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Cost Modelling of Cloud Computing

Raktim Deb*
Dept Computer Science
NERIM, Guwahati, India

Purnendu Acharjee, Akalpita Das, Laba Thakuria
Dept Instrumentation & USIC
Gauhati University, India

Abstract— Business model is relatively young topic in computing world and recently it has turned out as a very popular topic for research in academic or any research industry. Business model is a topmost and conceptual layer in the stack architecture of cloud computing [2] which represents a simplified description of what value is provided to customer and how it is implemented. The purpose of this model is to give a brief idea about financial capital requirements and describes the way to enhance the business.

Keywords— Total Cost of Ownership, Cost of Cloud, Power Usage Efficiency (PUE) or Capacity Utilization, Server Cost, Software Cost, Power Cost, Cooling Cost, Network Cost, Support and Maintenance Cost, Facilities Cost, Real-Estate Cost, Cost of IAAS Cloud.

I. INTRODUCTION

Based on stack architecture of cloud computing we proposed layered architecture of cloud computing, given in figure 1. This layered architecture provides an idea about abstractions of service layers that exists in Cloud technology. Our study suggests that the core of this architecture represents cloud infrastructure from which resources are pooled and then produced to different layer. as a component of services. This architecture is based on assumption that each layer maintains the hierarchy of providing service component to its upper layer. The solid arrow shows that the cloud infrastructure is a key resource to build IASS layer. Using IASS layer instances PAAS can be build and similarly by using PAAS layered instances SAAS layer can be build. It shows that cloud infrastructure is the key layer to build any kind of service layer. Cloud infrastructure is very much similar to datacenter architecture but it differs from that in utilizing the virtualization technology and ability to serve its computing power on demand[3].

