A Survey of Cloud Computing Variable Pricing Models

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Abstract: Cloud computing has grasped the attention of scientific community and business industry towards the provisioning of computing resources as utility and software as a service over a network. Profitability and revenue maximization are the most important goals for any cloud service provider which can be employed through different pricing models. Historically, cloud providers were following the fixed pricing strategies while provisioning their services to the clients. However, these approaches have their own shortcomings resulting in resource wastage, lack of fairness and user satisfaction. With expansion of cloud users in market every day, provisioning of fair resource allocation with service differentiation and efficient pricing model is demand seeking, resulting in a shift from static to dynamic pricing models. In this paper, we discuss and investigate different pricing scheme with respect to their advantages, limitations and possible future directions. The study will open a way for vendors to seek new research directions in dynamic pricing schemes.

1 INTRODUCTION

Cloud Computing is an emerging IT development, deployment and delivery model consisting of a collection of interconnected and virtualized computers enabling real time delivery of services/ products and solutions over the Internet. It is a paradigm shift from traditional cluster and grid computing. Many companies are now taking advantage by developing their IT transformation strategy to fasten their time to market by using cloud pay-per-use services. This new view of building private network to provide value added services in economic terms is known as Market Oriented Computing. Some popular Industrial cloud providers in market are Amazon EC2 (Elastic Compute Cloud), Google App Engine, GoGrid, Microsoft Azure and many more (Shang, 2010).

Cloud computing has drawn increasing attention in the past few years due to the inherent characteristics of flexibility, scalability and ease of use. Just like business organizations, scientific community is also getting benefits from cloud capacities by adopting the utility of cloud computing offered with low cost involved. As more resources are required for high Performance Computing (HPC) applications to accomplish their tasks/workload, the advent of cloud computing has shifted their computation from the dedicated clusters to the widely available cloud provided utilities in a pay as you go fashion (Huang, 2013). It is commonly perceived by many researchers that in near future, it will become the fifth utility after electricity, gas, water and telephone provisioning the people with computing capacities to use in their daily life without incurring the capital investments.

Cloud Service Providers (CSPs) offer various instance types of their Virtual Machine (VM) each with different price, capacity and computation. CSPs provide their services to the clients by renting their spare capacities on hourly, monthly, semi-annual and annual basis to the clients at comparable offers. They are liable to manage the peak load capacity and resource utilization strategically. With the concept of ‘virtualization’ where reallocating resources, to fulfill the market demands, is managed dynamically through VM migrations over the network, it has become easier for providers to manage the load with negligible cost (Ma, 2012).

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Profitability and revenue maximization are the most important goals for any cloud service provider, which can be employed through different pricing models; however, the end-users are typically more interested in Quality of Service (QoS), Cost-effectiveness, Usability and Availability of cloud resources (Users maximize utility and CSPs maximize profits). Keeping a balance between these two (trade-off) is the most challenging design decision to be made by cloud service providers. In this research, we are particularly more interested in pricing policies for cloud computing which may affect user satisfaction, behavior and loyalty to CSPs (Al-Roomi, 2013).

Cloud pricing models can be categorised in the following two general models:

1.1 Pay-as-You Go Pricing/ Pay-per-Use Fixed Pricing

Historically, cloud providers were following the fixed pricing strategies while provisioning their services to the clients i.e., clients were charged with constant unit price for a computing capacity regardless of the capacity of the compute unit. This approach has its shortcomings in a way that resource wastage may occur if the user is not or seldom use a resource from the set of resources he paid for. Moreover, vendors are free to charge the user without taking measures for QoS and other satisfying metrics, for example, Amazon on-demand and reserved instances, Google Apps are the examples of employing such schemes.

The pay as you go billing model by the cloud providers cut down the ownership cost required to configure and maintain the real capacities and storages. Amazon provided the simple price calculation for a resource as (EC2, 2014):

$$P = P_{comp} + P_{storage} + P_{in} + P_{out} + P_{tran} \tag{1}$$

where

P_{comp} is the VM instance price. These include standard, High Memory and High CPU.

$P_{storage}$ is the price charged for storing user data on cloud.

P_{in}, P_{out} is price associated with uploading and downloading the data between different regions of the same cloud.

P_{tran} is the price of file operation within a VM.

This type of pricing scheme is best suited for IaaS.

1.1.1 Pay for Resources

In this technique, user is charged for the use of storage and bandwidth size accordingly.

