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Service models and pricing schemes for cloud computing

Se-Hak Chun · Byong-Sam Choi

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Abstract Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources. To ensure large-scale adoption of cloud computing by businesses, several challenges including security, privacy, trust, performance and other quality attributes need to be addressed. Also, as with other utility services, adequate selection of service models and pricing schemes by service providers plays a pivotal role in market expansion. This paper investigates optimal pricing schemes for cloud services. In particular, this paper analyzes two pricing schemes: subscription and pay-per-use pricing models from a provider's standpoint. Using a theoretical analysis of a simple economic model this paper analyzes the optimal choices of providers and discusses implications on consumer surplus and social welfare.

Keywords Cloud computing · Service models · Pricing scheme · Subscription pricing · Pay-per-use pricing

1 Introduction

Cloud computing is a significant step towards realizing the mission of utility computing, where computing services are commoditized and delivered in a manner similar to traditional utilities such as water, electricity, gas, and telephony [1]. It can be defined as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [2]. The characteristics of cloud computing include on-demand access, elasticity, resource pooling, abstracted infrastructure, and no commitment [3].

The expected advantages that cloud computing can provide to users are numerous. First, the economies of scale of delivering computing from a centralized, shared infrastructure have set the expectation among customers that cloud computing costs will be significantly lower than those incurred from providing their own computing [3, 4]. An analysis based on a simulation reveals that over a 13-year life cycle, the total cost of implementing and sustaining a cloud environment may be as much as two-thirds lower than maintaining a traditional, non-virtualized IT data center [5]. Secondly, cloud computing allows users to focus on their main businesses by relieving them of the task of managing data centers [6, 7]. Businesses may start their operations immediately without the need to invest in software and hardware upfront. Thirdly, cloud computing has made it possible to analyze very large data sets in scalable and cost-effective ways [8].

However, to ensure large-scale adoption of cloud computing by businesses, several challenges including security, privacy, trust, performance and other quality attributes need to be addressed. Also, as with other utility services, adequate selection of service models and pricing schemes from a provider's standpoint play a pivotal role in market expansion [9, 10]. While different criteria such as availability, capability and reliability also influence the selection

S.-H. Chun (✉)
Department of Business Administration, School of Business and Technology, Seoul National University of Science and Technology, 172 Gongreung 2-dong, Nowon-gu, Seoul 139-743, Korea
e-mail: shchun@seoultech.ac.kr

B.-S. Choi
Industry and Strategy Department, Samsung Economic Research Institute, 1321-15, Seocho 2-dong, Seocho-gu, Seoul 137-955, Korea
e-mail: byongsam.choi@samsung.com

of services and providers, cost is the most important factor [9, 11, 12].

Although recently much research has been undertaken regarding cloud computing, most of the research focuses on the technical aspect. Literature on the managerial aspect of cloud computing is far from sufficient. The implementation of adequate service models and pricing schemes for cloud services are critical challenges because user demand, provider's profit, and social welfare vary with the service models and pricing schemes [9, 10]. In addition, the cost structure of cloud services is another critical issue because some critics have claimed that revenue from cloud services is not able to support the costs of providing the services [3]. The costs of providers, as well as those of users, are important for diffusion of cloud computing. The costs of providing cloud computing services is a topic that seems to have even less coverage than pricing.

This paper investigates optimal pricing schemes for cloud services from the perspective of cost structure. The paper analyzes two pricing schemes: subscription and pay-per-use pricing models, from a provider's standpoint. The study differentiates itself from previous ones in several ways. First, it uses a theoretical analysis of a simple economic model unlike earlier studies that analyzed the pricing issues of cloud providers using simulation [9, 12]. Economic analysis can better teach us the rationale of providers' choices. Secondly, Song's [18] model was extended to explicitly consider the cost structure of service providers. Thirdly, the study compares pricing schemes from a social point of view. Analysis was undertaken on the optimal choices of providers and the implications on consumer surplus and social welfare are discussed.

This paper is organized as follows: Sect. 2 discusses service models and price schemes in cloud computing; Sect. 3 investigates two pricing schemes for cloud services using a theoretical analysis and discusses implications; Sect. 4 presents conclusions and potential future work.

2 Service models and pricing schemes in Cloud computing

2.1 Cloud service models

Cloud computing consists of three layers analogous to the technical layers in most cloud realizations: infrastructure, platform, and application. The corresponding service models are infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) [2, 3, 13].

