# *An Empirical Investigation of Cost-Resource Optimization for running Real-Life Applications in Open Source Cloud*

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*Abstract* — **Open source cloud technology can optimally increase resource utilization and reduce costs in many organizations to support and execute their applications. The extent to which cloud can reduce memory wastage and save costs is an important issue of research. This paper aims to address this issue through the evaluation of an organization's cost-resource benefits by executing real life applications on open source private cloud platform and evaluating the empirical data. The variability in performance of the cloud and traditional systems is shown by defining metrics and provisioning inputs to obtain results. Through the experimentation, memory utilization is seen to increase by 22.16% in the cloud. Direct-indirect cost savings sum up to 40%. The cloud features playing key role to this improved cost-resource performance are revealed.**

***Keywords-cloud computing and architectures; clouds applications; resource allocation, sharing and management***

## I. INTRODUCTION

Today, the computing resources of many organizations can be managed in cloud environment at reduced costs. Despite the significant and technological benefits, little research has been done to show the performance on the on the basis of concrete data [1] since most researches are based on assumed data. The fact is more prevalent for executing real life applications in open source cloud platform.

In this paper we compare and contrast the cost-resource performance of running five real life applications on the cloud to traditional systems. Empirical experiments are carried out to answer the following questions:

- What is the difference in resource utilization between open source cloud computing and existing systems?
- What are the direct-indirect monetary cost advantages for running real life applications in open source cloud?
- What are the cloud features that cause this difference in performance?

Performance in terms of CPU and memory utilization is already identified for commercial cloud services [2]. While considering the processing power, I/O operations, memory and network as bottlenecks, the processor performance for executing heterogeneous and complex scientific calculations is identified [3]. The bottlenecks have been selected based on their impact on cloud processing capability. Dynamic resource allocation is another way to ensure effective resource allocation in the cloud. A Virtualized multi-tier Application Execution Environment (VAEE) is proposed that can support Virtual Machines (VM) running in parallel [4]. This ensures simultaneous execution of multiple virtual machines from a single physical machine. However, the limitation of this work was to use limited empirical data to show the increased utilization of resources. Pricing strategies are found to reduce capital expenditure in cloud, for example, reduced maintenance cost of proprietary cloud services like Amazon Elastic Cloud Compute and Microsoft Azure are illustrated in their pricing strategies [5]. Similar analyses for open source cloud computing are necessary to expedite the power of open source cloud applications.

In this research, an exhaustive investigation is done to show the ability of cloud to optimize the cost-resource benefits in an open source platform. The analysis is conducted in two folds. Most common and widely used real life scenarios were generated by using five real life services namely Database, Short Message Transmission Protocol (SMTP), MAIL, File Transfer Protocol (FTP) and Domain Name Services (DNS). In the first phase those services were run on separate traditional servers and in the second phase, same services were run on the cloud for comparison. Here memory resources were allocated dynamically according to the requirements of the services. Data constituting of resource allocation and cost comparison were obtained for both phases of the experiment.

The metrics identified for cost performance analysis are Resource Utilization (RU), Resource Wastage (RW) and Direct-Indirect costs (DC and IC). Results show that resource utilization increases while cost decreases by 22.16% and 40% respectively when the applications were executed in cloud. This is because, cloud can accommodate multiple services in the same machine, contrasting to the traditional systems.

## II. RELATED WORK

This section focuses on recent researches that are conducted for performance analysis of cloud computing environment in terms of cost and memory utilization. Comparison of performance between cloud computing and existing systems is an area of keen research interest. Organizations are shifting towards cloud for resource management, hence open source cloud technology is a key component in today's cloud environment [6].

A resource effective mechanism for memory selection in cloud is proposed to reduce memory wastage. Transparency algorithm has been implemented to make resources from different physical machines appear as one to the end user [7]. At the same time, virtualization technology is used to provide these resources as services. Results of the experiment do not identify the proportion to which the proposed transparency mechanism increases resource utilization or reduces resource wastage.

Costs of proprietary cloud services are important to identify cost factors. Performance of four commercial cloud service providers has been analyzed in [2]. In this case, the performance metric is the CPU utilization for running data intensive scientific applications. CPU, Memory and Application are the controls for allocation of virtual machines in [3]. For implementation, Xen environment is used to run Apache web server to support the web-based applications. The virtual machines are capable of handling load fluctuations. Direct-indirect cost of memory allocation is not considered.

