Performance Evaluation of VDI-Based Private Cloud Technology for Education and Research

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Abstract
Enhancing educational and research environments in universities and research institutions is continually chal-lenging. Currently, educational organizations provide physical facilities to their staff and students. Such setups can be expensive, inflexible and difficult to maintain and suffer from the limitations on the services provided by their traditional information technology infrastructures to their various end users. Also, the overheads which are caused by managing, upgrading and maintaining all the traditional IT components and services are very high compared to virtualization environments. The aim is to utilize and to enhance one of the cloud computing technologies, Virtual Desktop Infrastructure (VDI), for supporting teaching and research activities within an educational organization. Cloud computing has redefined the view of computing resources as a framework where these resources are provisioned dynamically on demand. With cloud computing, these resources can be delivered to users across geographical and time boundaries. For example, virtualization stores the resulting virtualized desktop on a remote central server, instead of on the local storage of a remote client; thus, when users work from their remote desktop client, all of the programs, applications, processes, and data used are kept and run centrally. In this article, we explore VDI platforms and evaluate their suitability for universities and research institutes. We study the performance for these well-known VDI platforms, namely VMware Horizon and Citrix XenDesktop, using the Login VSI tool as software benchmarking. Performance evaluations are conducted using homogeneous architectural designs.

Key words:
Citrix, VMware, Login VSI, Benchmarking

I. Introduction

Many educational organizations have adopted cloud computing, in particular, educational institutions specializing in teaching and research. Thus, cloud computing can be utilized in teaching and research for allowing the contents of various courses and computing resources to be available constantly for students and faculty members to access remotely from either on-campus or off-campus, as stated in [1] and [2]. Furthermore, according to [3], [2] and [4], one of the main reasons that educational organizations have been attracted towards cloud computing is the sharp reduction of expenses. For instance, a software licensing model, which is pay-per-use, can be utilized by educational organizations in order to reduce costs. Licenses can thereby be utilized in a cost-efficient manner according to student use or disuse. Also, money can be saved by the lower consumption of electricity that cloud computing technologies can offer. In cloud computing, all educational services are residing on servers which are centrally administrated. As a result, virtual labs can be easily implemented and deployed for students and instructors and therefore the educational environment will always be ready faster than the traditional environment. In addition, the educational organizations employing cloud computing will be relived from managing their IT infrastructures, which leads to time and effort saving as well. Teaching and administration can be the priority. Moreover, The security is enhanced in the educational services based on cloud computing when one server is being affected by a virus other servers will be isolated from that affected server.

Educational and research activities are supported by many cloud technologies. However, one of the most significant cloud technologies is known as VDI, which has been applied in many educational environments because of its great advantages. According to [1], [5], [6], [7], [3] and [8], The security risks of VDI are highly minimized. This is because VDs and end users' data are stored centrally on servers. As a result, VDI can provide better control to its many VDs because of the central management by the IT technical support team and reliving end users from maintaining their personal computers by themselves. Also, VDI uses SSL encryption in the connection to its VDs. In addition, VDI can be the best solution for the compatibility issue between applications and different versions of Windows operating system. Furthermore, VDI is a helpful technology for reducing costs. This can be done by utilizing thin client devices rather than PCs and also existing computers can be used without the need for upgrading their hardware resources, as stated in [4]. Also, VDI utilizes virtualization to consolidate all VDs to be working on only one server, reducing the power consumption.

Other VDI features, as mentioned in [6], [9], [7], [3], [8] and [4], are flexibility and availability. Flexibility in VDI is achieved when end users, either students, instructors or staff, can use different terminals to run their VDs for carrying out their tasks and still receiving the same environment. Availability in VDI is meant for allowing remote access to VDs regardless of time, place or device used as well as type of operating system for accessing these

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VDs. Thus, the access to VDs can be practically unlimited making the workspace for end users very wide.

According to [3], [2] and [4], VDI can save time and effort for the IT technical team since they will be able to deploy many VDs in a very short time. As stated in [8], 120 VDs can be deployed in 40 minutes. Also, test or production environments can be implemented in a faster and easy manner by VDI. Furthermore, the environments provided on VDI will be unified and identical for all end users, especially when installing and updating the master images linked to a set of VDs and these images can be copied and shared among various subject contents. Building virtual labs is an easy task on VDI and therefore physical labs can be changed to be virtual labs while these physical labs can be utilized to be other classrooms or offices. Finally, VDI is capable of performing backups and maintaining VDs faster and easier than the traditional technologies.

