Proceedings Paper:
Aldossary, M and Djemame, K orcid.org/0000-0001-5811-5263 (2016) Energy Consumption-based Pricing Model for Cloud Computing. In: Awan, I and Cullen, A, (eds.) 32nd UK Performance Engineering Workshop. 32nd UK Performance Engineering Workshop, 08-09 Sep 2016, Bradford, United Kingdom. University of Bradford , pp. 16-27. ISBN 978-1-4276-5567-7

Energy Consumption-based Pricing Model for Cloud Computing

Mohammad Aldossary*†, Karim Djemame*

Abstract

Pricing mechanisms employed by different service providers significantly influence the role of cloud computing within the IT industry. The purpose of this paper is to investigate how different pricing models influence the energy consumption, performance and cost of cloud services. Therefore, we propose a novel Energy-Aware Pricing Model that considers energy consumption as a key parameter with respect to performance and cost. Experimental results show that the implementation of the Energy-Aware Pricing Model achieves up to 63.3% reduction of the total cost as compared to current pricing models like those advertised by Rackspace.

1 Introduction

Cloud computing has been named as the fifth utility along with telephone, gas, electricity and water where nowadays cloud services are available on demand, such as any other utility services [1]. Generally, cloud services offer computational resources for customers including for instance, CPU, RAM, Network and Storage capacity. Each cloud provider has different resource pricing options. Thus, payment models and resource utilization determine these pricing options. Computing resources are offered as Virtual Machine (VM) instances with their price being determined based on the integration of CPU, RAM, Network and Storage capacity. In [3], the authors have noted that most cloud computing service providers usually charge consumers for the offered services on a timely basis regardless of the actual resource usage and consideration of energy consumption, which is considered one of the biggest cost factors by cloud infrastructure providers.

A number of initiatives are found in the literature towards the modelling of pricing mechanisms for offered services including subscription-based, dynamically priced such as Amazon EC2 spot instances [5] and usage-based such as Jelastic plans [2]. The cloud providers offer different types of pricing based on the customer requirements such as prepaid (reserved), on-demand and auctioned are the most popular pricing models. Prepaid: this type of instances allows customers to pay a fixed price up-front for a specific period of time. Usually, customers pay lower prices for long-term commitments due to the fact that this can help cloud providers to estimate the expenses of their infrastructure

*School of Computing, University of Leeds, UK. {Scmmald, K.Djemame@leeds.ac.uk}

†Prince Sattam Bin Abdulaziz University, KSA. {mm.aldossary@psau.edu.sa}

[6]. On the other hand, on-demand: there are no long-term commitments with these types of instances that enable customers to pay service fees on an hourly basis. For businesses that cannot pay up-front or cannot estimate their required computing resources, the pay-as-you go model is ideal [7]. Lastly, auctioned: the idea of the auction pricing model is based on selling the idle time of cloud services, which enables customers to bid for cloud services while cloud providers have the right to accept or reject the offer [6].

Recently with the increasing electricity cost of cloud data centre to the point that it can often override the cost of IT equipment over a period of time [4], power consumption has become an important problem for infrastructure providers. Consequently, modelling a new pricing mechanism for offered services to be adjusted to the actual energy costs has become an important research topic that has attracted the attention of many researchers. Therefore, we consider two factors to determine the costs incurred by Cloud providers: (1) the resource usage level, and consequently the power consumption, (2) the performance variations (degradation/improvement) faced by customers at service operation and its impact on energy consumption and cost.

Considering the challenges in pricing models, this paper is the first step in the investigation over the relationships between pricing, energy consumption and performance. The main contribution of this paper is a novel Energy-Aware Pricing Model that considers energy consumption as a key parameter with respect to the performance and cost.

The remainder of this paper is organised as follows: In Section 2, we discuss the related work on pricing models in cloud computing. In Section 3, we present the description of the proposed model. Section 4 provides an overview of experimental design, followed by the experiment setup, and implementation. In Section 5, we present the results and discussion. We discuss future work and conclude in Section 6.

2 Related Work

Cloud computing is an important and growing business model; yet it has attracted the attention of many researchers. While contributing to the debate about pricing models and energy consumption in cloud computing, Li et al. [8] presented a cost and energy aware scheduling algorithm to reduce the cost and the energy consumption of workflow while meeting the deadline constraint. The proposed Cost and Energy Aware Scheduling (CEAS) algorithm consists of five sub-algorithms. The authors use CloudSim to evaluate the algorithm using four scientific workflow applications. However, the proposed algorithm does not consider the actual electricity cost and their energy model only considering CPU power consumption.