Memory utilization in a virtual environment is another important aspect of cloud computing service. Intelligent resource utilization of the cloud architecture is proposed to reduce energy consumption [8]. A large task is consolidated into a number of small homogeneous tasks which are assigned to a single processor. In this methodology, the processing power and energy consumption can be effectively calculated. Virtual machines in cloud can be launched in batches for similar tasks. The analyses in [9] are based on launching multiple virtual machines at once. Implicit allocation ensured that all the virtual machines have equal memory and processing power. Memory is statically allocated to a group of virtual machines. The benefits of explicit memory allocation for each virtual machine according to the customer requirements have not been identified.

High scale data centers provide cloud services at reduced expenses. Cost effectiveness of cloud architecture is estimated for large scale cloud data centre [10]. The authors have analyzed the billing system of AWS and derived the cost of 300 and 500 servers on a daily basis. At the same time, the cost of procuring the equal number of servers is calculated. This is done to evaluate and differentiate the current market and the difference has been evaluated. The research does not analyze the cost effectiveness at a finer detail in terms of hardware, space and power consumption.

Cost benefits of cloud computing over traditional systems are important to analyze cost differences. Costs of taking cloud service of 100 servers for a period of 3 years have been estimated by procuring the servers using traditional techniques [3]. Dynamic technique for resource allocation has been proposed in [4]. Simulation has been used to develop a three tier system in virtual environment that supports multiple workloads according to demand. Models used for resource allocation are M/M/c and M/M/1. Both researches are based on simulated cloud environment and real life application of cloud computing is not carried out.

Ideal metrics for measuring the performance of using open source cloud architecture to run standard applications needs to be identified. The authors in [11], provided the methodology of analyzing cloud performance using availability, criticality of test cases and data security. The importance of cloud standards have been stated in [12]. The paper identified certain advantages of cloud computing technology in terms of power efficiency and the deployment of virtual machines. The authors have based their work on estimated values and did not provide empirical data about the extent to which these features make the cloud a better solution over existing systems.

Resource utilization of commercial Amazon Web Services (AWS) is stated in the AWS whitepaper [4] and pricing strategy of Amazon Elastic Cloud Compute (EC2) has been provided in [6]. Tools are used to analyze the economic advantage of proprietary cloud services to desktop grids [2]. The researchers in [13] have improved [14] with the respect that they have analyzed the efficiency of data migration from one provider to another. Multiple cloud provider services are taken and certain data are transferred from one provider to another and the cost-performance is evaluated. The authors do not mention the use of open source cloud architecture to establish on the premises private cloud and thereby reduce computing costs.

The challenges to successful cloud implementation are necessary to identify the areas where additional work needs to be done. The challenges faced by proprietary cloud computing services in the banking sectors have been specified in [3]. Service Level Agreements (SLA) of proprietary cloud services have been used to identify security and data migration as key challenges for successful use of cloud computing technology. Deployments of open source cloud architecture to mitigate these challenges are yet to be defined.

As seen above, the importance of analyzing cost-resource performance of open source cloud computing is profound. Empirical data needs to be collected to analyze the performance of cloud to support real life applications.

## III. PROPOSED METHODOLOGY TO ANALYSE COST-RESOURCE PERFORMANCE

The methodologies of the experiment and result evaluation are discussed in this section. As stated earlier, the cost-resource performance analysis of open source cloud computing is significantly important. At the same time, little

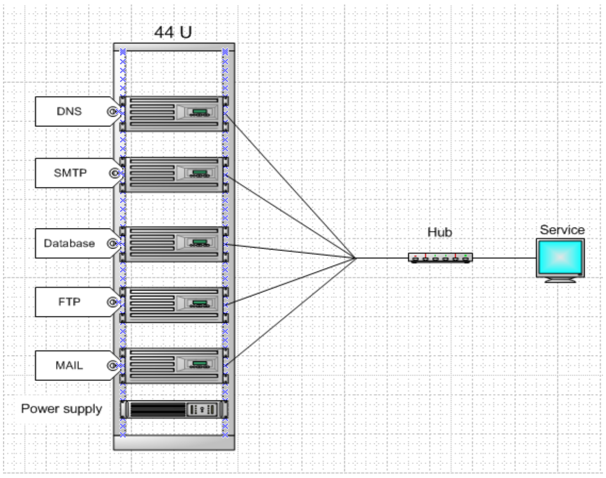


Figure 1. Architecture of the traditional system

work has been done in this regard. Hence the cost-resource performance comparison between cloud environment and existing systems is analyzed.