However, there are some disadvantages of using VDI, as stated in [6]. VDI is a network-based technology and therefore its performance will be subject to the bandwidth of the network used. Furthermore, if all VDI configurations and setting are successfully completed but the network on which VDI works is not appropriately assigned, or encounters some technical issues the whole VDI environment will collapse. In addition, the VDI technology suffers from a single point of failure. However, this issue can be solved due to its flexibility feature by migrating the running VDs on the halted server in time to another active server which has an identical VDI platform environment in order to keep them continuously running regardless of the server used.

2. Motivation

Enhancing the educational and research environments in universities and research institutes is continually challenging. A migration to a virtual environment would be the sole best solution nowadays. Many respective features of virtualization, which traditional environments do not contain, can be employed for improving the learning process and the research activity. As known, universities and research institutes in reality are not usually interested in utilizing open-source virtualization environments within their local data centers due to many factors. The main reason is that they always need support, updates and maintenance for their new virtual IT infrastructures to provide persistent, stable services to their faculty members, students and researchers. This makes choosing only proprietary venders more significant. Therefore, the scope of this work will be limited to the two well-known venders in VDI virtualization, Citrix and VMware.

3. Contributions

Until Now, studies of VDI platforms have been homogeneous in nature; that is experiments have been conducted, due to high compatibility, using softwares from the same vender only. The main contribution of this work, however, will be to concentrate on evaluating the different VDI platforms heterogeneously as well as homogeneously along with interchangeable hypervisors. Such work has been partially accomplished thus far by only one paper [10]. The authors of this paper conducted only a single experiment testing VMware vSphere hypervisor with Citrix XenDesktop VDI platform from a performance standpoint. However, they did not use Citrix XenServer hypervisor with VMware Horizon VDI platform in order to test the performance of such an experiment. This thesis seeks to close the gap and perform the first full heterogeneous experiments on these softwares.

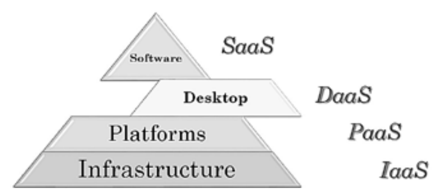

Fig. 1 The New Cloud Computing Structure for The Service Layers

Also as another contribution, the VDI-based cloud technology is providing DaaS VDs. The cloud computing consists of only three service layers in its main structure. They are IaaS, PaaS and SaaS. The DaaS has been coined as an additional layer to the cloud computing structure to be four layers rather than the current three layers and all can be provided for educational and research institutes according to their needs, as shown in Figure 1. DaaS does not fall under SaaS or PaaS cloud service layers. The reason is that DaaS does not provide the end user with a pure VM where the user can have the full control of that VM to perform privileged tasks on it as an administrator as PaaS does. Also, DaaS is much more versatile than SaaS because SaaS provides specific desktop applications like MS Word, Eclipse and others offered by the SaaS provider in which the end user can only utilize them for their own files but at the same time the user will not be able to use or install other desktop applications in such an environment. Therefore, DaaS has indeed this flexibility in its own environment for the end user.

4. Problem Statement

Universities and research institutes suffer from limitations on the current services provided by their traditional IT infrastructures to all their various end users. Also, overheads, which are caused by managing, upgrading and maintaining all the traditional IT components and services, are very high compared to virtual infrastructures. There is a cloud technology that can help enhance the learning experience in higher education, called VDI. Therefore, there is a variety of venders for varied VDI platforms and hypervisors by which virtualizaion environments can be built to provide VDs. Thus, when applying virtualization to an infrastructural environment, is it feasible for universities and research institutes to adopt and utilize a specific VDI platform with its suitable hypervisor among two popular VDI vendors?

5. Related Work

The papers in the references section have been surveyed in order to investigate a variety of hypervisors and VDI platforms used for providing VD environments produced by top market vendors. The implementation of the experiments has been evaluated in terms of the architecture type of the hypervisor as well as the nature of the experimental environments whether they are homogeneous or heterogeneous. Also, the various products of the software hypervisors and VDI platforms have precisely been taken into consideration.

