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Evaluation of Virtual Machine Performance and Virtualized Consolidation Ratio in Cloud Computing System

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Abstract. The physical server transition to virtualized infrastructure server have encountered crucial problems such as server consolidation, virtualization performance, virtual machine density, total cost of ownership (TCO), and return on investments (ROI). This paper introduces five distinct virtualized cloud computing servers (VCCS), and gives appropriate assessment to five well-known hypervisors in VCCS. We thus have taken the analysis of virtualized server and shared storage accessing performance as well as the estimation of consolidation ratio and TCO/ROI in server virtualization. As a result, VM performance nearly achieves the same level for all hypervisors, but the estimation of VM density and TCO/ROI are totally different among them. Finally, we have the recommendation to choose the ESX server if you need a scheme with the highest ROI and the lowest TCO in server virtualization. Alternatively, Proxmox VE would be another best choice if you like to save the initial investment at first and own a high-performed virtualized infrastructure in server virtualization.
Keywords: Virtualized Cloud Computing Server, Hypervisor, Consolidation Ratio, TCO, ROI

1. **Introduction.** Present cloud-computing and services are dominated by large-size public cloud and enterprise-owned private cloud. As a matter of fact, the small and medium enterprises (SMEs), schools, and social groups need lot of services on virtualized cloud computing servers (VCCS) [1]. With this service, the department's information costs can be drastically reduced as well as it can quickly increase the competitiveness of its information system due to the following reasons: centralized monitoring, quick management, dynamic optimization, and efficient backup.

Technically, unexpected situations with service-type servers, such as websites, databases, AP servers, and file servers, bring much trouble for enterprises. Once a service comes to a halt, it can cause faulty data, stalled production lines, and interrupted operation procedures, leading to multiple losses. However, a physical host has problems of promptness of service transfer to another host, restarting the service, and inability to update data in real time. The hardware, information, and data will be obstacles for enterprises to overcome.

To solve above stated issues, virtualized cloud server systems (Hypervisor), such as VMware ESX/ESXi Server[2], Microsoft Hyper-V R2 [3], and Proxmox Virtual Environment [4], have integrated virtualization, virtual machines, and virtual services. With this method, users need only to connect to the system using low cost thin clients (a low-end PC or PDA) to complete general tasks [5], reducing IT purchasing fees considerably. As thin clients are easier to setup, chances of malfunctions, heat crashes, and computer viruses will also decrease, thus saving money on costs and electricity.

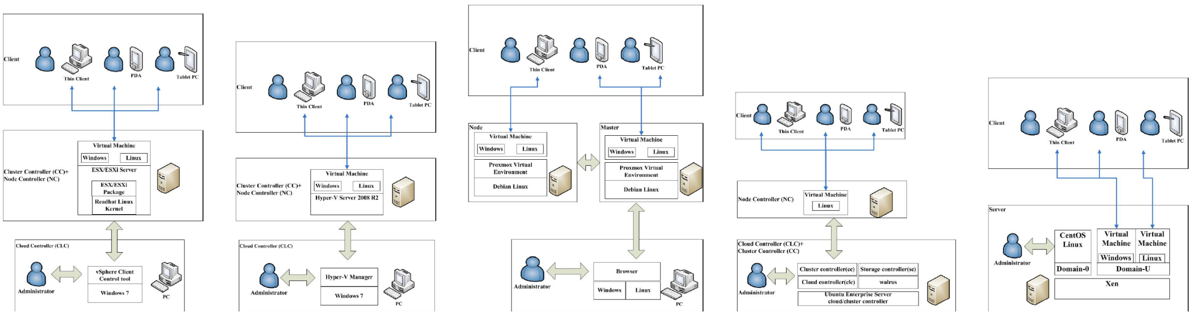
As the virtualization architecture expands continuously, network storage services have become part of the virtualization architecture. Openfiler [6] is a storage management system provided to enterprises. It is a free and conducive system that supports both network-attached storage (NAS) [7] and storage area network (SAN) [7] functions. As installed, it can be managed via web browsers in conjunction with iSCSI shared storage (IPSAN) [7] technique, to provide file accessing on cloud computing servers. One can also use LUN [8] through iSCSI to complete the placement of block accessing for virtual machines that are created by VMware or Hyper-V. This paper will evaluate the performance of accessing to block storage area network with Openfiler.