The experiments are based on five services mentioned earlier that must be running simultaneously. First, the tests are performed in traditional architecture. Next, identical tests are executed on the cloud architecture. The traditional infrastructure involves physical servers, each having a Random Access Memory (RAM) of 2 Gigabyte (GB).

The machines are single core where virtualization environment was not established. As a result two processes cannot be executed simultaneously in one machine of the traditional architecture. Since existing systems do not support running multiple services at once in the same server, to run the five services all at once, five separate physical machines were used [13]. Since each server has a RAM of 2 GB, so a combined RAM of 10 GB is involved to run the five services. After the services are implemented in traditional infrastructure, the resources utilized by each concerned process are identified. Resource consumption of the system was considered negligible. The resources utilized by a service for a fixed time period are tabulated.

The cloud setup for this research includes a master machine with two nodes. Hence only three servers are involved in the second phase. Each node has 2 GB RAM, so a combined 4 GB resource is available for use. In the next phase the same machines are implemented in cloud instances and the resource utilization and wastage in both cases are analyzed. The master machine is connected to the nodes via the hub. Open source Kernel Virtual Machine (KVM) hypervisor was implemented on the nodes and hence virtualization environment was established [11]. So the virtual machines are designed according to the variable needs of the instances. In both the nodes combined, 30 instances of 100 MB, 14 instances of 200 MB and 7 instances of 1GB RAM space can be launched. Figure 2 gives a visual of the system under consideration.

Since the services are memory intensive, the resources taken under consideration are Random Access Memory [2]. The concerned resources are identical in each of the physical servers. Processor utilization has not been considered a bottleneck because each machine hosted only one application in the traditional systems, and each virtual machine hosted one service in case of cloud infrastructure.

### *A. Metrics to calculate memory resource utilization*

Resource utilization can be achieved in cloud computing by intelligent management. Here empirical data have been analyzed and it has been deduced how cloud can be a suitable solution to increase resource utilization and reduce wastage. The percentage of Resource Utilization (RU) is derived by the formula below.

$$\text{Percentage of RU} = ((UR) \div TR)*100 \quad (1)$$

Percentage of Resource Wasted (RW) can be calculated as,

$$\text{Percentage of RW} = ((TR-UR) \div TR) * 100 \quad (2)$$

Where, TR = Total Resource
UR = Used Resource
RU = Resource Utilization
RW = Resource Wasted

The above formulae can effectively derive the comparison on the amount of resource used by the system and amount of resource that are wasted. In traditional systems, the percentage of memory resource utilization for running the five services is found to be 34.74%.

In phase 2, two nodes have a combined capacity of 4 GB RAM. Considering 100 MB for internal processes of each node, 4.8 GB RAM is available for resource provision. The following table shows the data collected from the second phase. It is seen that in cloud environment, 56.90% of the memory resources are utilized which is 22.16% greater utilization compared to traditional infrastructure.

### *B. Metrics to calculate cost difference*

The fact is determined that both direct and indirect costs can be minimized by proper utilization of resources [4]. The difference in costing between cloud and on-the-premises architecture is shown by the two phases carried out in the experiment. The measurement tools are the direct and indirect costs (DC and IC). DC consists of two areas:

a. Hardware Cost (HC)

b. Power Cost (PC)

The HC is calculated by addition of the cost of servers. Additional cost of wiring is considered negligible. The PC is calculated with the following formula:

$$PC = N * Cp * X \quad (3)$$

Where, PC = Power Cost
N = Total number of Servers
Cp = Cost of unit power
X = Power consumed by each machine

IC consists of one area:

a. Space Cost (SC)

The formula for SC is proposed below:

SC = N * SQS * SQC (4)

Where, SC = Space Cost

N = Total Number of Servers

SQR = Square feet for one Server

SQC = Cost per Square feet

Factors such as system maintenance cost have not been considered for the sake of simplicity.