Overall, with the increasing electricity cost of the data centre to the point that it can often override the cost of IT equipment over a period of time [4], power consumption has become a vital concern for infrastructure providers. Therefore, cloud providers should consider energy consumption when designing pricing mechanisms for the offered services. Zhang et. al. [9] have proposed resource allocation algorithm for a heterogeneous environment. The problem focused about data centres that consume huge amounts of energy, and have the impact on environmental and operational costs. The authors have proposed two techniques, one to lower high energy consumption is decreasing the scale of data centres, and another is using a resource allocation algorithm to achieve the trade-off between performance and energy consumption. The proposed algorithm is based on energy aware scheduling policy. However, they need to implement that algorithm to validate the cost fairness and effectiveness.

Moreover, Berndt and Andreas [3] proposed a hybrid IaaS pricing model to address an issue when Cloud providers practice of overbooking and double selling capacity in order to retain profitability, which would affect performance and Cloud adoption. To clarify, this pricing model charges based on a flat rate part that guarantees a certain performance to the consumers and on a flexible part that charges for the resource usage exceeding the flat rate portion. Their approach only requires measurement of performance in one side and measurement of resource usage on the other side, as stated in their work. However, their approach is still limited in the essence that it does not consider the cost of energy consumption and performance variations.

Furthermore, Qureshi et al. [13] emphasize the variability of electricity price in different geographic locations, it helps to reduce data centre costs. Narayan and Rao [12] proposed a pricing mechanism that maps between the cost of electricity input to the infrastructure and the output cost of the Cloud services. Their assumption that, pricing scheme varies dynamically in conformity with the variation of the electrical input costs that measured by a smart grid. Nevertheless, customers have no information on the consumption of energy that they consume. Consequently, we need to make them aware about their energy usage, which may help them change their behaviour accordingly e.g. by shutting down/consolidating VMs and running applications which are energy efficient.

However, the proposed model differs from those reviewed in this section. The main difference is that our Energy-Aware Pricing Model considers energy consumption as a key parameter with respect to performance and cost. Furthermore, customers will get charged based on their actual resource usage.

3 The Proposed Model

In this paper we designed a pricing model considering energy consumption in addition to resource usage for cloud computing offered services. This led us to come up with a novel Energy-Aware Pricing Model that considers energy consumption as a parameter with respect to performance and cost. The proposed model will charge the customer based on the actual resource usage per unit such as (CPU, RAM, Network and Disk) including energy consumption. Therefore, we have applied a mathematical approach to calculate power and energy consumption, as well as resource usage.

1. To calculate the **Power Consumption** per VM we use [15]:

$$VM_{power(x)} = \frac{Host_{idle}}{VM_{count}} + (Host_{power} - Host_{idle}) * \frac{VM_{Util(x)}}{\sum_{y=1}^{VM_{count}} VM_{Util(y)}} \tag{1}$$

   Where $VM_{power(x)}$ is power consumption for one VM measured by Watt per second. The $Host_{idle}$ is power consumption for idle single host and $Host_{power}$ is power consumption for a single host. The VM_{count} is number of VMs in a single host. The $VM_{Util(x)}$ is a VM CPU utilisation divide by $\sum_{y=1}^{VM_{count}} VM_{Util(y)}$total VMs CPU utilisation in a single host.

2. To calculate the **Energy Consumption** and **Energy Price** per VM we used:

$$Energy_{VM(x)/kWh} = \frac{VM_{Power(x)}}{1000} * \frac{Time_{(s)}}{3600},$$
$$EnergyPrice_{VM(x)/kWh} = Energy_{VM(x)/kWh} * EPrice_{kWh} \tag{2}$$

   We convert power consumption from formula (1) using the formula (2) to get the energy consumption where $Energy_{VM(x)/kWh}$ is energy consumption for one VM measured by Kilowatt per hour and $Time_{(s)}$ the time for using one VM. $EnergyPrice_{VM(x)/kWh}$ is the Energy Price, we multiply energy consumption by electricity price, as reference in UK electricity prices [11] average estimate $EPrice = 0.12$ per kWh.