Our goal in this study is also to provide a credibility of cost and benefits before and after infrastructure virtualization. Speaking of cost and benefit, we will define and explore total cost of ownership as well as return on investment, respectively, in the following statements. Return on investment (ROI) [9] related to two factors, savings and investment, is equal to savings / investment, where investment represents the sum of incremental investment in transition from physical to virtual (new servers, shared storage, software licenses & support, services and training, etc.). In addition to investment, total cost of ownership (TCO) [10] yet includes IT administration and downtime costs. Apparently, ROI and TCO can be properly undertaken well according to how big infrastructure has been virtualized. In term of virtualization, how many infrastructures can be virtualized that intuitively depends on the virtual machines per core (VMs / core) ratio, so-called consolidation ratio [11]. Consolidation ratio is a measurement unit that virtualization vendors use with extreme prudence to provide a rough idea of the server consolidation level that can be achieved on their hypervisors.

2. **Analysis of virtualized server together with shared storage.** The purpose of this session is to setup five different virtualized cloud servers (VCS), and provide an appropriate assessment of each system's virtual machine monitor (hypervisor). These assessments can provide an optimal solution for SMEs, schools, and social groups. This research will setup and implement five heterogeneous virtualized cloud computing systems listed below: (a) vSphere ESX/ESXi Server (b) Hyper-V R2 Server (c) Proxmox Virtual Environment server (d) KVM at Ubuntu Enterprise Server [12] (e) CentOS-based Xen Server [13], as shown in Fig. 1- (a), (b), (c), (d) and (e), respectively. Moreover, five heterogeneous virtualized clouds link to a shared storage with Openfiler through LAN, i.e., IPSAN structure, as shown in Fig. 2.

Noted that vSphere ESX/ESXi Server, Hyper-V Server 2008 R2, or CentOS-based Xen required at least a stand alone machine for installation; Ubuntu Enterprise Server have to at least include 2 physical machines (Cloud Controller and Node Controller); Proxmox VE at least a master or optionally adding multiple nodes as well.

As shown in Table 1, the above mentioned five virtualized cloud servers include all kinds of virtual machine architectures and types, hence referred to as heterogeneous virtualized cloud servers. Virtual machine architectures are divided into hosted architecture, such as (a) and (b), and bare-metal architecture, such as (c), (d), and (e); its types are classified into para-virtualization, such as (d) and (e), full-virtualization, such as (a), (b), and(c), and hardware-assisted virtualization for all of them. This is because the new x86 machines, regardless of 32-bit or 64-bit, now support Intel VT-x and AMD-V virtual commands.



(a) vSphere ESX/ESXi server (b) Hyper-V Server 2008 R2 server (c) Proxmox VE (d) KVM at Ubuntu Enterprise Server (e) CentOS-based Xen server

Figure 1. Five heterogeneous virtualized cloud computing systems.