In this section the cost of the system where five services are implemented on individual machines. The data obtained are tabulated below:

Hence, DC = ∑HCServerName + ∑PCServerName

And, IC = ∑SCServerName

Hence TC = DC + IC (5)

Considering same cost for each HC, it is found,

∑HCServerName = 5HC

∑PCServerName = 5PC

∑SCServerName = 5SC,

When the entire system is implemented in cloud instances, only two servers are needed. Here the indirect and direct costs of running the services on the cloud have been evaluated. Considering same cost for each HC, it is found,

∑HCServerName = 3HC

∑PCServerName = 3PC

∑SCServerName = 3SC,

Comparison: Analysis of the above results in terms of percentage can be calculated as,

((TCTraditional-TCCloud) ÷ TCTraditional) * 100% (6)

The performance analysis included identical hardware in both the cases to eliminate any effect of hardware dependency. If the resources of the front end machine were not considered then the memory utilization could have been further maximized. The results show 40% reduction in costs when the applications are executed on the cloud.

## IV. Analysis Of Results And Performance Evaluation

In the following, the results obtained during the tests on the Linux servers are evaluated. In the case of traditional architecture, the DNS service is allocated 1.9 GB memory, out of which only 0.1 GB (5.26%) memory is used for the time for which the system was monitored. Hence it is seen that 1.8 GB resource has been wasted in this case. The MAIL service used 1 GB out of the 1.9 GB memory allocated to it, yielding a percentage resource utilization of 52.63%. The SMTP and Database services use 1 GB memory each. Hence the memory usage of MAIL, SMTP and Database are identical in case of traditional infrastructure. Both SMTP and Database services have the resource utilization percentage of about 52.63%. The FTP service used 0.2 GB out of the total 1.9 GB memory.

From the above data it is seen that the DNS service incurs the greatest memory wastage, followed by FTP service. The low value of resource utilization of these two services is critical for the reduced percentage of total resource utilization found in traditional infrastructure, which is calculated by determination of the combined memory usage by the five selected services. The results are tabulated in Table 1 and the analysis is carried out in the following formulae. From the data obtained during the course of the experiments, the results for resource utilization were obtained using the formula described previously,

Percentage of RU = (3.3/9.5) * 100%

= 34.74%

Percentage of RW = (6.2/9.5) * 100%

= 65.26%

The application of the data to the formula found that out of the total 9.5 GB memory allocated for the concerned services, only 3.3 GB are being used for the time period of the test. Hence the percentage of memory usage has been found to be 34.74%. On the contrary 65.26% of the resources are found to be wasted in traditional infrastructure.

From the above analysis it can be deduced that more than half of the memory resources have remained unused when the cloud was not implemented. It is found that large proportion of memory wastage is true for any real life organizations who implement the services on individual physical machines without making the best use of technologies such as cloud which are available to those.

TABLE I. RESOURCE UTILIZATION IN ON THE PREMISES IT

| Server Name | Total Resource (TR), GB | Utilized Resource (UR), GB | Resource Wastage (RW), GB |
|---|---|---|---|
| DNS | 1.9 | 0.1 | 1.8 |
| MAIL | 1.9 | 1 | 0.9 |
| FTP | 1.9 | 0.2 | 1.7 |
| SMTP | 1.9 | 1 | 0.9 |
| Database | 1.9 | 1 | 0.9 |
| Total | 9.5 | 3.3 | 6.2 |

The open source cloud technology that was used in the research enabled launching multiple virtual machines of individual physical servers. The five services were running simultaneously in two nodes of the cloud, which were in turn controlled by the front end server. To eliminate the fact that difference in hardware efficiency could impact the test results, the servers used as the cloud front end and nodes were identical to the servers used in case of traditional systems. As shown in Table 2, a total of 52 instances were launched which consisted of various memory capacities using the optimized cloud architecture. Using the available memory resources of the two nodes, it is possible to launch 30 instances of 100 MB memory each, 15 instances each having 100 MB memory and 7 instances of 1 GB memory. The large number of virtual machines could be launched only with two servers each having 2 GB memories by resource management provided by the cloud technology.

