pricing methods of a cloud broker

Name	Description	Evaluation	Results
Financial brokering method for cloud computing [2]	• Clients send to the broker probabilities revealing the utilization of instances in the following month • Reserved instances are committed by the broker through option contracts	• The simulation was programmed in Python • Use of a pool of 1000 user agents submitting probabilities	• The broker is profitable • It is more profitable for the broker to purchase long-term options contracts • The past performance of clients benefits the broker

(*continued*)

Table 2. (*continued*)

Name	Description	Evaluation	Results
	• The broker, based on the probability and the previous performance of clients, purchases reserved instances or waits to buy instances on demand		
A cloud computing broker model for IaaS resources [19]	• The model is based on provider tariffs instead of providers • Each client presents to the broker his priorities (CPU, RAM, and Storage) • The broker collects tariffs from the provider market and assesses them by calculating the cost-performance of each tariff • The lowest price per performance unit is the most suitable solution for the consumer's task	• The cost-performance ratio of an IaaS instance was estimated by UnixBench • The data of simulation was obtained from three providers: Amazon, Azure and Rackspace	• Rank of price/performance price: different from the order by price or performance alone • Performance and price deflect among providers → less performance at a higher price. • Larger instances have a worse price/performance price
Dynamic Cloud Resource Reservation via Cloud Brokerage [22]	• The broker reserves a large pool of instances from providers and optimally exploits both pricing benefits of long-term instance reservations and multiplexing gains • Users purchase instances from the broker in an "on-demand" way and are served with price discounts • Dynamic strategies are used for the	• The simulations were driven by large-scale Google cluster-usage traces • >900 users' usage traces on a 12 K-node Google datacenter were used • Users' computing demand data were converted to IaaS instance demand • Users: 3 groups based on demand fluctuation level	• Users receive a lower price when trading with the broker. There is no need for upfront payment for reservations and no money wasted on idled reservation instances • The broker makes profit by leveraging the wholesale (reservation) model

(*continued*)

Table 2. (*continued*)

Name	Description	Evaluation	Results
	broker in order to make instance reservations with the objective of minimizing its service cost • When demand predictions are unavailable, an online reservation strategy to make decisions based on history is proposed		
Quantized Billing Cycles [23]	• Quantized Billing Cycles (QBC): user pays the same price for an on-demand instance, regardless if the time of usage is smaller than the whole Billing Cycle • When a broker needs to buy VMs faces the risk of underutilization of the VM and has to decide without knowledge of future demand • The idea behind dynamic pricing is: "Suffer a small loss in one interval by decreasing the demand, rather than buying a VM and then suffering a major loss in the subsequent intervals due to low demand" • Decrease of demand and not increase of revenue, so that the role of dynamic pricing is to regulate the demand	• The proposed algorithms were based on *ski-rental problem* • It was made use of the *breakeven point*: the point after which buying is cheaper than renting • The simulations were based on google cluster usage traces and the generation of demand function • Comparative studies of demand prediction and threshold for switching between renting and buying were conducted	• Dynamic pricing turns out to make more profit than static pricing, mainly due to the underutilization of the VMs met in the latter approach • The results revealed the importance of demand prediction and indicated the appropriate breakeven points for the different threshold values considered

5 Discussion

The overview of the cloud broker discussed in this paper focuses on the numerous benefits of this widely known business model. From a business oriented perspective, the broker assists enterprises to develop themselves, makes cost savings, creating at the same time a competitive environment with more job opportunities and challenges. The cloud brokering has a substantial potential for cloud service providers and small, upstart entrepreneurs, who gain improved profitability and new revenue opportunities, resulting to the growth of the society's economy and the increase of social surplus.

Furthermore, the pricing methods adopted by a broker offer economic benefits to both consumers and providers, while creating profits for the broker as well. Into that context, a research area of high interest and importance, regarding the cloud brokering services, is the development of more intelligent and flexible pricing approaches, since the existing ones do not succeed to adequately address the pricing of cloud services.

Towards this direction, some of the most common cloud brokers pricing methods are presented in this paper. According to them, the broker reserves instances from cloud providers, based on past performance of clients, using either a probability which reveals the utilization of instances for the next month [2] or an online reservation strategy to make decisions based on history [22]. In addition, a broker may collect tariffs from the provider market and assesses them by calculating the cost-performance of each tariff always according to clients' priorities for resources [20]. Dynamic pricing is also proposed as an approach aiming to regulate clients' demand based on the underutilization of the VMs [23] or minimize the broker's service cost using dynamic programming and approximate algorithms [22].

6 Conclusions

In the market of cloud computing, a broker functions in the same way as it does in other, real-world, markets. It matches users' demands with providers' supplies, aiming to succeed in settling the best financial agreement between the supply and the demand side of the corresponding market, in order to make profit and this is the successful result of a deal in a commodity market.

The work presented in this paper describes the cloud broker and its promising future, in terms of maintaining an essential role in an increasingly complex cloud computing scenario and in profit making. It highlights the broker's vital role and the benefits that arise from the use of its services. The economic context of the cloud broker model is also examined by presenting a short review of the contemporary literature for the pricing methods that can be adopted by a cloud broker in order to achieve cost savings.