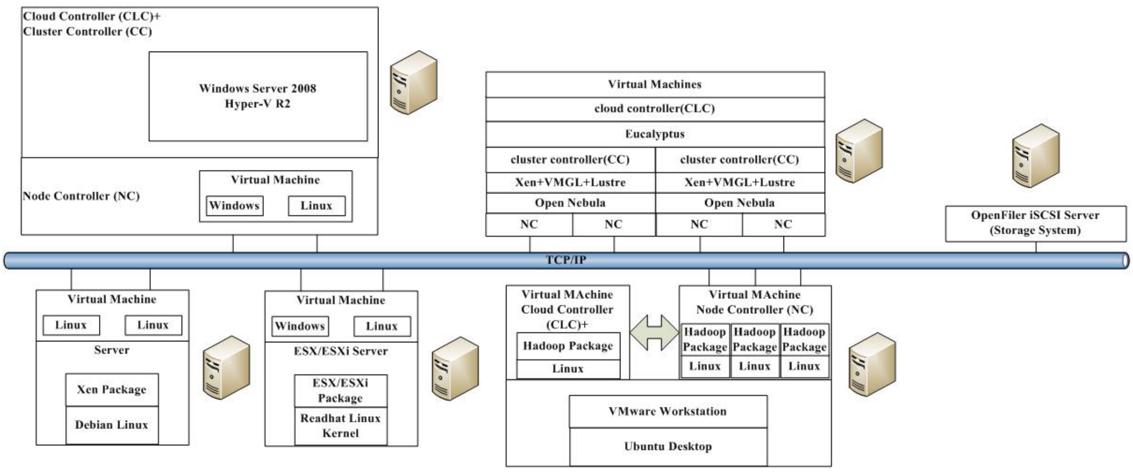


Figure 2. Virtualized cloud servers and a shared storage with Openfiler.

3. **Analysis of consolidation ratio and TCO/ROI.** The aim of this session is The aim of this session is first to understand consolidation ratio of VMware ESX server as well as TCO/ROI evaluated at VMware TCO/ROI Calculator [14]. Consolidation ratio means the number of VMs running in a server concurrently depending on the number of workloads and the average number of VMs per core. The max consolidation ratio per VMware ESX server is by default calculated as 1.5 VMs per core multiplied by the total number of cores per server [15]. That is, it gives 12:1 in ESX's server favor. Based on Taneja Group observations early in 2009 [16] during testing as well as their familiarity

Table 1. Hypervisor architecture

VMM	Hypervisor Architecture
VMware ESXi 5.0 (Redhat)	Bare-Metal/Monolithic
MS Hyper-V R2 (Windows Server 2008)	Bare-Metal/Microkernel
Proxmox VE* (Debian)	Hosted
KVM* (Ubuntu Enterprise Server)	Hosted
Xen* (Cent OS)	Bare-Metal/Microkernel

*: Open Source

with a broad range of virtual server infrastructures, they claimed there are many realistic workloads under which ESX4 will demonstrate a 2:1 VM density advantage when compared to Hyper-V R2 and XenServer 5.5. Thus, we extensively proposed to analyze VM density according to VMware official document for EXS server [14] and testing report from consulting services [16] so that consolidation ratio for the other Hypervisors can be obtained.

On the other hand, ROI required to transition to virtualized infrastructure evaluates the percent of total savings /total cost, where total savings consist of capital expenditure, operational expenditure, and downtime cost and total cost is composed of new servers, storage, network storages, software license & support, server, and training [9]. TCO is the costs associated with operation of datacenter which includes capital expenditure (servers, storage, and network switches), operational expenditure (power & cooling, infrastructure administration labors, and rack space), and business agility (planned downtime, unplanned downtime, and business downtime) [10]. Furthermore, the estimation of TCO/ROI for the other hypervisors have been undertaken appropriately according to both VM density and the ratio of ESX normalized performance index to the alternative one.

4. **Method and procedure.** With respect to the performance evaluation for the virtual machine monitor, a variety of guest OS and two well-known test tools are adopted in this study. PassMark PerformanceTest 7.0 (at http://www.passmark.com/download/pt_download.htm) is applied to the test of virtual machine performance for the Windows series guest OS like Windows XP, Windows 7, and Windows Server 2003, and UnixBench5.1.3 (at http://byte-unixbench.googlecode.com/files/UnixBench5.1.3.tgz) is employed for Linux series guest OS like Ubuntu. According to evaluated performance score for each virtual infrastructure server, we derived the respective scores into a composite index each hypervisor and sequentially normalized it to be a value ranging from 0 to 1, where we refer to this as a normalized composite index related to virtual machine performance.

In order to achieve virtual infrastructure together with a shared storage, we first have to establish a set of block storage area network system called Openfiler and then mount shared storage to each virtual server. After that, we go for the performance evaluation of accessing block storage by using Linux hdparm command [17] to test disk reading speed. Likewise, we do the same thing as the above-mentioned procedure to infer a composite index and its normalized composite index associated with storage-accessing speed performance. Finally, we drive the composite index for total and a normalized one.