Researchers in [5] have only used a XenDesktop VDI platform on a XenServer hypervisor from the Citrix vendor. The Citrix XenServer hypervisor works only on a Type 1 architecture and it is closed-source. Also, the comparison to other different hypervisors along with their corresponding VDI platforms is not taken into account. Also, the experiments conducted in this paper are all considered homogeneous since the hypervisor and VDI platform used are both compatible and come from the same vendor. However, an experiment to be considered heterogeneous is that the hypervisor and VDI platform used are both compatible but come from different vendors. The evaluation of their experiments have been done using a benchmarking software tool in terms of a network emulator and the specific name of the tool is mentioned in the paper which is Wlinee.

In [10], authors have used a XenDesktop VDI platform on a XenServer hypervisor from the Citrix vender and also a Horizon VDI platform on a vSphere hypervisor from the VMware vendor for their experiments. In addition, they have conducted experiments using a XenDesktop VDI platform on a vSphere hypervisor. The Citrix XenServer and VMware vSphere hypervisors work only on a Type 1 architecture and they are closed-source. Also, the comparison to other different hypervisors along with their corresponding VDI platforms is indeed taken into account. In addition, the experiments conducted in this paper are all considered homogeneous as well as heterogeneous in only one side. The evaluation of their experiments have been done using two benchmarking software tools in terms of a workload simulation and the specific names of the tools are mentioned in the paper which are Microsoft Remote Desktop Load Simulation and Login VSI.

Authors in [7] have only used a Horizon VDI platform on a vSphere hypervisor from the VMware vendor for their experiments. The VMware vSphere hypervisor works only on a Type 1 architecture and it is closed-source. Also, The comparison to other different hypervisors along with their corresponding VDI platforms is not taken into account. In addition, the experiments conducted in this paper are all considered homogeneous. The evaluation of their experiments have been done using a monitoring hardware tool (physical device).

The research done in [3] explored the usage of a Horizon VDI platform on a vSphere hypervisor from the VMware vendor. The VMware vSphere hypervisor works only on a Type 1 architecture and it is closed-source. Also, The comparison to other different hypervisors along with their corresponding VDI platforms is not taken into account. In addition, the experiments conducted in this paper are all considered homogeneous. The evaluation of their experiments have been done using the built-in monitoring software tool in the VMware vshpere hypervisor.

The authors of paper [11] have only used a Horizon VDI platform on a vSphere hypervisor from the VMware vendor. The VMware vSphere hypervisor works only on a Type 1 architecture and it is closed-source. Also, The comparison to other different hypervisors along with their corresponding VDI platforms is not taken into account. In addition, the experiments conducted in this paper are all considered homogeneous. The evaluation of their experiments have been done using a benchmarking software tool in terms of disk I/O workloads and the specific name of the tool is mentioned in the paper which is Open Source Oracle VDBench.

In [1], authors have only used a Microsoft VDI platform on a Hyper-V hypervisor from the Microsoft vendor. The Microsoft Hyper-V hypervisor works only on a Type 1 architecture and it is closed-source. Also, the comparison to other different hypervisors along with their corresponding VDI platforms is not taken into account. In addition, the experiments conducted in this paper is considered homogeneous. The evaluation of their experiments have been done using a benchmarking software tool in terms of network load monitoring but the specific name of the tool is not mentioned in the paper.

In order to summarize the experiments carried out in the related work, it has been discovered that the total number of homogeneous experiments is eleven, (92%). The details of these experiments are six experiments applying the VMware product, (55%), four experiments applying the Citrix product, (36%) and only one experiment applying the Microsoft product, (9%). On the other hand, only one experiment is partially heterogeneous in which it applied only the Citrix VDI platform product on top of the VMware hypervisor product, (8%). Figures 2 and 3 illustrate the various types of the experiments conducted and the various types of the VDI platforms used.

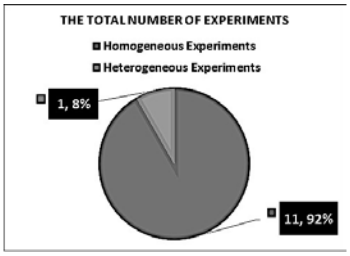

Fig. 2 The Representation of the Homogeneous and Heterogeneous Experiments

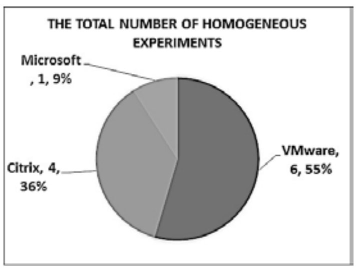

Fig. 3 The Representation of the Various Homogeneous Experiments

As shown in Figure 4, the benchmarking tools used in the twelve experiments are all software except one experiment which is the only hardware benchmarking tool. As noticed, the Login VSI software benchmarking tool is only used once in paper [10]. However, using Login VSI for once represents (8%) among other tools used in these experiments.