1.1.2 Subscription

As the name indicates, user gets subscribe to a particular CSP with fixed price per unit consumed for a long period of time (normally 1-3 years) with a fixed pricing scheme.

Above mentioned pricing models are more biased towards the providers of the cloud than the consumers. Thus efficient cloud market mechanism to deal with maximum number of transactions along with flexible pricing model to meet the requirements is the next evolving step that users and providers are seeking for (Shang, 2010).

1.2 Dynamic Pricing

The environment of the cloud is inherently dynamic. With the expansion of the cloud users every day in the market, provision of fair resource allocation with service differentiation and efficient pricing model is demand seeking. This has opened a way for vendors to adopt varying pricing schemes, from static to dynamic pricing models (Sowmya, 2012). Amazon was the first to provide the concept of dynamic pricing model through spot pricing scheme. The concept was to utilize unused and spare capacity available in the data centres after fulfilling the demands of the on-demand and reserved instances. These unused capacities are referred as spot instances and are charged based on the fluctuating supply and demand of these spot instances.

In cloud computing, the provision of leasing technology as a utility is one of the potential opportunities to achieve market-based price by the provider. Thus the concept of auction is the instrument to achieve this potential benefit from the market with proper allocation of resources to the clients. Amazon leads in presenting and adopting the idea of ‘Auctioning’ the technology as utility in the market rather than conventional fixed price schemes. Users can request particular type and number of instances with willingness of paying maximum price for it in a particular auction. Cloud providers could lease their computing capacities in an auction where in a particular cloud market place, products advertised in a broker module. Moreover, customers also submit their demand to this module to fetch the suitable result for them. In a general auction model, broker search for the best provider/customer match with specific parameters and thus provides opportunity to provide benefit at both ends. However, there is growing urge of setting the price offered by providers to bid in a market driven manner; where the prices are set to bid in accordance with the supply and demand of the instance requests. Different researchers have opinion that spot prices set for bidding are not market driven. Rather they are internally fixed prices; selected randomly from a small predefined interval. But still auction scheme is capacities in an efficient manner of allocating resources with low cost (Lampe, 2012). The current study is aimed to investigate different research directions and possible future extensions in dynamic pricing schemes.

2 RELATED WORK

Cloud computing has grasped the attention of the industry towards the provision of computing resources as utility and software as a service over a network. This is because cloud computing has combined varying aspects of IT into a business model that brought revolution in the market. As both users and providers of cloud are trying to get acquainted of this paradigm shift, it is important for them to investigate the pricing models that are adopted in provisioning the capacities.

a) Salesforce.com for example is leading SaaS provider and customers are charged monthly subscription fee for their online CRM software apps.
b) Amazon EC2, on other hand, charge customers on hourly basis.
c) CloudSigma, an IaaS provider also charges their customer on hourly basis with the benefit of short billing segment.

Amazon collets bid for a spot instance from all the requesters and decide a spot price. For customers' convenience, the website maintains the 90 days history to get idea of the bid prices before they submit their own. However, the user of the spot instance has risk of service interruption associated with him as Amazon periodically updates its bid price. So the user is safe only of his/her bid price exceeds the set bid price of the provider. This is not the case with the on-demand and reserved instances offered by Amazon. But user has advantage of cheap price being charged for spot instances to work out for their low valued jobs. SEOMOZ, a software vendor used Amazons spot instances for their services. But due to spot price spike once happened, Amazon terminated all the services of SEOMOZ.

This accident led SEOMOZ to change their strategy for job submission strategically and they used mixed pricing strategy by putting their low valued jobs/services on spot instances and high valued jobs/services to on-demand instances. This infers that service differentiation is important aspect to be learned by the user in order to adopt the mixed pricing strategy and get advantage form it (Ma, 2012).

The following table lists some of the studies based on dynamic pricing along with the research novelty, methodology, limitations and future directions that can be further explored.