As the cloud broker business model is still developed, there are a number of important aspects to be further explored, mainly towards the direction of developing and adopting more efficient pricing methods and the role of the broker into the reduction of costs. Research must be extended to accommodate the SaaS and PaaS models as well, which are also expected to diffuse quickly in the coming years, raising the imperative need for new, innovative, business models.

References

1. Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., Ghalsasi, A.: Cloud computing—The business perspective. Decis. Support Syst. **51**(1), 176–189 (2011)
2. Rogers, O., Cliff, D.: A financial brokerage model for cloud computing. J. Cloud Comput. **1**(1), 1–12 (2012)
3. King, M.: Cloud services brokerage market to increase by 55% (2013). http://www.companiesandmarkets.com/News/Information-Technology/Cloud-services-brokerage-market-to-increase-by-55/NI6908. Accessed 8 Apr 2013
4. Rivera, J.: Gartner identifies the top 10 strategic technology trends for 2014 (2013). http://www.gartner.com/newsroom/id/2603623. Accessed 8 Oct 2013
5. Clancy, H.: Cloud integration brokerage services mature. Next-Gen Partner (2014). http://www.zdnet.com/article/cloud-integration-brokerage-services-mature. Accessed 15 Apr 2014
6. Marketsandmarkets: Cloud services brokerage market by types (Cloud Brokerage Enablement (Internal, External (Telecom Service Providers, System Integrators & ISVs, Hosting & Cloud Providers)), Cloud Brokerage) - Global Forecast to 2020 (2015)
7. Nair, S.K., Porwal, S., Dimitrakos, T., Ferrer, A.J., Tordsson, J., Sharif, T., Sheridan, C., Rajarajan, M., Khan, A.U.: Towards secure cloud bursting, brokerage and aggregation. In: 2010 IEEE 8th European Conference on Web Services (ECOWS), pp. 189–196. IEEE (2010)
8. Buyya, R., Yeo, C.S., Venugopal, S., Broberg, J., Brandic, I.: Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Gener. Comput. Syst. **25**(6), 599–616 (2009)
9. Pritzker, P., Gallagher, P.: NIST cloud computing standards roadmap, pp. 500–291. NIST Special Publication (2013)
10. Bohn, R.B., Messina, J., Liu, F., Tong, J., Mao, J.: NIST cloud computing reference architecture. In: 2011 IEEE World Congress on Services (SERVICES), pp. 594–596. IEEE (2011)
11. Yasin, R.: Mid-year review: 10 predictions for cloud computing. GCN (2013). https://gcn.com/articles/2013/08/21/cloud-predictions.aspx. Accessed 21 Aug
12. Geetha, D.V., Hayat, R.M., Thamizharasan, M.: A survey on needs and issues of cloud broker for cloud environment. Int. J. Dev. Res. **4**(5), 1035–1040 (2014)
13. Sampson, L.: A cloud broker can be a cloud provider's best friend. SearchCloudProvider.-com (2012). http://searchcloudprovider.techtarget.com/feature/A-cloud-broker-can-be-a-cloud-providers-best-friend
14. Mihai, C.: Cloud broker or cloud provider? Or both? (2013). https://enterprisetechnologyconsultant.wordpress.com/2013/05/07/cloud-broker-or-cloud-provider-or-both/. Accessed 7 May
15. Papazoglou, M.P., van den Heuvel, W.-J.: Service oriented architectures: approaches, technologies and research issues. VLDB J. **16,** 389–415 (2007). doi:10.1007/s00778-007-0044-3
16. Clearwater, S.H., Huberman, B.: Swing options: a mechanism for pricing IT peak demand. In: Paper Presented at the International Conference on Computing in Economics (2005)
17. Clamp, P., Cartlidge, J.: Pricing the cloud: an adaptive brokerage for cloud computing. In: 5th International Conference on Advances in System Simulation (SIMUL-2013), pp. 113–121. IARIA XPS Press, Venice (2013). Citeseer
18. Wu, F., Zhang, L., Huberman, B.A.: Truth-telling reservations. Algorithmica **52**(1), 65–79 (2008)

19. Gottschlich, J., Hiemer, J., Hinz, O.: A cloud computing broker model for IaaS resources (2014)
20. Mell, P., Grance, T.: The NIST definition of cloud computing (2011)
21. Smith, B., Grehan, R., Yager, T., Niemi, D.: Byte-unixbench: a Unix benchmark suite. Technical report
22. Wang, W., Niu, D., Li, B., Liang, B.: Dynamic cloud resource reservation via cloud brokerage. In: 2013 IEEE 33rd International Conference on Distributed Computing Systems (ICDCS), pp. 400–409. IEEE (2013)
23. Saha, G., Pasumarthy, R.: Maximizing profit of cloud brokers under quantized billing cycles: a dynamic pricing strategy based on ski-rental problem (2015). arXiv preprint arXiv: 150702545

http://www.springer.com/978-3-319-61919-4

Economics of Grids, Clouds, Systems, and Services
13th International Conference, GECON 2016, Athens, Greece, September 20-22, 2016, Revised Selected Papers
Bañares, J.Á.; Tserpes, K.; Altmann, J. (Eds.)
2017, XVII, 320 p. 96 illus., Softcover
ISBN: 978-3-319-61919-4