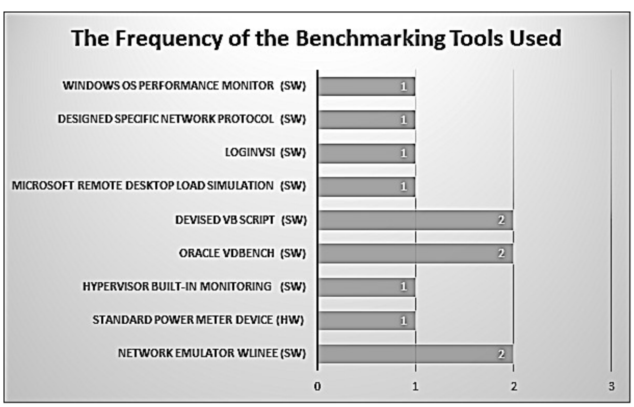

Fig. 4 The Frequency of the Benchmarking Tools Used

In light of the above, all the architecture types of the experiments implemented in the reviewed papers are Type 1 except the papers [4], [12] and [13]. In regard to the testing types, almost nine papers have evaluated VDI in terms of performance while other papers have evaluated VDI in terms of either network utilization, network transmission, network protocol, audio transmission, I/O operations, usability or power consumption. However, there are some other papers which have no evaluations as in the papers [2], [12], [14], [15] and [13].

According the paper [10], it is the only paper which has evaluated VDI by using the Login VSI as a software benchmarking tool that this thesis is going to use. As seen in the paper, it has implemented three experiments, two of which are homogeneous and the third one is heterogeneous. The evaluation has overlooked considering the impact of inter-arrival time of VDs on the results of a test as a factor for evaluation. Also, the experiments have a lack of a confidence level on the results since the authors did not have multiple runs for their experiments in order to get reliable results. In this thesis, the missing factor as well as increasing the level of confidence on the results will be considered in order to fill in the gab.

6. Vdi Methodology Architecture

It should be known that the layers needed for any VDI environment to be tested are shown below in 5. They are composed of a layer of a server hardware, a layer of a hypervisor and a layer of virtual machines. The VDI platform must be installed in one or a set of virtual machines forming the VDI environment and the Login VSI benchmarking tool must too. For this reason, the virtual machines running on the layer of hypervisor are necessary to exist as a base for the VDI environment itself as well as the Login VSI benchmarking tool although the latter can be also used and running in separate physical machines as an alternative way from using virtual machines. Although the whole VDI environment is built on top of virtual machines, it will produce eventually virtual desktops as an outcome rather than new other virtual machines.

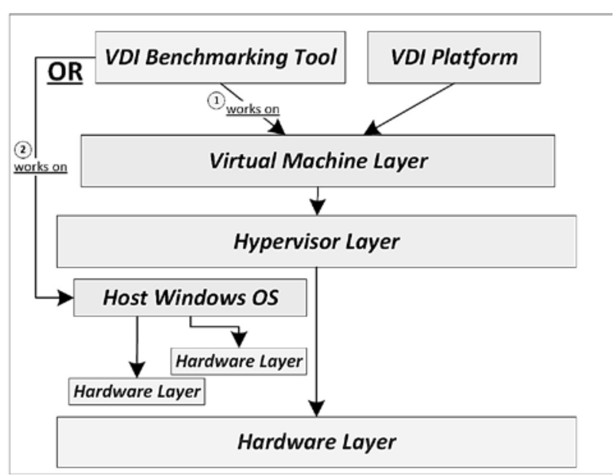

Fig. 5 The Architecture of the Required Layers for the Experiments

A. Login VSI Architecture

The Login VSI benchmarkring software tool is composed of two main components for tests. They are Login VSI Management Console (MMC) and Login VSI Launcher. The performance monitoring of experiments cannot be accomplished unless both are together used in tests. In addition, Login VSI Analyzer is another component for automatically analyzing results collected by MMC. The MMC is a console platform where a VDI evaluator is able to configure a test to their VDI target environment. The Launcher is the component that is responsible for launching virtual desktops in every certain time during which the test is running as configured. All Login VSI main components must be installed in separate machines. Furthermore, both must be parts of an active directory and join to the domain.