The capability to control the memory capacity of the different instances enabled to run services with different memory requirements. Earlier, it was found that the five chosen services required a combined memory of 3.3 GB. The two cloud nodes have a combined memory of 3.8 GB. The formulae are used to get the results based on the data,

Percentage of RU = (3.3/5.8) * 100%
= 56.90%

Percentage of RW = (2.5/5.8) * 100%
= 43.10%

Individual virtual machine instances were launched for the services. Out of the five instances, two were small memory capacity instances, with a memory capacity of 200 MB. The remaining three virtual machines had 1 GB memory assigned to each. The instances were assigned separate Internet Protocol (IP) addresses. Shell access was obtained to the instances, and the five services were installed in those. The DNS and FTP services were installed in the instances with small memory capacities. The rest of the three services were installed in each of the three remaining instances of virtual machines. Hence the five services were simultaneously running in the five different virtual machines.

Since two cloud nodes were responsible for resource provision, 3.3 GB memory was used out of 3.8 GB. Hence the amount of memory resource wasted was 0.6 GB. The

TABLE III. COST DISTRIBUTION IN TRADITIONAL INFRASTRUCTURE

| Server Name | HC | PC | SC |
|---|---|---|---|
| DNS | HCDNS | HCDNS | SCDNS |
| MAIL | HCMAIL | HCMAIL | SCMAIL |
| FTP | HCFTP | HCFTP | SCFTP |
| SMTP | HCSMTP | HCSMTP | SCSMTP |
| Database | HCDatabase | HCDatabase | SCDatabase |

Hence the memory of the front end cannot be allocated to the services. The resource of the front end was considered to be in the group of the unused resources for this reason. It is found that the unutilized resources in the cloud sum up to 2.5 GB. The percentage of resource utilization on the cloud is found to be 56.90%. The resource wastage percentage is 43.10%. The rate of resource utilization is 22.16% greater in the cloud that in traditional infrastructure.

In the financial analysis, the direct cost was calculated as a sum of the hardware cost and power cost. The indirect cost is deduced by calculating the space cost of each physical machine. In case of traditional systems, the unit cost of each server was equal since the machines were identical. The servers consumed same amount of power since the uptime of all the servers was equal to the time period of the experiment. The space cost was identical for each server since they occupied equal amount of space. For ease of calculation, the unit cost of hardware has been denoted, power and space as HC, PC and SC respectively and calculate the total cost by summation of the direct cost and indirect cost. Hence the results yield, TCTraditional = 5 (HC + PC + SC).

In the second phase of the cost comparative analysis only three servers were required. The servers used in the cloud architecture were identical to the ones used in traditional systems. Virtualization was enabled in the cloud by using the KVM hypervisor. As a result three physical machines were needed in the cloud to launch five virtual machines. This provided a strict advantage in terms of hardware, power and storage cost. The hardware cost reduction from 5HC to 3HC resulted from increased resource utilization. The power consumption by each machine is identical in both cases, so it reduced by 2PC when moved to cloud. This showed that cloud computing was strictly governed by software rather than being hardware oriented approach. Hence the results yield, TCCloud = 3 (HC + PC + SC).

The direct cost influences the experiment directly. The indirect costs, does not have a direct influence on the tests however play critical role in cost analysis. The value of space may vary depending on the cost of housing in various regions, so it is considered units and not the value for space. It is clear that by keeping the cost of unit power and consumption rate constant, the power cost is proportional to the number of servers. The hardware cost is dependent on

TABLE IV. COST DISTRIBUTION IN CLOUD

| Server | HC | PC | SC |
|---|---|---|---|
| Master | HC | PC | SC |
| Node | 2HC | 2PC | 2SC |
| Total | 3HC | 3PC | 3SC |

tax rates on computer equipments, geographic regions and similar other factors. So for acceptance of the results in this case it is considered units of hardware cost instead of values for hardware. Finally a comparison between the TCCloud and TCTraditional showed the cost reduce by 40% when moved to cloud. The results have been derived as follows:

((5-3) ÷ 5) * 100% = 40% cost savings

The analysis shows after running all the above instances, 56.90 % resource utilization has been achieved which is 22.16% more than that of traditional architecture. By moving onto cloud 40% costs can be saved in both direct and indirect costs. Cloud computing is an ideal solution for small, mid-sized and large companies. It helps cut down hardware acquisition costs, power costs, space and maintenance costs [12]. Also the instances can be terminated when they are no longer required, preventing the memory and disk from being wasted.