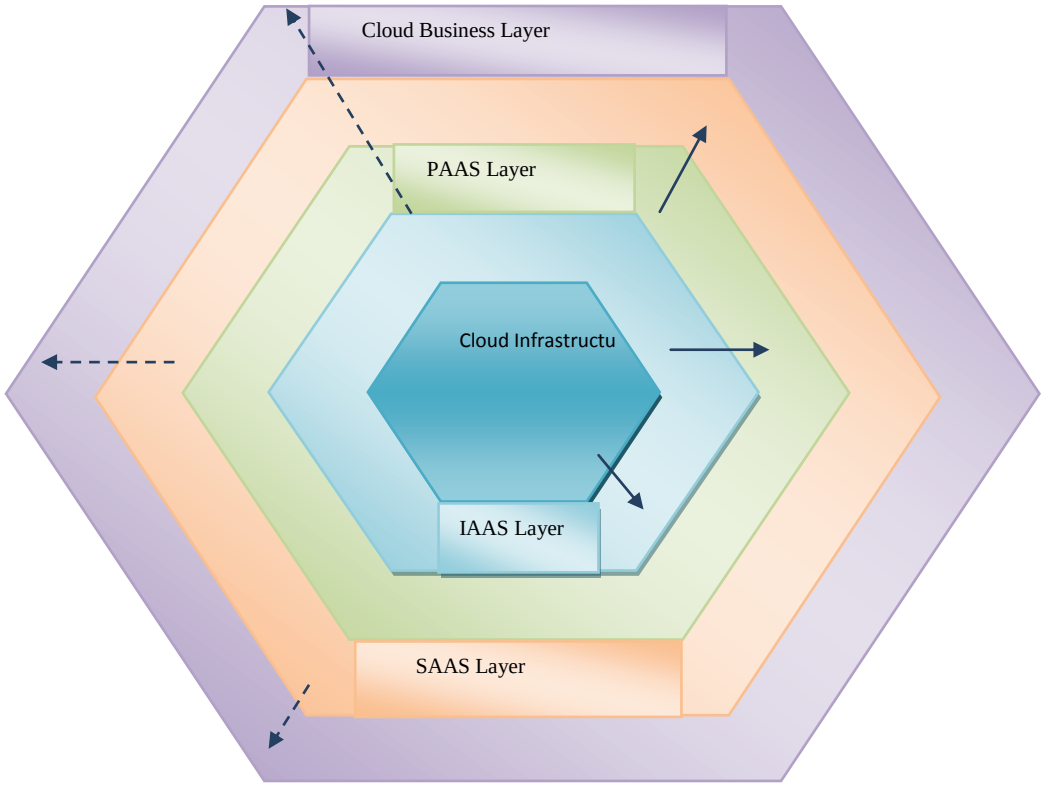


Figure 1 Layered architecture of Cloud

A business layer is the topmost layer of layered architecture. It is not necessary that the business layer should come after the SAAS layer. Depending on service provider, business model can be derived. The dotted arrows given in the figure 1 depicts that a business layer can be derived from any layer of this architecture. The layered architecture given in figure 1 is based on stack architecture of cloud computing [2]. Findings of our study suggests that core of the architecture represents cloud infrastructure from which resources are pooled and then produced in different layers for services. Key things like datacenter servers and software are also main components of cloud infrastructure. Usable capacity in traditional datacenter is generally 60-80% of the install capacity [1]. Server utilization is a key factor to improve the cost efficiency from producer point of view. By adapting virtualization technique cloud infrastructure can able to improve utilization rate up to 1 and make itself cost effective. Virtualization is the technique which allows portioning of physical resources into a virtualized container popularly known as virtual machine or virtual hardware [3]. This virtual hardware's are capable to provide any kind of services or host any kind of application that a typical server can provide. Using virtual hardware multiple applications can be hosted in the same server which allows distributing the different workloads in small servers.

This architecture is a hierarchical model so that modular service can be build on top of other services. As stated earlier cloud architecture contains component like traditional datacenter in its core, our assumption for the given model is that: A cloud service provider (any type of services) can have a single infrastructure which is pooled and sells its capacity to its upper layer of service as describe in figure 2. On top of infrastructure cloud provider creates virtual infrastructure or virtual computing resources which is popularly known as virtual density or virtual machine. The VM's can be made to perform effectively on a hypervisor without any disruptive performances [5]. The VM density determines the total physical equipment, software licensing, and infrastructure management needed for a virtual infrastructure. VM density is termed as instances of IAAS layer and sells those capacities to its upper platform layer and so platform layer to its upper layer.