In IaaS, the capability provided to users is to provision processing, storage, networks, and other fundamental computing resources, where the consumer is able to deploy and run arbitrary software including operating systems and applications. The infrastructure layer focuses on enabling technologies. Amazon, for example, offers services based on its infrastructure as a computing service (EC2) and a storage service (S3).

In PaaS, the capability provided to users is to deploy applications acquired or created using programming languages and tools supported by the provider. The platform layer represents solutions on top of a cloud infrastructure that provide value-added services from both a technical and a business perspective [14]. Platform as a service does provide users a convenient environment for developing applications [7]. Examples would be application stacks such as Google's App Engine and business platforms such as SalesForce.com.

In SaaS, the capability provided to users is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser. NetSuite, SalesForce.com, and SAP are some examples.

2.2 Cloud pricing schemes

As more providers are starting to offer cloud services, how to determine the right price for users is now becoming increasingly critical for cloud providers. This is because pricing is able to regulate the supply and demand of computing services and thus affects both providers (who supply the services) and users (who demand the services) respectively [9].

There are many different potential pricing policies available to cloud content providers. These pricing strategies can be categorized as fixed and dynamic prices. Fixed pricing includes subscription pricing and pay-per-use pricing [15]. With subscription pricing, users pay on a recurring basis to access software as an online service [9]. The customer subscribes to use a preselected combination of service units for a fixed price and a longer time frame, usually monthly or yearly [14]. With pay-per-use pricing, users only have to pay for what they use. While pay-per-use pricing could achieve social efficiency, it is not easily acceptable for users who want to control their budgets [10].

With dynamic pricing, a target service price is established as a result of dynamic supply and demand, for example by means of auctions. Amazon Web Services has introduced 'Amazon Spot Instances' to allow customers to bid for their unused capacity. Amazon runs the customer's instances as long as the bid price is higher than the spot price, which is set by Amazon based on their data center utilization [15]. While dynamic pricing policies could achieve more economically efficient allocations and prices for high-value services [9, 14, 16], fixed prices are simpler to understand and more straightforward for users, as compared to dynamic ones. In reality, fixed prices, including subscription pricing and pay-per-use pricing, are typical.

An example of IaaS is Amazon S3, which is an online storage web service offered by Amazon Web Services. The pricing structure of several Amazon S3 services is shown

Table 1 Amazon S3 pricing

	Standard storage	Reduced redundancy storage
First 1 TB/month	$0.095/GB	$0.076/GB
Next 49 TB/month	$0.080/GB	$0.064/GB
Next 450 TB/month	$0.070/GB	$0.056/GB
Next 500 TB/month	$0.065/GB	$0.052/GB
Next 4000 TB/month	$0.060/GB	$0.048/GB
Over 5000 TB/month	$0.055/GB	$0.037/GB

Source: Amazon website

Table 2 Google AppEngine pricing

Resource	Unit	Unit cost
Outgoing Bandwidth	Gigabytes	$0.12
Frontend Instances	Instance hours	$0.08/$0.16/$0.32/$0.48
Discounted Instances	Instance hours	$0.05
Backend Instances	Hourly per instance	$0.08/$0.16/$0.32/$0.48/$0.64
Stored Data	Gigabytes per month	$0.18/$0.24
Channel	Channel opened	$0.0001

Source: Google developers' website

Table 3 Sales Cloud of Salesforce.com pricing

Product	Description	Price (per user per month)
Contact Manager	Contact management for up to 5 users	$5
Group	Basic sales & marketing for up to 5 users	$25
Professional	Complete CRM for any size team	$65
Enterprise	Customize CRM for entire business	$125
Unlimited	Premier + Success Plan optimizes CRM	$250

Source: Salesforce.com website

in Table 1. Basically, it uses pay-per-use pricing and offers volume discounts.

An example of PaaS is Google AppEngine, which is a platform for developing and hosting web applications in Google-managed data centers. The pricing structure of Google AppEngine is shown in Table 2. As in Amazon S3, it uses pay-per-use pricing. To develop and host web applications, users typically purchase several resources.

An example of SaaS is Sales Cloud by Salesforce.com, which is CRM. For example, it provides sales representatives with a complete customer profile and account history, allows the user to manage marketing campaign spending and performance, tracks all opportunity-related data including milestones, decision makers, customer communications, and any other information unique to the company's sales process. The pricing structure of Sales Cloud by Salesforce.com is shown in Table 3. It charges a subscription rate, which is determined per user, per month. It does not depend on the amount of usage.