3. To calculate the **Resource Usage** per VM we used:

$$\begin{aligned} CPU_{usage} &= \sum_{S=1}^{Time} CPU_{Util}, \\ Memory_{usage} &= \sum_{S=1}^{Time} Memory_{Util}, \\ Disk_{usage} &= \sum_{S=1}^{Time} Disk_{Util}, \\ Bandwidth_{usage} &= \sum_{S=1}^{Time} Bandwidth_{Util}, \\ Time_h &= \frac{Time_{(s)}}{3600} \end{aligned} \tag{3}$$

   We calculate the resource usage individually, such as CPU_{usage} per second at a specific period of time (usage time) where $\sum_{S=1}^{Time} CPU_{Util}$ is total CPU utilised during that period and so on for each resource such as Memory, Disk and Bandwidth and convert the time from seconds to hours.

4. To calculate the **Price for Resource Usage** per VM we used:

$$
\begin{aligned}
Price_{VM(x)/h} = & (CPU_{usage} * CPrice_h) \\
& + (Memory_{usage} * MPrice_h) \\
& + (Disk_{usage} * DPrice_h) \\
& + (Bandwidth_{usage} * BPrice_h) \qquad (4)
\end{aligned}
$$

From the formula (3) we use the resource usage calculation and multiply it by the price for each resource per hour. For estimating the price for each resource, we follow Rackspace [14] and ElasticHosts price [21]: where $CPrice$ is pricing fee per hour for $CPU_{usage} = 0.0092$ per GHz/h, $MPrice$ is pricing fee for $Memory_{usage} = 0.0092$ per GB/h, $DPrice$ is pricing fee for $Disk_{usage} = 0.0001$ per GB/h and $BPrice$ is pricing fee for $Bandwidth_{usage} = 0.0000001$ per MB/h.

5. For applying **Energy-Aware Pricing Model** we used this formula:

$$TotalPrice = Price_{VM(x)/h} + EnergyPrice_{VM(x)/kWh} \qquad (5)$$

which is the price for resource usage and energy consumption for one VM per hour by considering (4) and (2).

4 Experimental Design

4.1 Experiment Setup

Cloud computing service providers usually charge their customers on an hourly basis with no performance guarantee instead of considering the actual resource usage. For instance, in Rackspace [14] and Amazon EC2 [17] on-demand schemes assume the average utilisation is 100% [16], customers are charged the same price no matter what CPU and RAM utilisation can be. In other words, Rackspace, Amazon EC2 and Microsoft Azure [18] charge consumers for the offered services on a timely basis regardless of the actual resource usage and consideration of energy consumption, which is considered one of the highest cost factors by cloud infrastructure providers. A number of experiments have been designed and implemented on a local Testbed with the support of the Virtual Infrastructure Manager, OpenNebula [19]. Heterogeneous virtual machines were created and their monitoring was performed through Zabbix [20]. This has allowed full control of the cloud environment in order to get detailed results of how the Energy-Aware Pricing Model affects cost and energy consumption. VM cost considerations in the experiments were based on information available on Rackspace [14] and ElasticHost [21]. The data gathered during the experiments was input into this tool to get a cost estimate of deploying the VM on a public cloud. The server and the virtual machine configurations are shown in Tables 1 and 2.

Server - Testnode2	
MODELNAME	Intel(R) Xeon(R) CPU E3- 1230 V2
CPU	3.30GHz
Number of cores	8
Memory	14.7GB
Disk	915GB
HYPERVISOR	KVM
Operational System	Linux Debian 7.8

Table 1: The server configurations.

Small - VM	
CPU	0.25
vCPU	2GHz
Number of cores	2
Memory	2GB
Disk	40GB
HYPERVISOR	KVM
Operational System	Windows 2003 x86

Table 2: The virtual machine configurations.

4.2 Implementation

The objective of these experiments is to evaluate the variation of the actual resource usage and energy consumption when running software intensive workloads and their influences on the price. We applied three different workloads to the VMs: (HeavyLoad) to stress all resources under heavy load, (CPUSTRES) CPU stress tool to simulate CPU usage used multi-threading to exploit multi-cores to test high workloads, and (Pi Java Program) to simulate resource usage in one hour. In this paper, we have shown the execution of (CPUSTRES-workload) in the following figures when the CPU utilisation and the energy consumption are relatively high.

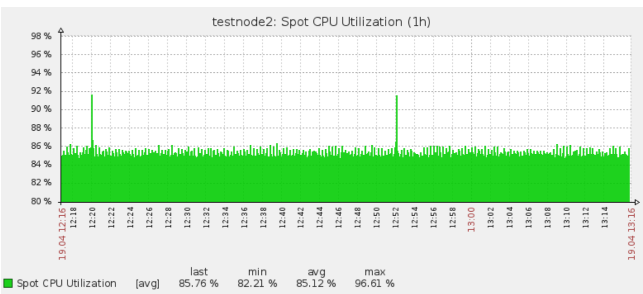

Figure 1: CPU Utilisation.