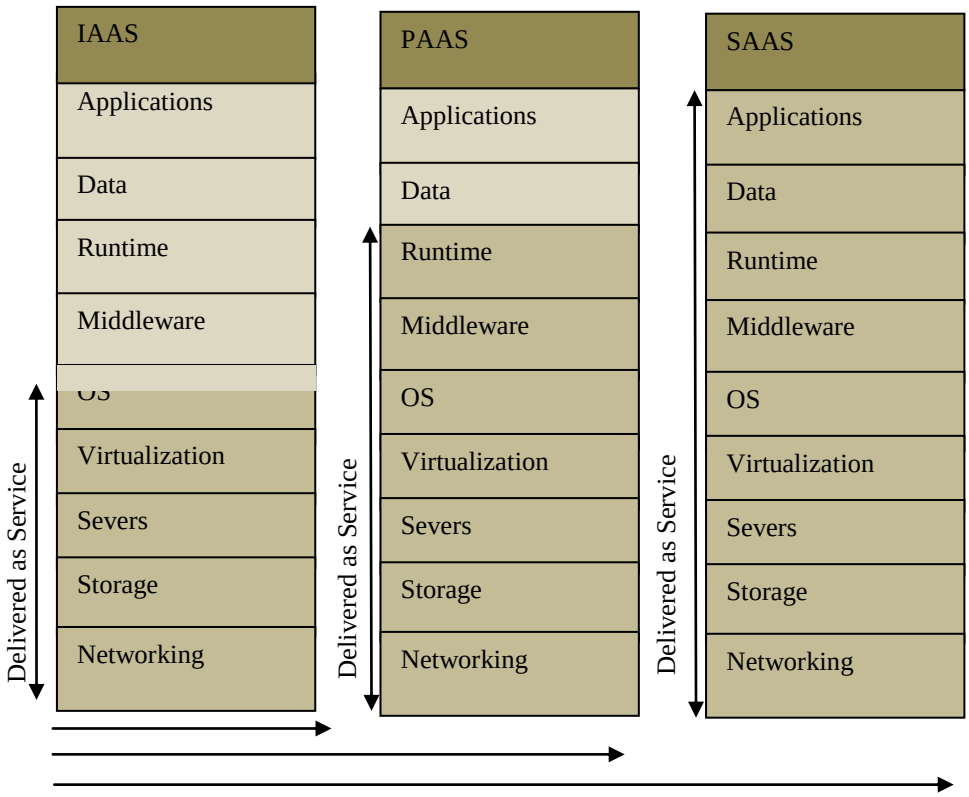


Figure 3 Cloud Delivery Model

Figure 3 shows those resources which are provided by different service providers [4]. Each computing resource which is created to provide as a service, are known as instances of services. An IAAS instance has predefine resources like memory, processor storage and any other computing capacity. These instances cost as per uses made by consumer. For this architecture given in figure 2 we assume that immediate platform layer consumed services of IAAS layer and might have additional quality such as additional software, database etc. Finally end user service, so called SAAS is build on top of platform as services layer. There are possibilities that producer may sell infrastructure and platform layer instances directly to SAAS layer. Business layer is a conceptual layer and is derived at the top of any services, depending on level of services. For example if a producer is producing PAAS services than the business layer is derived above the PAAS services. The down arrows in figure 2, simply states that each layer can have a business layer in above of it to describe its business transaction to the commercial world. To make an easy depiction and easier calculation, we draw the business layer at the top most position. It is not necessary that business layer should come after SAAS layer. It comes only at the end point of our services.