B. Login VSI Selected Types of Predefined Workloads

Login VSI has a set of standard predefined workloads although a customized workload can be constructed by the user. The Login VSI predefined workloads are Task Worker, Office Worker, Knowledge Worker and Power Worker. Only two particular workloads have been selected among others for the performance evaluation in the thesis VDI environments which are the lightest predefined workload (Task Worker) and the heaviest predefined workload (Power Worker).

As shown in Table 1, the predefined light workload will use at least two desktop applications as minimum and at most seven desktop applications as maximum. The minimum hardware requirements to operate this workload successfully are (1 vCPU) and (1 GB of RAM). However, the predefined heavy workload will use at least eight desktop applications as minimum and at most twelve desktop applications as maximum.

There are main differences between these specific predefined workloads in terms of CPU utilization and reading or writing from/to the disk. The CPU operations in the light workload will consume up to 70% of the total 1 vCPU processor whereas the CPU operations in the heavy workload will consume up to 119% of the total 2 vCPUs processors, (consuming up to 100% from one vCPU and 19% remaining from the other vCPU or 60% of each vCPU if they are equally divided). The ratio of CPU utilization between these workloads is 70% difference. For the disk operations, the ratio between these workloads is about 80% difference.

Table 1: the configurations and utilizations of computing resources for login vsi workload types

Workload Name / Type	Application Opened	Estimated CPU Usage	Estimated IOPS Per User	Typical VM Memory Profile	Typical VM vCPU Profile
(Light) Task Worker	2-7	70%	6.0	1.0 GB	1vCPU
(Heavy) Power Worker	8-12	119%	10.8	2.0 GB	2vCPU+

C. Experimental Description

The first step towards implementing VDI virtualization environments is to install a software hypervisor directly on top of the hardware, usually on powerful servers. The next step is to implement a complete VDI platform that must be implemented on the Type 1 hypervisor within some of its operating-system-based virtual machines in order to provide virtual desktops as a service. Finally, a benchmarking software tool must be installed on an isolated virtual machine or a stand-alone physical machine so that all the virtual desktops running can be monitored and their performance can be evaluated based on available metrics in the benchmarking software tool. Each experiment will be conducted in an identical separate server so that all the hardware resources of the server will be fully dedicated to the VDI environment and the results obtained can be fairly and reliably analyzed.

Table 2: the total number of systematic experiments

Experiment #	# of VDs	Workload Type	Inter-Arrival Time
Experiment 1	10	Light	2.5 Minutes
Experiment 2		Heavy	2.5 Minutes

Table 3: the hardware specifications of the five servers

Specifications	Server #1	Server #2	Server #3	Server #4	Server #5
Hardware Model	Intel Xeon				
Processor Speed	2 GHz				
CPU Processors	12 Cores				
Logical Processors	24 cores				
Main Memory	64 GB	96 GB	64 GB	96 GB	32 GB
Storage Capacity	1.08 TB				280 GB

D. Experimental Infrastructure

1) Hardware Specifications: For the sake of conducting the proposed experiments, there will be five servers that need to be allocated. All the experiments can be only conducted sequentially not in parallel at the same time. However, one server will be dedicated to the benchmarking tool installed and running on it for simulating end users' behaviours by invoking various workloads and monitoring the VDs in a session. Table 3 above describes the hardware specifications of the five servers used.

Table 4: the software specifications installed on the five servers

Software	Type	Version	Installed Location
VMware vSphere	Hypervisor	6.5	Servers: #1 and 2
Citrix XenServer		7.0	Servers: #3 and 4
VMware Horizon	VDI platform	7.0	Server #1
Citrix XenDesktop		7.9	Server #3
VMware vSphere Client	Administrating Tool	6.5	Administrator Machine
Citrix XenCenter Client		7.0	Administrator Machine
Login VSI	Benchmarking Tool	4.1	Server #5
Microsoft Windows Server	Operating System	2012 R2	Servers: #1,3 and 5
Microsoft Windows		8	Server #5
Microsoft Windows		7	Servers: #2 and 4

2) Software Specifications: In Table 4 above, two hypervisor types only are used: Citrix XenServer and VMware vSphere along with their administrating clients. Also, the two VDI platforms used are Citrix XenDesktop and VMware Horizon. The benchmarkng tool is a commercial product, Login VSI. In addition, three versions of the Windows operating systems will be used: Windows server 2012 R2, 8 and 7

7. Results and Analysis

A. Experiment #1 [10-VDs, 2.5-Minutes]

Also, as stated in Table 5, the significant observation of the E1 comparison is the following. The VMware VDI platform has reached the maximum capacity which is 10 out of 10 VDs while the Citrix VDI platform has reached only 8 out 10 VDs. As a result, the VMware VDI platform is much suitable than the Citrix VDI platform by 25 % difference in this specific test.