In this paper, we mainly conduct a credibility of cost and benefits before and after infrastructure virtualization. Speaking of cost and benefit, we will explore the consolidation ratio and TCO/ROI of server virtualization as mentioned above. VMware ESX server is first chosen to evaluate its consolidation ratio and estimate TCO/ROI at VMware calculator platform. The consolidation ratio and TCO/ROI of server virtualization for the other hypervisors will proportion to both its VM density (major portion) and the ratio of ESX normalized composite index to alternative one (minor portion). We broke the costs about capital expenditure, operational expenditure, and business agility into 13 items. Technically the following table as listed in Table 2 gives us an insight to understand which item is concerned with the VM density and/or normalized performance index ratio during TCO/ROI calculation.

Table 2. Cost Affected by VM density and Normalized Performance Index Ratio

Cost	**VM density (Workload Counts)**	**Normalized Performance Index Ratio**
Capital Expenditure		
Client HW+MS VDA	x	x
Server HW	v	x
Storage HW	x	x
Networking & Security HW	v	x
Hypervisor SW+SnS	v	x
Operational Expenditure		
Infrastructure Admin	v	v
Power & Cooling	v	v
Rack Space & Office Spacs	v	x
Services + Training	x	x
Business Agility		
Planned Downtime	x	x
Unplanned Downtime	x	x
Business Downtime	v	v
Other + Tax	v	x

5. **Experimental results and discussion.** There are three experiments and a discussion presented in the following sub sessions.

5.1. **Virtual machine performance evaluation.** The server hardware specification is set in Table 3.

The resulting score is an average of various scores form test items, foe example, CPU, Memory, storage, network, and 2D graph. In the experiment, two testing softwares (PassMark PerformanceTest 7.0 and UnixBench5.1.3) are applied to evaluate the virtual machine performance for hypervisors such as ESXi 5.0, Hyper-V R2, Proxmox VE, Ubuntu Enterprise Server KVM, and CentOS Xen. A summary of the virtual machine performances has shown in Table 4.

5.2. **Performance evaluation of accessing shared storage.** In the experiment, according to the same server hardware specification as mentioned above, Openfiler storage device is separately mounted onto five virtualized cloud computing servers to test disk-accessing speed. Tests carried out using two disk-accessing speed indicators, (a) timing cached reads (MB/sec) and (b) timing buffered disk reads (MB/sec) [18]. A summary of storage-accessing speed performances has shown in Table 5.

Table 3. Comparison of VM Performance at Hypervisor

Hardware Specification	CPU	Memory	Hard Disk	Network Card
Server	Intel(R) Core(TM) i7-2600 CPU 3.40GHz*2	ASint DDRIII 8G-1600*2	Seagate Barracude 7200 1TB	RTL8169SC B7C33A5 GB29 TAIWAN (TG-3269)
Shared Storage	Intel E5620 CPU 2.4GHz *1	8GB DDRIII RAM	1TB SATA HDD	RTL8169SC B7C33A5 GB29 TAIWAN (TG-3269)

Table 4. Comparison of VM Performance at Hypervisor

VM Performance	Unix Bench 5.1.3	PassMark PerformanceTest 7.0			Composite Index	Normalized Composite Index
	Linux Ubuntu	Win XP	Win Server 2003	Win 7		
ESXi 5.0	1545.5	1026.4	1126.1	1108.8	1316.3	1
Hyper-V R2	1624	1213.4	1328.3	1318.9	1455.4	1.11
Proxmox VE	1419.9	1013.3	750.9	976.4	1166.7	0.89
KVM	1419	730	688.4	902.7	1096.4	0.83
Xen	1089.2	700	597	860.3	904.2	0.69