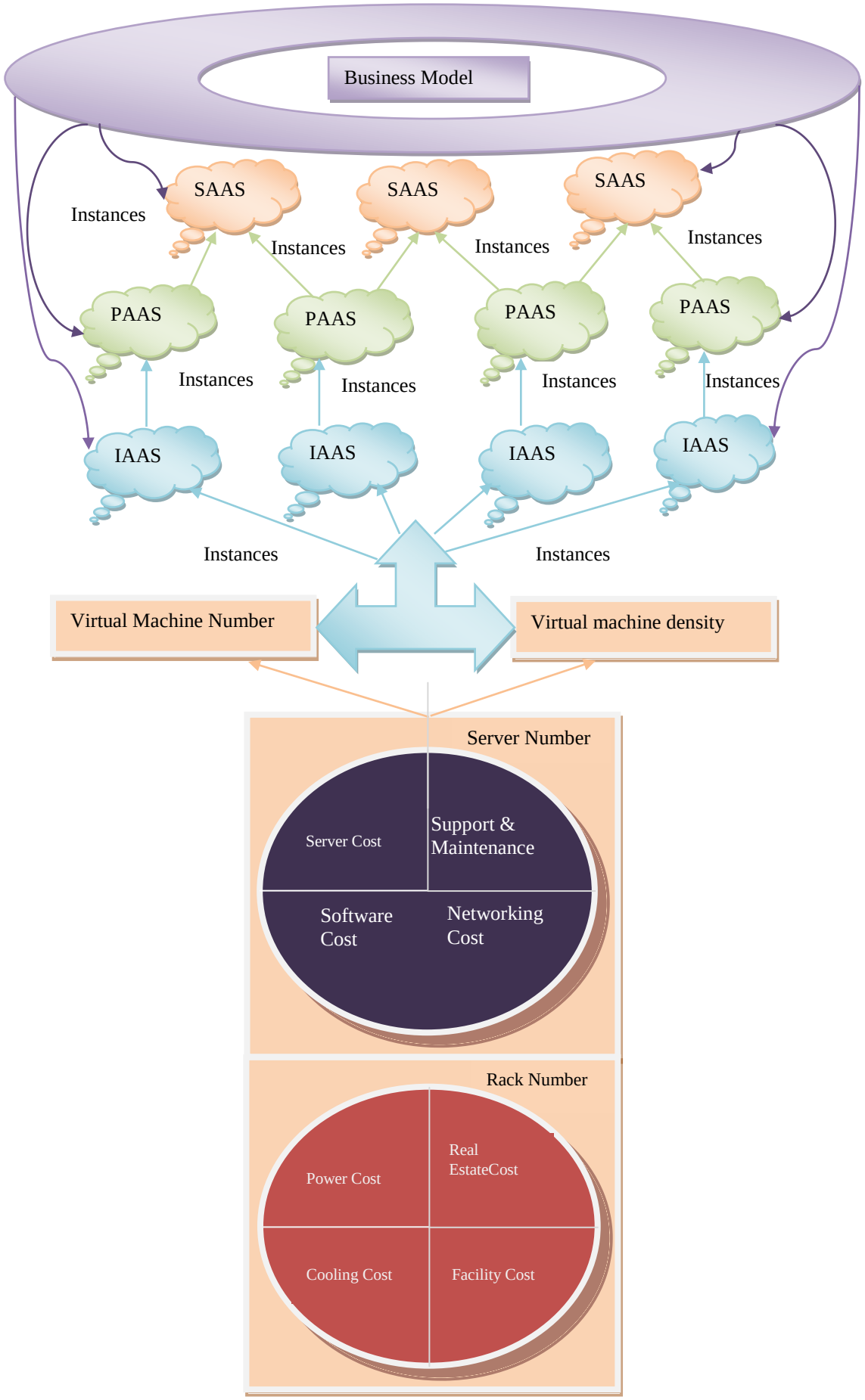
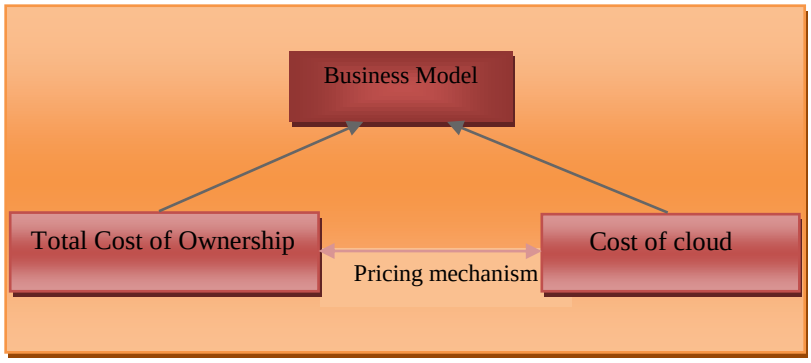


Figure 2 Stack Architecture of Cloud Computing

II. BUSINESS LAYER

A business model is considered as an important tool for commercial industry, for scale up business and financial needs. It is an important tool to compete in this highly competitive business world. Intention of this paper is to give a brief idea about this tool and enhance their business. There are so many papers regarding business model of cloud, but most of them describes the end point cost which is related to the cloud consumers only. The cost to build cloud or cost that deals with the producer point of view is still abstract and gives us a research filed. This paper gives step wise cost of build cloud delivery model as shown in figure 3. Cloud architecture must have a business model and for dynamicity in its service providing, business layer must be dynamic. Findings of our research study suggest that a business model is composed of two type of cost analysis: Namely "cloud investment cost or total cost of ownership" and cost of cloud. These two types of cost are related to each other using pricing mechanism. Our suggested business model is given in figure 4. This business model helps industry people to grow up commercially in this competitive business world.

A. Total cost of ownership



The total cost of ownership or the cloud investment cost is the total cost. of producer to make cloud services readily available for use. It includes infrastructure investment along with associated cost like maintenance, cooling's etc. This cost estimation is very important for the capital investment to establish business paradigm. One can justify such investment if he/she anticipates many potential cloud instances like IAAS instances, PAAS instances, SAAS instances.