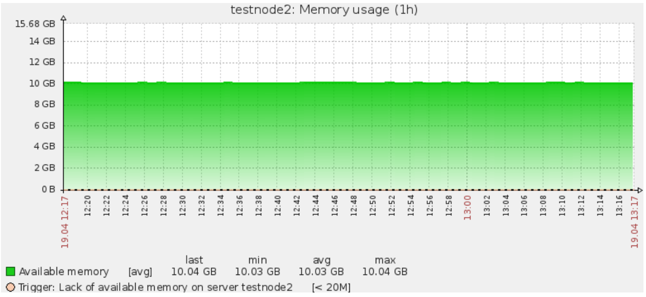

Figure 2: RAM Utilisation.

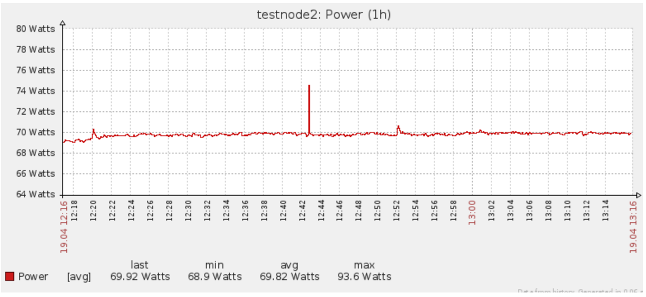

Figure 3: Power Consumption.

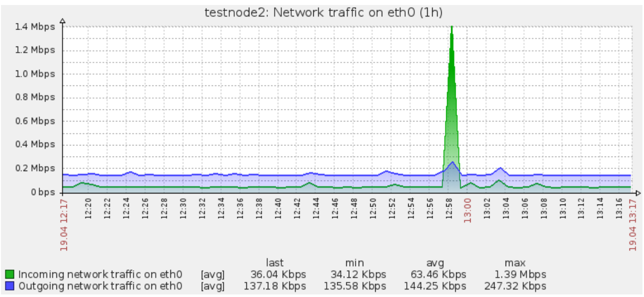

Figure 4: Network Utilisation.

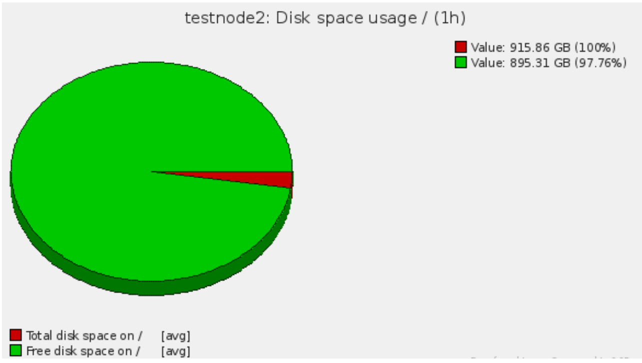

Figure 5: Disk Utilisation.

5 Results and Discussion

As shown in Figures.1-5 during the execution of (CPUSTRES-workload) the CPU utilisation and the energy consumption are relatively high. However, under a high workload, the implementation of the Energy-Aware Pricing Model shows a significant reduction in the total cost and energy consumption as compared to the current pricing models. We did the experiments with 4 Small-VMs using the (HeavyLoad-workload), (CPUSTRES-workload) and (Pi Java Program-workload), the results showed the same influence on the resource usage and the energy consumption. We compared Rackspace versus Energy-Aware Pricing Model based on a one-hour time frame. In Rackspace and Amazon EC2 assumed average resource utilization is 100%, which is not realistic. Moreover, in Amazon EC2 the smallest pricing time unit for instance is one hour [22]. In this case, if the customers run their applications for 20 minutes, they will have to pay for the full hour cost [10]. Additionally, the customers could not be scaling up/down the VMs in terms of CPU and RAM. For instance, the customers need to purchase the closest instance type of the VM. If the VM capacity is greater than the application requirement then the resources will be wasted and customer will pay more without any benefit. On that other hand, if the VM capacity is less, then the performance might degrade. However, the Energy-Aware Pricing Model when a server is started the customer is only charged based on the actual resource usage by taking into account the energy consumption; that showed a significant reduction of total cost and energy consumption compared to Rackspace pricing models.