2.3 Cost structure of providers

The costs of providing cloud computing services are a less frequently covered topic than pricing. One widely used method to outline the cost structure of an IT service is found in The Information Technology Infrastructure Library (ITIL), version 2 Service Delivery book [15]. The ITIL's framework suggests six different cost types for formulating an IT cost model. In the ITIL, cost type is the highest level of category to which costs are assigned in budgeting and accounting. Within each high level input cost type there will be a number of defined cost elements. As shown in Table 4, cloud computing includes both fixed cost elements and variable cost elements.

Li et al. [17] argue that elastic resource utilization and virtualization in cloud computing paradigms challenge existing cost analysis methods and therefore they have developed a new cost analysis method. They argue that two cost elements are required because only part of the resource pool, or the cloud, is used at a time according to users' dynamic demands. The first element is cloud total cost of ownership (TCO) and it represents the foundational costs such as the investment to cloud infrastructure, which does not change much with the utilization of cloud by users. In other words, cloud TCO is the cost to build and operate the cloud. The second element is cloud utilization cost that refers to the dynamic cost incurred by the users. Cloud utilization cost is

Table 4 Cost types and cost elements according to ITIL

Cost type	Cost elements (examples)
Hardware	Central processing units, LANs, disk storage, peripherals, wide area network, PCs, portables, local servers
Software	Operating systems, scheduling tools, applications, databases, personal productivity tools, monitoring tools, analysis packages
People	Payroll costs, benefit cars, re-location costs, expenses, overtime, consultancy
Accommodation	Offices, storage, secure areas, utilities
External service	Security services, disaster recovery services, outsourcing services, HR overhead
Transfer	Internal charges from other cost centers within the organization

the cost of the used part of cloud resources directly associated with the real resources locked up or committed to a particular user or application.

Different service models entail different cost structures. While cloud total costs of ownership are common for all service models, cloud utilization costs, or marginal costs, are high for IaaS and PaaS. For example, additional usage of storage requires the purchase of additional disk drive. However, the marginal cost of adding users to a centralized software application can be nearly zero when deployed in a dynamically scalable infrastructure, such as the one cloud provides. This study proposes that different cost structures tend to be associated with different price schemes.

3 Theoretical analysis of two pricing schemes

To analyze the social welfare effects of pricing schemes of cloud computing, an economic model was set up, which includes the cost structure of cloud providers. Song's [18] model has limitations in that his subscription model overvalued users' utility. For simplicity, this report assumes that there is a monopoly provider of cloud computing services. The cost of providing the services includes both fixed cost elements and variable cost elements and is shown as $cQ+f$, where c and f are the marginal cost and fixed cost of providing cloud computing services respectively.

The report's main focus is public cloud services such as IaaS (for example, Amazon S3), PaaS (for example, Google AppEngine), and SaaS (for example, Salesforce.com). For public cloud services, the users are more likely to be business users rather than individual consumers. However, individual consumers do not have to be excluded. The report assumes that consumers' reservation prices are uniformly distributed along $[0, V]$ with unit height, i.e., $v \in [0, V]$. Thus, V can also represent the potential market share of the product. Consequently, given the provider's unit price (p), a consumer of type $v \in [0, V]$ will obtain the following surplus in consuming one unit of the product:

$$U(v) = v - p$$

An individual consumer's demand function is downward sloping and is expressed as $q_i = v_i - p$, where v_i is the maximum willingness to pay for the services. Thus, a consumer v_i purchases the service when $v_i \geq p$. It was assumed that maximum cloud services are limited to sV, where a consumer can buy s units of the service under a subscription pricing scheme and s consumer can buy one unit of the service under a pay-per-use pricing scheme.

3.1 Subscription pricing

Under subscription pricing, a consumer v_i uses s units of services and obtains the total benefit of $\sqrt{s}v_i$ since it was assumed a law of diminishing marginal utility. If the provider offers the subscription price P per consumer, the consumer, v_i purchases s units of the service when $\sqrt{s}v_i \geq P$ or $v_i \geq P/\sqrt{s}$. Thus, the number of consumer (or business users) is $V - P/\sqrt{s}$. In addition, the actual quantity of service used is $s(V - P/\sqrt{s})$ when each v_i buys s units of the service.[1] Under the subscription pricing strategy, the provider has transactions of quantity of demand, $(V - P/\sqrt{s})$. Although actual usage is $s(V - P/\sqrt{s})$, the provider incurs providing costs according to a transaction based concept and lower providing costs than pay-per-use pricing. Thus, the profit function of the provider is given as follows.

$$\begin{aligned} \Pi_S &= (P-c)\cdot Q - f \\ &= (P-c)\cdot[V - P/\sqrt{s}] - f. \end{aligned}$$

From the first order condition $(d\Pi_s/dP = 0)$, we obtain the optimal subscription price

$$P^* = (V\sqrt{s} + c)/2.$$

Also the profit is derived as given by

$$\Pi_S^* = \left(c^2 - 2\sqrt{s}Vc - 4f\sqrt{s} + V^2 s\right)/4\sqrt{s}.$$

[1] A consumer with higher v_i may use more units of service, thus s can be a function of v_i. However, it is simply assumed that each consumer uses s units of the service.