5.3. **Estimation of consolidation ratio and TCO/ROI.** This part goes to the estimation of consolidation ratio and TCO/ROI for each virtualized infrastructure server as mentioned above. We choose VMware ESXi server as a benchmark and use VMware TCO/ROI Calculator to yield its server consolidation ratio and TCO/ROI quantity. According to VMware ESX exceeds 2 times workload capacity per server for the competitive hypervisors such as Hypervisor-V R2, XenServer 5.5 and the others [16], we assumed ESXi achieved 2:1 VM density per server advantage over the other hypervisors in this study. Thus, ESXi achieved 12:1 consolidation ratio in server virtualization because of 1.5 VM per core; instead the other hypervisors result in 6:1 in server virtualization. We estimate TCO/ROI for alternative hypervisor is greatly proportion to its VM density (i.e., major portion of estimation) and additionally add somewhat fluctuations or changes to the evaluation of TCO part based on the ratio of ESXi normalized composite index to alternative one (i.e., minor portion of estimation). In the experiment, we have deployed up to 50, 100, 150, 200, 250, and 300 workloads for the transition to their respective server virtualization with a 5-year duration. A summary of TCO/ROI calculation for 5 years has shown in Figs. 3 and 4 in sever virtualization.

5.4. **Discussion.** As shown in Figs. 3 and 4 in server virtualization, the best choice is to take 150 workloads with VMware ESX server because this combination will achieve the highest ROI and the lowest TCO with the duration of 5 years. However, when we look at Proxmox VE virtualization, it outperforms very well when comparing with the

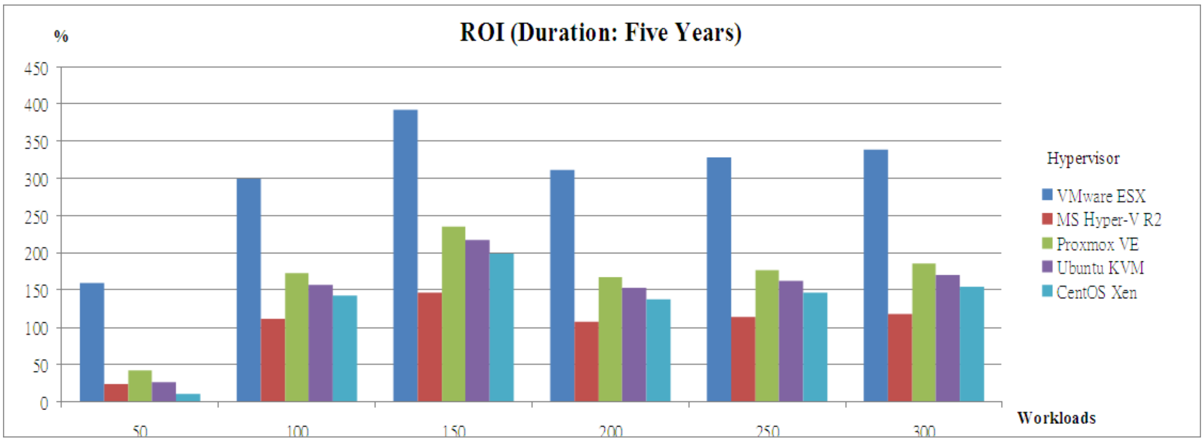


Figure 3. Histogram of TCO for server virtualization.