B. Cost of cloud

The Cost of Cloud is the total cost to the utility components consumed by any customer of the cloud. This price comprises of adaption and searching of cloud utility components. Thus a consumer can identify a plausible level of consumable cost of the cloud instances. The cost of cloud is the basic unit of cloud instances consumed on behalf of consumer. Basic difference of these two types of cost is TCO which is used to evaluate the foundational cost or infrastructure cost during its whole life time but cost of cloud is the cost elastic resources or instances of cloud. The cost of cloud is determined by the pricing mechanism for which cloud gets proper return of investment with respect to TCO. Pay-as-you-go pricing mechanism is used by most of the cloud providers.

III. TCO OF IAAS CLOUD AND COST OF IAAS CLOUD

Traditionally in commercial places TCO means cost of attributing to owning and managing an IT infrastructure. TCO not only includes capital expenditure, but it includes operating expenditure too [7][9][12]. Like traditional datacenter, cloud infrastructure also include these fundamental cost, with describing capital expenditure as server cost, software cost, power cost, cooling cost, network cost, real estate cost and facilities cost, support and maintenance cost as operating expenditure. Since virtualization is greatly adapted in cloud it has great impact on all these cost mainly software cost, power and cooling cost. Cloud provider provide his resources as cloud instances with pay as you go business model, so it is important to estimate how all the cost metrics are distributed in cloud instances.

A. Server Cost

Like any other traditional datacenter, in cloud datacenter or cloud infrastructure servers are also mounted in racks. Resources are pooled from here and provided to consumer, while calculating TCO server essential cost component must come in to consideration. Server cost can be accounted by simple straight line depreciation model [6][10]. Using this simple accounting model, the depreciation of fully mounted industry servers racks can be determine as follows

$$\text{Cost of servers} = \frac{\text{Unit Cost of fully mounted}}{\text{Life time of servers}} \cdot \text{Number of servers mounted for resources pooling}$$

A server life time varies between 3 to 5 years. In a cloud environment, pay-as-you-go type of pricing is implemented, so computing component may be sold as hourly, weekly or monthly basis packages. For easy calculation we determine hourly basis plan. So, life time of a server can be determined as follows.

$$\text{Life time of server} = 30 \cdot 24 \cdot 7 \cdot \text{Numbers of years.}$$

1) *Server cost Distributed in IAAS instances:* Since for any cloud infrastructure, resources are pooled from here and creates instances for IAAS layer. Therefore server cost distributed in each instances of IAAS cloud is as follows

$$IAAS_{\text{server cost per instance}} = \frac{\text{Cost of}}{\text{Number of instances created without disrupting the performance of physical machine}}$$

B. Software Cost

Cloud Infrastructure is based on a key technology called virtualization which makes software cost estimations different from traditional datacenter. Cloud software costs are divided into two categories: First one, the software's that are installed in physical machines and second kind is software's that are installed in virtual machines. These two types of cost merge together to estimate the software cost and are determined as follows

$$\text{Cost of Software I} = \frac{\text{Total software licensing cost for Physical Machines}}{\text{Number of physical machine mounted}}$$

$$\text{Cost of Software II} = \frac{\text{Total software licensing cost for Virtual Machines}}{\text{Number of virtual machines created}}$$

1) *Software cost distributed in IAAS instances:* software cost type II is the direct cost for the virtual machines or IAAS instances but software cost type I is being distributed in IAAS instances as their number of count. So software cost in IAAS instances can be determined as follows

$$IAAS_{\text{software cost per instance}} = \frac{\text{Software cost I}}{\text{Number of instances created}} + \text{Software cost II.}$$

C. Power Cost

By Power cost we mean the cost associated with consistent power delivery system. Like any datacenter power delivery system cloud infrastructure also include battery-backups, conditioning, onsite power generation and redundancy in both delivery system and generation. To enable each of these functions amortization cost is also associated with these cost. Chanradkant D Patel and Amip J. Shah's research in HP laboratory describes that while calculating power cost of datacenter a burden cost must be considered and cost of power can be determine as

$$\text{Power cost of datacenter} = U_{\$,\text{ grid}} \cdot P_{\text{consumed hardware}} + k_1 . U_{\$,\text{ grid}} \cdot P_{\text{consumed hardware}} \quad \ldots\ldots\ldots\ldots 1$$