Table 5 Welfare analysis of Heavy User V

Firm	Subscription pricing (S)	Pay per use pricing (P)	Difference (S − P)
Total utility	$V\sqrt{s}$	Vs	≤ 0
Total payment	$(V\sqrt{s}+c)/2$	$s(V+c)/2$	
Net utility (total utility-total payment)	$(V\sqrt{s}-c)/2$	$s(V-c)/2$	≥ 0 if $c \geq \frac{\sqrt{s}}{\sqrt{s}+1}V$

3.2 Pay-per-use pricing

With pay-per-use pricing, if the provider offers the price p per each unit of service, a consumer v_i purchases s units of the service when $v_i \geq p$. Thus, the number of consumers (or the quantity of service used) and the profit of the provider are given as follows.

$$Q = s(V-p),$$
$$\Pi_P = (p-c)Q - f$$
$$= (p-c)\cdot s(V-p) - f.$$

From the first order condition ($d\Pi_P/dp = 0$), the optimal price under a pay-per-use pricing scheme was obtained

$$p^* = (V+c)/2.$$

In addition, the profit of the provider can be derived as follows;

$$\Pi_P = \left(sc^2 - 2sVc - 4f + sV^2\right)/4.$$

3.3 Result of study

Below is an examination of which pricing scheme is desirable from a provider's point of view. By comparing the provider's profits in the cases of subscription pricing (Π_S^*) and pay-per-use pricing (Π_P^*), the following proposition is obtained.

Proposition 1 (i) *The monopoly provider prefers subscription pricing to pay-per-use pricing when the providing cost is higher, while the monopoly prefers pay-per-use pricing to subscription pricing when the cost is lower.* (ii) *As the level of usage increases, the possibility of providing a subscription increases.*

Proof (i) Comparing two profits under different pricing strategies, the result shows $\Pi_S^* \underset{<}{\overset{\geq}{}} \Pi_P^*$ when $c \underset{<}{\overset{\geq}{}} c^* = \frac{s\sqrt{s}(2s-s\sqrt{s}-1)}{s\sqrt{s}-1}V$.

(ii) $\frac{\partial c^*}{\partial s} < 0.$

Proposition 1(i) shows that the monopoly provider prefers subscription pricing to pay-per-use pricing if the providing cost is higher. This implies that if the providing cost is very low, the provider prefers pay-per-use pricing because the pay-per-use strategy incurs higher transaction or providing costs. Proposition 1(ii) says that as the level of usage increases, the possibility of providing a subscription increases. As shown in Table 5, some heavy business users may prefer a subscription scheme according to cost type. This will be discussed later in Proposition 2.

Looking at which pricing scheme is desirable from business users' and a social point of view, a social welfare concept is used, which can be represented by the sum of consumer and producer surpluses (or a business' profits). Thus, by comparing the consumer surplus and social welfare in the cases of subscription pricing (CS_S) and pay-per-use pricing (CS_P), the following proposition is obtained. □

Proposition 2 (i) $CS_S < CS_P$ *and* (ii) $SW_S < SW_P$.

Proof Omitted because of a simple calculation using $c < V$. □

Proposition 2 says that pay-per-use pricing (CS_P) is always desirable from the viewpoint of consumer surplus and from a social welfare perspective. This is because pay-per-use pricing provides additional utility without reducing for some users who want to buy minimal services while subscription pricing can provide more services to consumers who cannot predict the exact level of services that they would use. Thus, some heavy business users may want to choose subscription pricing. Looking at heavy business users with a maximum willingness to pay, V, the amount of utility, price, and net utility for the business user is summarized in Table 5.

As shown in Table 5 when c is large, the heavy business user prefers subscription pricing. However, when c is low businesses prefer pay-per-use pricing. In reality, there are additional considerations besides user benefits and cost structure. For example, the providers need to resolve the issue of metering to implement pay-per-use pricing. Business users who want to gain control over their IT budget might choose pay-per-use pricing.