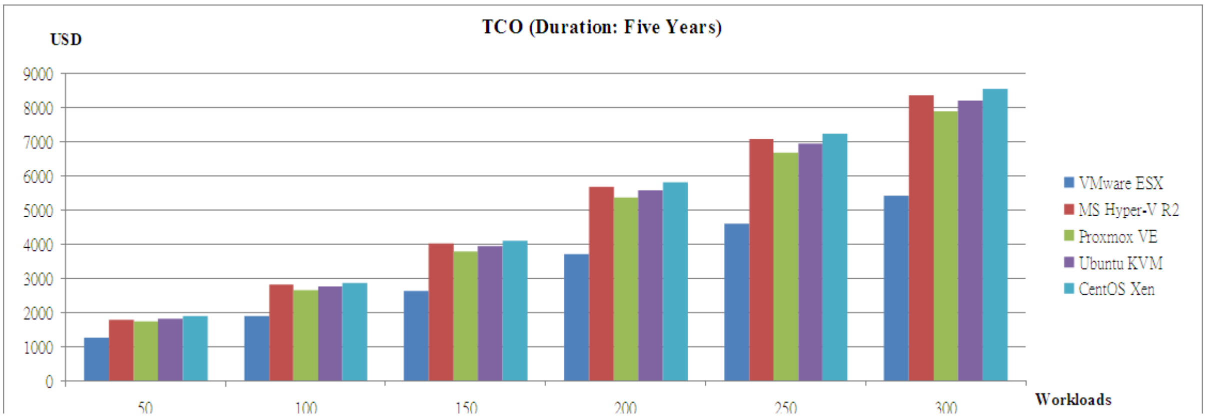


Figure 4. Histogram of ROI for server virtualization.

others to achieve pretty good ROI with a 5-year duration, even thought its TCO is a little bit less than ESXi's TCO. In the performance analysis, speaking of ESX server, we adopted ESXi 5.0 that is free software, its function is limited, and does not have the full functionality of VMware vSphere 5, such as: distributed resource scheduling, high availability, consolidated backup, fault tolerance, and disaster recovery. Apart from that, in the process of virtualizing the network, ESX/ESXi has restrictions on the brand of the physical network card, only certain network cards can be detected by the virtual machine. For instance: Intel and Broadcom [19] network cards. The newer versions of ESXi 5.0.0 and above now support parts of Realtek [20] series (Realtek 8186, Realtek 8169, and Realtek 8111E). Under the same combination with 150 workloads and 5-year duration, the second choice is Proxmox VE with which a friendly GUI for the management and an open source hypervisor are acquired. It sounds like well worth its value and is very suitable for small-to-medium business and educational purpose to use.

It is worth noting that Xen + VMGL + GPU [21, 22] architectures can support 3D animation on virtual machine, while the others do not support it. They do not support GPU operations on virtual machine. Xen has a commercialized product call Citrix XenServer. Its functions are parallel to that of ESX/ESXi server, and it is moderately priced. Regarding open source, Xen functions rather well, but the interface is not easy to manage. Proxmox VE achieves high hardware usage rate and is energy efficient; it is easy to install and comes up with a manageable interface. However, network connection may not be detected when using newer network cards. Therefore, it is a safer bet to use older network cards. The performance evaluation of KVM is very similar to Proxmox VE, but the elasticity of virtual machine is a little slower than Proxmox VE. It is noted that Eucalyptus installed on the Ubuntu Enterprise Server 10.04 has been commercialized, many of its functions have been disabled, and therefore the functions of KVM on Ubuntu Enterprise Server 10.04 are quite limited. Finally, a summary of the rating of virtual infrastructure server is listed in Table 6. Moreover, this paper do not discuss the security problem on virtualized cloud computing server which is related to access control [23] and cryptograph in VMs [24] to be explored in the further work.

Table 5. Rating of Virtual Infrastructure Server

Rating	Performance	Cost	GUI	Management
ESX 5.0	High	High	Very Good	Easy
Hyper-V R2	High	High	Very Good	Easy
Proxmox VE	High to Medium	Free	Very Good	Medium
KVM	High	Free	Average	Average
Xen	Medium	Free	Average	Average

6. **Conclusion.** This paper introduces five distinct virtualized cloud computing servers (VCCS), and provides the appropriate assessment to five well-known hypervisors built in VCCSs. In order to fulfill this objective, we thus carry out the analysis of virtualized cloud computing server as well as shared storage implementation on these servers. Furthermore, the estimations of consolidation ratio and TCO/ROI in server virtualization has also explored in this study. The necessitated calculation have been performed to disclose the critical information about server consolidation, virtualization performance, virtual machine density, total cost of ownership, and return on investments. The experiment demonstrated that VM performance achieve nearly the same level for all of them, but the estimation of VM density and TCO/ROI are totally different among them. You may choose ESX server if you need a scheme with the highest ROI and the lowest TCO in server virtualization. Alternatively, Proxmox VE would be another best choice if you like to save the initial investment at first and own a high-performed virtualized infrastructure in server virtualization.

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