$$U_{\$,\text{ A\&M Power}} . J_1$$

Where K is the burden cost and describes as $k_1 = \frac{}{U_{\$,\text{ grid}}}$ and J_1 total power usage efficiency (PUE) or capacity utilization which and describes as

$$J_1 = \frac{\text{Total Facility Power}}{\text{IT equipment consumed power}}$$

In efficient datacenter power usage cost hardly varies 1.3 to 1.7 [6][8] . From L.A Barros and U. Hlze's term, energy proportionality of computing resources which describes server running at N% load can consume N% power [11]. And from our research study on Virtualization, VM'S can increase resources utilization approximately to 100 %. From these two conditions we can conclude that in cloud environment total facility of power (P_{rated}) is equal to the IT equipment consumed power. Now, we reconsider the power cost for cloud environment as follows:

$$J_1 = \frac{\text{Total Facility Power}}{\text{IT equipment consumed power}} = 1 \text{ and}$$

$$k_1 = \frac{U_{\$,\text{ A\&M Power}} . J_1}{U_{\$,\text{ grid}}} = 1, \text{ as } J_1 = 1 \text{ determine in previous equation and}$$

unit cost of power consumed from grid $U_{\$,\text{ grid}}$ and unit cost amortization and maintenance are approximately equal ($U_{\$,\text{ grid}} \sim U_{\$,\text{ A\&M Power}}$) . This means in cloud no burden factor comes in consideration. So the power cost of the cloud infrastructure can be determined as follows:

$$\text{Power cost of cloud infrastructure} = 2. U_{\$,\text{ grid}} \cdot P_{\text{rated}}$$

P_{rate} using equation 1 and P_{rated} and P_{consumed} is equal in cloud environment.

1) *Power cost distributed in IAAS instances:* Since for any cloud infrastructure, resources are pooled from here and creates instances for IAAS layer. Therefore power cost distributed in each instances of IAAS cloud is as follows

$$IAAS_{\text{power cost per instace}} = \frac{\text{Power cost of cloud infrastructure}}{\text{Number of instances created}}$$

D. Cooling Cost

Cooling resources of datacentre is also consumed power. So amortization and maintenances cost is also added as a burdening cost of cooling equipment. It is argued that consumed power of datacenter hardware is transformed into heat. Therefore a load balancing factor is introduced while calculating of cooling cost. Power required for cooling equipments is directly proportional to power consumed by hardware. Therefore, $P_{cooling} = L. P_{consumed}$. And the cost of cooling of any datacenter can be determined as follows

$$Cost_{cooling} = (1+ k_2)\, U_{\$,grid} . P_{cooling}$$
$$= (1+ k_2) .L. U_{\$,grid} . P_{consumed}$$

As seen in earlier section, the PUE factor (value is equals 1) always exists in cloud. Based on research study, unit amortization and maintenance cost for cooling infrastructure is half of power amortization and maintenance unit cost. The burdening factor of cooling's can be determine as

$$K_2 = \frac{U_{\$,\text{ A\&M cooling}} . J_1}{U_{\$,\text{ grid}}} \qquad \frac{(0.5) . U_{\$,\text{ A\&M Power}} . 1}{U_{\$,\text{ A\&M Power}}} \qquad [\text{as } U_{\$,\text{ grid}} \sim U_{\$,\text{ A\&M Power}}]$$
$$= 0.5$$

Therefore cost cooling in cloud infrastructure is determine as

Cooling Cost of Cloud infrastructure = $(1.5) . L . P_{rated}$, [As $P_{consumed} = P_{rated}$]

1) *Power cost distributed in IAAS instances:* Since for any cloud infrastructure, resources are pooled from here and creates instances for IAAS layer. Therefore cooling cost distributed in each instances of IAAS cloud can be calculated as follows

$$IAAS_{\text{cooling cost per instace}} = \frac{\text{Cooling cost of cloud infrastructure}}{\text{Number of instances created}}$$

E. Network cost

Cost of networking mainly deals with routers, switches, NIC, load balancer etc which are attached with computing hardware's. These components have certain life time so using simple straight depreciation model we can calculate the networking cost as follows.