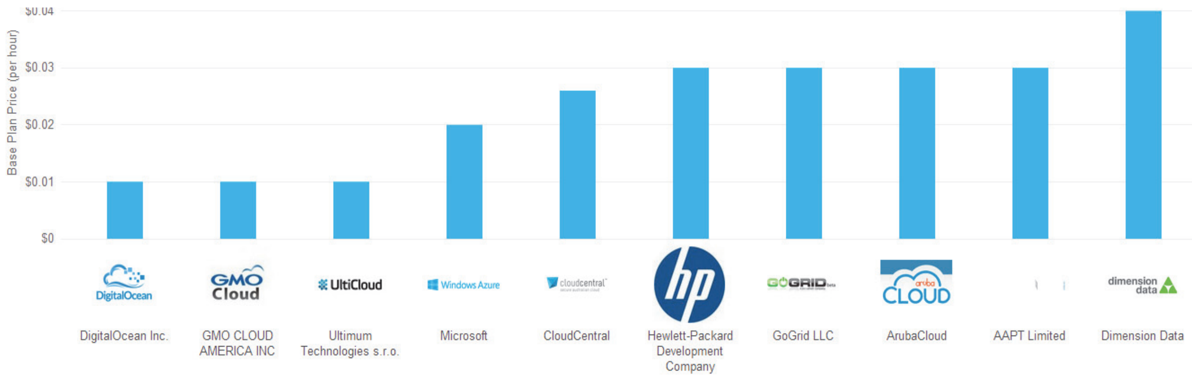

Figure 1: Price Chart of IaaS Cloud Vendors (Base Plan Price per Hour).

Table 1: Comparison of Cloud Computing Variable Pricing Model.

Paper Title	**Objective**	**Methodology**	**Novelty**	**Tools /software used**	**Limitations**	**Future Work**
Strategic bidding for Cloud resources under Dynamic Pricing Schemes (Sowmya, 2012)	To examine the behavior of the bidders under the dynamic pricing scheme.	Simulation	Modeling of strategies for the bidders in spot market	Real time spot data form Amazon EC2 and ARENA 12.0	-----	Observing users' strategic behavior in dynamic pricing environment

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Table 1: Comparison of Cloud Computing Variable Pricing Model (cont.).

Paper Title	**Objective**	**Methodology**	**Novelty**	**Tools /software used**	**Limitations**	**Future Work**
CAP[3]: A Cloud Auto provisioning Framework for Parallel Processing Using On-demand and Spot Instances. (Huang, 2013)	To provide a tool that helps in reducing the cost of running the HPC applications within deadline by providing the appropriate cluster size and cloud instance type	Experimentation by implementing CAP[3] on top of Amazon EC2	Prediction of application performance by providing the proper cluster size to finish job within its deadline and cost	Python with NumPy Lib to program CAP3	Present schedule module of CAP3 only supports one task per customer	To integrate sophisticated bidding strategies and recovery mechanism during pre-emption
Maximizing Cloud Provider Profit from Equilibrium Price Auctions (Lampe, 2012)	To examine the Equilibrium price auction allocation problem (EPAAP) and to provide heuristic approach in maximizing the profit of the cloud provider using Equilibrium Price Auctions	Qualitative Assessment of the optimal and heuristic approaches	Scientifically addresses the EPAAP and presented heuristic solution for the distribution of VMs	Real time spot data form Amazon EC2 for VM types in evaluation of EPAAP	Each bid in auction is restricted to one VM instance only	To support the proposed approaches with optimized auction requirements like live migration of VM
The pricing model of cloud computing services. (Ma, 2012)	To study users' strategy of submitting varying jobs under mixed pricing scheme for better resource utilization and benefit for both user and service provider.	Numerical evaluation of proposed multi stage game	Studied the interruptible service in a business context and using mixed pricing scheme with service differentiation in cloud computing	----	Job arrival process of user in all stages of the modeled game is identical and independent	Strategic behavior of the cloud vendor in making decision about pricing schemes for varying offered instances.
A knowledge-based Continuous Double Auction Model for Cloud Market (Shang, 2010)	A model to attain high market efficiency and stable trading price in global cloud resource market for cloud interoperability	Simulation	-----	Double Auction Round Algorithm	Only one type of resource at a time in a particular auction	To apply the proposed model to real cloud resource Environment
Procurement Auctions to trade computing capacity in the Cloud (Di Modica, 2013)	To analyze auction based marketing mechanism based on accurate parameters that can lead to computing business opportunities with increasing revenue.	Simulation of Auction Cloud Market	Addressed the issues related to the bidder's strategy in procurement auction context	CloudSim Simulator	------	To build business model of auctioneer(broker) inorder to investigate the profit for all market actors
Themis: Economy Based Automatic Resource Scaling for Cloud Systems (Costache, 2012)	A spot market based system that maximizes the resource utilization of dynamic applications while supporting their SLO's	Simulation	A proportional share auction with support of SLO management on top of this auction.	CloudSim Toolkit	-------	To support multiple resource types in a single auction
Combinatorial Auction-Based Dynamic VM Provisioning and Allocation in Clouds (Zaman, 2011)	To evaluate Combinatorial Auction against fixed pricing Cloud strategies while provisioning dynamic resource allocation to solve VM Allocation problem in Cloud	Simulation Experiments	Formulated the dynamic VM Provisioning Problem and proposed the combinatorial auction based mechanism	CA-PROVISON Algorithm evaluated with real workload data from Parallel Workloads Archive	User can participate in an auction with one job at a particular time of auction	Setting up a private Cloud with real implementation of the CA-PROVISION Mechanism
ABACUS: An Auction-Based Approach to Cloud Service Differentiation (Zhang, 2013)	Automatic service differentiation of jobs with different budgets, utility properties and priorities while optimally allocating and scheduling resource	Experimentation	Provided automatic service differentiation along with job priority of the user while allocating resources	Experiments of ABACUS components on Hadoop0.20	Only 5 users in computing experiments on a cluster	To handle dependent resources in auction using dependency model
Cost-Optimal Cloud Service Placement under Dynamic Pricing Schemes (Li, 2013)	To investigate cost optimization problem from cloud providers perspective	Experimental Simulation	-------	Optimus cloud toolkit	-------	Scheduling mechanisms with dynamic pricing schemes for service placement in cloud infrastructure