Comparison of Utilisation and Cost		
4 Small-VMs	Energy-Aware Pricing Mode	Rackspace Pricing Model
vCPU	6.81GHz	8GHz
vRAM	4.67GB	8GB
HDD	20.5GB	160GB
Network	1MB	1600MB
Energy Consumption	0.069kWh	0.075kWh
Hourly Cost	£0.116	£0.316

Table 3: Energy-Aware Pricing Model vs. Rackspace pricing model based on resource utilisation and cost per hour (CPUSTRES-workload).

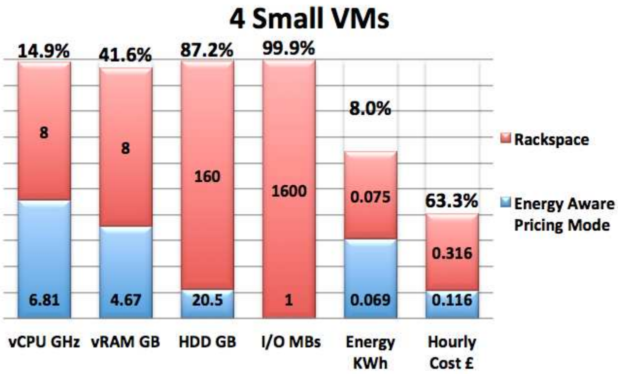

Figure 6: Rockspace versus Energy-Aware Pricing model based on percentage (CPUSTRES-workload).

The result of the experiments showed that the implementation of Energy-Aware Pricing Model achieve up to 63.3% reduction of total cost and 8.0% reduction of energy consumption as compared to the Rackspace pricing model as shown in Figure 6. Therefore, the Energy-Aware Pricing Model offers a cost benefit for the customers based on their resource and energy usage as shown in Tables 3. Thus, both the providers and the customers will get benefits. Providers will get cost benefit when more customers decide to move into the cloud, and will gain more revenue by applying Energy-Aware Pricing Model to attract more customers. On the other hand, customers will get cost benefit in the Energy-Aware Pricing Model due to the reduction of resource usage wasted and energy consumption.

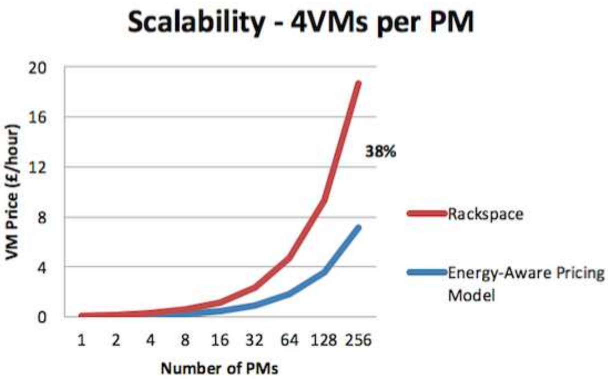

Figure 7: Comparison of total price in terms of scalability.

In terms of scalability, we assume if we have 1024 homogeneous VMs running the same workload on 256 PMs. As shown in Figure 7 the result of the experiments showed that the implementation of Energy-Aware Pricing Model achieves up to 38% reduction of total cost as compared to the Rackspace pricing model.

6 Future Work

We will evaluate the Energy-Aware Pricing Model under various assumptions and scenarios, including different applications, e.g. data/compute intensive applications (e.g. Hadoop and MPI), and in terms of scalability (number of VMs and Physical Hosts). Further, we will investigate dynamic pricing models that adapts performance variations (degradation/improvement) faced by customers at service operation. Their impact on energy consumption and cost will be addressed. Additionally, we will propose novel Energy-Aware Pricing Prediction Model that would predict the workload by estimating the resource usage, power consumption and total cost for VMs using appropriate algorithms and mathematical modelling based on historical and current data.

7 Conclusions

In this paper, we proposed novel Energy-Aware Pricing Model that considers energy consumption as a key parameter with respect to performance and cost. The proposed model charge the customer based on the actual resource usage, such as (CPU, RAM, Network and Disk) by taking into account the energy consumption. Moreover, we presented an early investigation on how the adoption of Energy-Aware Pricing Model influences on the energy consumption and total cost, in order to identify the competitive pricing models from the providers perspective.

References

[1] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, *Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility,* Futur. Gener. Comput. Syst., vol. 25, pp. 599616, 2009.

[2] Jelastic, 2016. *Dynamic Pricing: How Jelastic Beats Amazon Every Time,* [Online]. Available: http://blog.jelastic.com/2014/06/03/fair-pricing-model- jelastic-vs-amazon/. [Accessed: 04-Jan-2016].