$$\text{Cost of networking} = \frac{\text{Unit cost of network component}}{\text{Life of network component}} \text{ . Number of Component installed}$$

1) *Network cost distributed in IAAS Instances:* Optimizing the uses of network component is to partitioning their functionality and their state in the infrastructure. With creation of instances, latency of response is reduced in cloud environment. So, this much of cost can be distributed in instances of IAAS cloud which could be estimated simply by dividing cost of networking to number of created instances.

$$IAAS_{\text{server cost per instance}} = \frac{\text{Cost of networking}}{\text{Number of instances created without disrupting the performance of physical machine}}$$

F. Support and Maintenance cost

Support and maintenance cost mainly deals with the human resources uses in administrative purpose like software updating or upgrading, troubleshooting etc. This cost can be determined using straight line depreciation model with inflation rate. Suppose C_r is the salary of a person in the first year and inflation rate F per year. The person is assigned for the administrative job for N years. So support and maintenance cost for a person can be determined as

$$\text{Support and maintenance cost } (C_{sm}) = C_r . \{ 1 + \frac{1}{(1 + F)^N} \} \text{ [cost for N years per person]}$$

1) *Support and maintenance cost distributed in IAAS instance:* This type of cost comes under operating expenditure and it varies according to its inflation rate. To determine how this type of cost is distributed in IAAS instances we first need to determine present value of this cost and then divide that by number of instances of cloud. Therefore,

$$\text{Present value of support and maintenance cost} = C_{sm} . \{ \frac{\quad}{1 - (\ F^{\ N}} \}$$

$$IAAS_{\text{S \& M cost per instance}} = \frac{\text{Present value of support and maintenance cost}}{\text{Number of instances created without disrupting the performance of physical machine}}$$

G. Real-Estate cost

Like other datacenter cloud infrastructure also have real estate value. The total property value of a cloud may be the area necessary for plant chillers, power and cooling delivery system and other auxiliary system. We get the total space of a cloud infrastructure according to the computing equipment and its subordinate equipment occupies the space. So real-estate value of cloud infrastructure can be determined simply by using the formula described by Chandrakant D. Patel, Amip J. Shah in his paper [6] as follows

$$\text{Cost of Real-Estate} = \frac{(\text{NOI}/\text{ft}^2) \,.\, (A_{\text{cloud infrastructure}}) \,.\, (\%\ \text{Occupacy})}{\text{Cap Rate}}$$

While calculating distribution of this cost in IAAS cloud we just divide this cost with the number of instances.
All the major cost associated with cloud infrastructure and its evaluation policies is discussed above. To determine the TCO of IAAS cloud we need to simply add those values and for determining investment per instances we need to add all instances cost evaluated in above calculation. For hourly investment in IAAS Cloud instances.

$$\text{TCO of IAAS Cloud instances/ hour} = \frac{\text{Total investment of IAAS cloud}}{365 \,.\, 7 \,.\, 24. \text{ Number of instances}}$$

IV. COST OF IAAS CLOUD

Cost of IAAS cloud is the amount of market price of an instance per hour or per week or per year according pricing mechanism running on the cloud. The cost of IAAS cloud gives proper ROI to cloud provider with respect to their TCO. One should remember that cost of cloud must be greater than investment per instances (cost of IAAS cloud > TCO of IAAS instances). So, Net income of the IAAS provider can be calculated as Net Income of IAAS provider = (cost of cloud per instances – TCO of IAAS instances) . number of instances used . number of time

V. CONCLUSIONS

The basic definition of cost estimation of cloud computing environment is provided here to make industry people aware about investments in each phase of development. All these cost estimations made here are fully based on layred architecture; it may vary with different architecture and the topology of internal infrastructure. From the cloud provider point of view, the construction of very large datacenters at low cost sites using commodity computing, data storage, networking and then the possibility of selling those resources on a pay-as-you-go model well below the costs of many medium-sized datacenters while making a profit by statistically multiplexing among a large group of customers.

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