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Table 1: Comparison of Cloud Computing Variable Pricing Model (cont.).

Paper Title	Objective	Methodology	Novelty	Tools /software used	Limitations	Future Work
Provisioning Spot Market Cloud Resources To Create Cost-Effective Virtual Clusters (Voorsluys, 2011)	Resource allocation and job scheduling strategy to run deadline-constrained jobs on low cost virtual clusters	Simulation	Dynamic virtual cluster by utilizing spot instances to run streamed jobs in a fast and economical way	Real price variation data form Amazon	Rescheduling of missing deadline jobs is quite cost effective	To apply fault tolerance techniques in case of interruption from service of spot instances.
Optimal Pricing of Multi-model Hybrid System for PaaS Cloud Computing (Lu, 2012)	To maximize revenues and minimize costs by using an optimal hybrid system	Numerical Modeling	Demand Curve and Tiered pricing policy to obtain higher revenue	Mathematical approach	Job arrival and exit are assumed to be uniform	Job utility and service differentiation can be added to refine model
Optimal Bidding in Spot Instance Market (Song, 2012)	Optimal bidding strategy for reduction in computational cost by utilizing spot instance market while maximizing the profit	Simulation	Bidding algorithm to leverage spot instances, while and maximize profit	Matlab	Only single type of spot instance is utilized	Dynamically tune bids for deadline constrained jobs
On the Cost-QoE Trade-off for Cloud-based Video Streaming under Amazon EC2's Pricing Models (He, 2014)	To investigate trade-off between VM procumbent cost and achieved quality of experience of end user	Numerical Evaluation	Joint problem of resource provision and procurement under multiple pricing models	Theoretical Model	Bidding strategies for procurement of Spot VM is not addressed	------------

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3 DISCUSSION & CONCLUSION

Theoretically, fixed pricing scheme is a preferable cost optimization solution for cloud vendors as compared to variable pricing scheme (Abhishek, 2012). However, recent research work in this domain is more directed towards variable pricing scheme as it involves market dynamics of supply and demand and run-time cost optimization. Variable pricing models, as proposed in the literature, are mostly biased towards cloud providers by aiming profit maximization through equilibrium pricing (Shang, 2010; Lampe, 2012; Costache 2012; Di Modica 2013). However, most research ignored one important aspect; economic efficiency of cloud computing resources. Economic efficiency means that right quantity of products/ services are offered to the users at minimum cost (Supply and Demand, 2013). Hence, the relationship between highest QoS and price plays an important role in neoclassical economics of efficiency. Customers will search for the CSP with highest level of QoS along with the minimal cost involved in computation. This is the reason why Amazon spot instances are generated at 'random' within a tight price interval (upper, lower) instead of the claimed market driven pricing scheme (Agmon, 2013). We plan to incorporate financial options theory with cloud pricing schemes to address this issue and propose a pricing model based on market dynamics and economic efficiency.

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