[3] P. Berndt and A. Maier, *Towards Sustainable IaaS Pricing,* in Economics of Grids, Clouds, Systems, and Services SE - 13, vol. 8193, J. Altmann, K. Vanmechelen, and O. Rana, Eds. Springer International Publishing, 2013, pp. 173184.

[4] K. Brill, *Understanding The True Cost Of Operating A Server,* facilitiesnet, November, 2008.

[5] Amazon Web Services, 2016. *Amazon EC2 Spot Instances,* [Online]. Available: http://aws.amazon.com/ec2/spot/. [Accessed: 04-Jan-2016].

[6] S. Kansal, G. Singh, H. Kumar, and S. Kaushal, *Pricing Models in Cloud Computing,* in Proceedings of the 2014 International Conference on Information and Communication Technology for Competitive Strategies - ICTCS 14, 2014, pp. 15.

[7] H. Wang, Q. Jing, R. Chen, and B. He, *Distributed systems meet economics: pricing in the cloud,* in Hot topics in cloud computing, 2010, pp. 612.

[8] Z. Li, J. Ge, H. Hu, W. Song, H. Hu, and B. Luo, *Cost and Energy Aware Scheduling Algorithm for Scientific Workflows with Deadline Constraint in Clouds,* IEEE Trans. Serv. Comput., vol. 1374, no. c, pp. 11, 2015.

[9] S. Zhang, Y. Liu, B. Wang, and R. Zhang, *A Novel Resource Allocation Algorithm for a Heterogeneous Data Center,* International Conference on Information Science and Applications (ICISA), 2013, pp. 14.

[10] H. Jin, X. Wang, S. Wu, S. Di, and X. Shi, *Towards optimized fine-grained pricing of IaaS cloud platform,* IEEE Trans. Cloud Comput., vol. 3, no. 4, pp. 436448, 2015.

[11] Electricity Price *Electricity Price per kWh Comparison of Big Six Energy Companies — CompareMySolar.co.uk Blog.* [Online]. Available: http://blog.comparemysolar.co.uk/electricity- price-per-kwh-comparison-of-big-six-energy-companies/. [Accessed: 31-Mar-2016].

[12] A. Narayan and S. Rao, *Power-Aware Cloud Metering,* IEEE Transactions on Services Computing, vol. 7, no. 3, pp. 440-451, 2014.

[13] A. Qureshi, R. Weber, H. Balakrishnan, J. Guttag, and B. Maggs, *Cutting the Electric Bill for Internet-Scale Systems,* SIGCOMM Comput. Commun. Rev., vol. 39, no. 4, pp. 123-134, Aug. 2009.

[14] Rackspace, *Cloud Servers Pricing and Cloud Server Costs,* [Online]. Available: http://www.rackspace.co.uk/cloud/servers/pricing. [Accessed: 17-Apr-2016].

[15] R. Kavanagh, D. Armstrong, and K. Djemame, *Towards an Energy-Aware Cloud Architecture for Smart Grids,* 12th Int. Conf. Econ. Grids, Clouds, Syst. Serv, pp. 114, 2015.

[16] Amazon Web Services, 2015 *TCO Calculator,* [Online]. Available: https://awstcocalculator.com/. [Accessed: 15-Feb- 2016].

[17] Amazon Web Services, 2016 *EC2 Instance Pricing Amazon Web Services (AWS),* [Online]. Available: http://aws.amazon.com/ec2/pricing/. [Accessed: 15-Feb- 2016].

[18] Microsoft Azure,, 2016 *Pricing - Virtual Machines (VMs) — Microsoft Azure,* [Online]. Available: https://azure.microsoft.com/en-us/pricing/details/virtual- machines/. [Accessed: 15-Feb-2016].

[19] OpenNebula.org, 2016 *Sunstone Cloud Testbed,* [Online]. Available: http://opennebula.org/. [Accessed: 20-Jan-2016].

[20] Zabbix, 2016 *Zabbix - Enterprise Class Network Monitoring Platform,* [Online]. Available: http://www.zabbix.com/. [Accessed: 15-Feb-2016].

[21] Elastichosts, 2016 *Pricing — ElasticHosts Linux, Windows VPS Hosting,* [Online]. Available: https://www.elastichosts.co.uk/pricing/. [Accessed: 16-Feb- 2016].

[22] Amazon Web Services, 2015 *Amazon EC2 Pricing,* [Online]. Available: http://aws.amazon.com/ec2/pricing/. [Accessed: 29-Nov-2015].