Also, as stated in Table 5, the VMware VDI platform does not have any inactive or stuck sessions whereas the Citrix VDI platform does. The number of active sessions of Citrix VDI platform are 10 out of 10 VDs. Two of those active ten sessions were in a stuck state. However, the saturation point of both VDI platforms have not been reached.

Table 5: average run comparison between the pair of vdi platforms for e1

Experiment #1	VMware VDI Platform	Citrix VDI Platform
VSImax	[10]	[8]
Unlaunched Sessions	0	0
Inactive Sessions	0	0
Stuck Sessions	0	2
Active Sessions	10	10
System Saturation	NOT REACHED	NOT REACHED

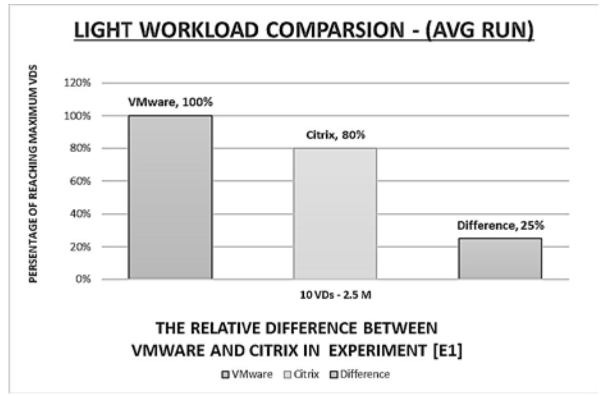

Fig. 6 The Comparison Between the Light Workload AVG-Runs of E1.

B. Experiment #2 [10-VDs, 2.5-Minutes]

As shown in Figure 7, the significant observation of the E2 comparison is the following. The VMware VDI platform has reached the maximum capacity which is 10 out of 10 VDs while the Citrix VDI platform has reached only 5 out 10 VDs. As a result, the VMware VDI platform is much suitable than the Citrix VDI platform by 100 % difference in this specific test.

Table 6: average run comparison between the pair of vdi platforms for e2

Experiment #2	VMware VDI Platform	Citrix VDI Platform
VSImax	[10]	[5]
Unlaunched Sessions	0	0
Inactive Sessions	0	0
Stuck Sessions	0	5
Active Sessions	10	10
System Saturation	NOT REACHED	NOT REACHED

Also, as stated in Table 6, the VMware VDI platform does not have any inactive or stuck sessions whereas the Citrix VDI platform does. The number of active sessions of Citrix VDI platform are 10 out of 10 VDs. Five of those active ten sessions were in a stuck state. However, the saturation point of both VDI platforms have not been reached.

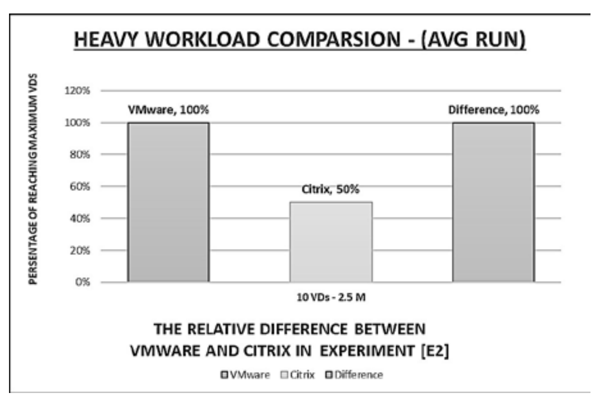

Fig. 7 The Comparison Between the Heavy Workload AVG-Runs of E2.

8. Conclusion and Future Work

The conclusion can be taken as an initial step towards utilizing cloud environments in teaching and research activities by using the VDI platform technology either from VMware or Citrix venders to enhance educational environments. The comparisons of the two experiments between VMware and Citrix VDI platforms in terms of VSImax shows that the VMware VDI platform is much suitable for educational environments than the Citrix VDI platform within their homogeneous environment. However, as a future work, the current work is limited by using products provided by only two venders. Therefore, this work can be expanded by including some other VDI platforms provided by other vendors to be evaluated as well. This will help universities and institutes to have wider options rather than only two from which the right choice can be easily and safely taken.

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