## V. DISCUSSION

In this section, some of the important attributes of cloud computing are identified. Upon analyzing the results of the above experiments, it is seen that cloud outperforms traditional systems in resource utilization and cost benefits. The researchers determined certain cloud attributes that help the cloud attain this performance.

### *A. Reliability*

A server that is kept idle for some time, results in a high probability of malfunctioning when brought to life. So enterprises have to keep track of this extra cost on maintaining the infrastructure. Clouds provide all these services under their simple usage plan, which is not disrupted by some physical disasters like earthquakes, etc or by issues like power failures and so on. Cloud infrastructure ensures reliability and reduced malfunctioning since the servers are constantly in service. The idle time of a cloud server can be considered negligible [2].

It is the need of a reliable computing infrastructure division of an enterprise to ensure reliable and disaster recovery storage, but also ensure reliable network and disaster recovery centers [3]. Networking between operational data centers and disaster recovery centers must be persistent. Hence they are required to maintain multiple data centers for the same data and application, and also to implement hot/cold machine standby approach and disaster resilient software [4]. In order to attain realistic disaster recovery, all the servers and data centers must be constantly under operation [15].

### *B. Manageability*

Cloud computing services are the latest addition in the field of Large scale Networked Systems (LNS). Maintaining cloud data involves keeping track of the system uptime, security breaches, system setup and billing information. The manageability mechanism of cloud datacenters should be scalable to increasing demand of the cloud architecture. As stated in [16], the schemes for cloud management system should be distributed and the monitoring functions should be pushed into the system instead of being pulled. This ensures improved throughput and the complexity of the cloud management scheme does not increase with increasing demand for cloud resources [17].

Difference must be stated between monitoring information and control information. The monitoring information has been discussed in this section of the paper. Control information is analyzed in terms of resource utilization which has been discussed in Section IV. Most customers state that services provided by cloud computing is more reliable than what they themselves can achieve and maintain [2]. Cloud providers have the task of monitoring the systems 24 hours a day, 7 days a week [4]. Operational excellence can only be ensured by established cloud computing architectures.

### *C. Security*

An organization using traditional data center is burdened with ensuring security of the data stored in a large number of servers where resources remain unused [16]. When in-house data centers are moved to the cloud, all these expenditures can be mitigated to about 40% as shown in the results. Cloud computing ensure end-to-end privacy and implement the most advanced security algorithms [15]. As a result, organizations can be benefitted from the reliable computing architecture of the cloud.

Provenance is an important issue of research in cloud computing. Three protocols for provenance detection of cloud data have been discussed in [16]. Data forensics in the cloud can be improved by keeping logs and auditing information of the data sources. Hence by strictly following the mechanisms mentioned, the cloud administrator will be capable of identifying the errors, the reason why they were caused and their effects on the system as a whole

## VI. CONCLUSION AND FUTURE WORK

This paper aims to present a comparison between traditional on-the-premises architecture to the IaaS service taken from the cloud with respect to standard metrics. Five real life applications on traditional infrastructure and their memory comparison and financial cost are identified. Then, the same services are run on cloud for comparison of performance.

The services that were used as test cases are real life services used by many companies. It is identified that resource utilization can be improved by 22.16% when moved to the cloud since cloud architecture supports multiple applications simultaneously. By empirical evaluation of concrete data obtained in the study, it is shown how cloud computing have reduced costs by 40% compared to traditional architecture as hardware costs are reduced in the cloud.

This research is based on a cloud computing architecture that was continuously monitored to check for proper resource utilization. From the above learning and experiments it can be concluded that cloud service is not only data storage and software provision, it is about intelligent utilization of the available computing resources. At the same time the service is on demand. Customers can use computation capacities on the cloud when needed, and release those upon completion of their tasks to prevent wastage.

There are a number of ways in which the performance analysis can be improved. The resource utilization analysis is based on memory usage. The metrics that identify CPU utilization can be used to enhance the research on the basis of minimizing resource wastage. The research only concentrates on IaaS but PaaS and SaaS should also be considered for further researches. Research needs to be done on how two cloud architectures can be made interoperable.

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