In summary, the cloud service provider may choose a subscription pricing strategy when the providing cost is relatively large, while consumers and providers prefer pay-per-use pricing, which is socially desirable. However, if the marginal cost of providing the service is smaller, the provider and consumers all prefer pay-per-use pricing and, in addition, even the heavy business users do.

Table 6 Cloud service models and pricing schemes

Ontology concept	Service type	Pricing model	Company/product
Applications	Business process management	Pay per use	Appian Anywhere
		Pay per use	process Maker Live
	Storage	Pay per use	Box.net
		Pay per use	Nirvanix
		Subscription	Xdrive
		Free	MS Skydrive
	Storage, email	Free/pay per use	Gmail drive
	Billing	Subscription	OpSource
	Data processing (video); Amazon EC2	Pay per use	MuxCloud
	Data sharing (photo)	Subscription	SmugMug
	Web services	Subscription/pay per use	StrikeIron
	Marketplace	Dynamic pricing	Zimory.com
Applications/Platform	platform	Pay per use	Salesforce.com
Platform/Infrastructure	Computing, storage, database, payment, billing	Pay per use	Amazon EC2 and S3, SimpleDB, SQS, FPS, DevPay
	Infrastructure	Pay per use	Network.com
Infrastructure	Infrastructure, Web applications	Pay per use	Google App Engine
	Infrastructure	Pay per use	FlexiScale
		Subscription	XCalibre

3.4 Discussion

Our predictions are that the cloud service models with sizable marginal costs such as IaaS and PaaS tend to be coupled with pay-per-use pricing, and the others with subscription pricing. Table 6 shows service models and the pricing schemes of some real-world examples.

As shown in the table, pay-per-use pricing is general among IaaS and PaaS and subscription pricing is often used for SaaS and IaaS offerings. The examples, though not a perfect match, conform to the predictions of this study. The cost structure of service providers cannot fully explain the reality, but it is one of the important determinants of pricing schemes. The rationale behind providers' choices is that subscription pricing generates fewer transactions, consequently saving marginal costs compared to pay-per-use pricing.

4 Conclusion

This paper examined current various pricing models and investigated correct pricing strategies for cloud services. In particular, the paper examined service models and their pricing schemes according to cost structures. The main focus of this paper was to compare two widely used pricing schemes: subscription pricing and pay-per-use pricing, and to examine the right pricing strategies for cloud services. Initial discussion centered on cloud ontology and cloud service types. Next a review of various pricing schemes available to service providers and cost structures of IT systems was displayed and finally a theoretical model to analyze cloud service providers' profits, as well as social welfare.

The main results were first, service providers prefer pay-per-use pricing when the providing cost is lower, which is desirable from the viewpoint of business users and social welfare. However, when the cost is higher, service providers prefer subscription pricing. Also, providers favor subscription pricing when users want greater levels of service at a time. Secondly, business users may differ in their preference for pricing schemes. Heavy business users may like subscription pricing while light business users prefer pay-per-use pricing, depending on the cost structure. Thirdly, if the marginal cost of providing a service is low and negligible, all providers and consumers favor pay-per-use pricing, which is socially desirable. Thus, cost structure can be a critical component in determining correct pricing schemes for the providers.

This paper has studied pay-per-use and subscription-based pricing separately. However, another pricing scheme that a service provider may want to consider in order to improve its profits is to offer options, pay-per-use and subscription, for a consumer to self-select. The possibility for a consumer to self-select among multiple pricing schemes might change the providers' optimal choices of pricing levels. The situation should be dealt with the more complex model of providers and consumers. It would be a promising topic for future research.

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Se-Hak Chun is a Professor at Seoul National University of Science and Technology. He received his B.S. in Economics from Korea University in 1994. He completed both his M.E. (1997) and his Ph.D. (2002) in Management Engineering at KAIST. He has published articles in journals including Expert Systems, Expert Systems with Applications, Artificial Intelligence in Medicine, Decision Support Systems, International Journal of Forecasting, Information technology and management, personal and ubiquitous computing and International Review of Economics and Finance, among others. His research interests include financial forecasting, data mining, cloud computing, economics of electronic commerce, economics of information security, complexity theory, telecommunication economics and policy, industrial organization and law and economics.

Byong-Sam Choi is a research fellow at Samsung Economic Research Institute, Seoul, Korea. He has about 10 years of experience with strategy and policy consulting there. He holds a Ph.D. and M.S. in Management Engineering and a B.Sc. in Mechanical Engineering from Korea Advanced Institute of Science and Technology (KAIST). His current research interests include cloud computing, strategic and policy issues in business platforms, and an economic analysis of two-sided markets.