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Virtual Desktop Infrastructure for Oil and Gas Training Center: Evaluation and Case Study

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Abstract: Virtual Desktop Infrastructure (VDI) technology is advancing rapidly. Organizations, including hospitals, banks, Oil and Gas companies, and universities have considered VDI as an alternative to the typical office workstation. Implementation of VDI technology has several attractive benefits such as simple management for desktops, reduction of operational cost, and better resource utilization. A study has been conducted in a specialized Oil and Gas training center located in a Gulf Cooperation Council (GCC) country. The motivation behind the study was to evaluate VDI technology as an alternative to workstations when considering complexity of administration, improving end-user experience, and application performance. In this study, different types of GPU/CPU applications were evaluated to provide an indication of whether this technology is capable of replacing the conventional workstation environment in Oil and Gas companies. Throughout this paper the evaluation of VDI implementation in an Oil and Gas training center is presented along with the associated system design, benefits, and challenges.

Keywords: Cloud Computing, Virtual Desktop, Virtualization, Private Cloud Evaluation, VDI Deployment at Training Center and Testing VDI in Academic Environment.

1. INTRODUCTION

Recently, a huge number of organizations have begun implementing Virtual Desktop Infrastructure (VDI). The success of large-scale VDI deployment, particularly in the educational sector, is a leading motivator for evaluating VDI technology in training centers. Such specialized centers run different types of applications that require heavy GPU and CPU processing. In fact, the nature of the training center is dynamic where an average of 6-7 training sessions are conducted simultaneously.

However, in the current traditional workstation environment, there are challenges associated with administration, applications, and workstation configurations. One challenge is the inefficient and lengthy process of class preparation, which involves providing a fresh operating system with certain number of applications for each student. This activity usually requires an administrator to install the operating system and applications on every workstation prior to the start of any training session. Furthermore, managing workstation activities such as software installation, vulnerability remediation and OS migration remain additional challenges in the current workstation-based approach.

VDI, as an alternative to a conventional workstation solution, facilitates better handling of key operational functions such as desktop provisioning and patch management processes. VDI also helps simplify complex class preparation for any training session. Additionally, VDI is a secure option because user data is not locally stored in end-user devices; therefore, losing devices will not cause data loss.

The intent of VDI implementation is to offer a similar desktop experience through Virtual Machines (VMs), which can be maintained in a data center and accessed from any device. Basically, the concept of shifting the workload and processing to the data center will contribute indirectly towards cost savings. These savings are realized because user can utilize thin clients that are inexpensive, with low computing capabilities and less power consumption devices [2][7].

Therefore, the motivation behind this study is to analyse and assess the feasibility of VDI technology as a replacement of conventional workstations in an Oil & Gas training center. The evaluation covers different key aspects of VDI technology that are considered major

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benchmarking areas including administration, performance of desktop and applications, and end-user devices.

2. Historical Overview of Virtualization Technology

A. The Onset of Virtualization

The concept of server virtualization has existed since the era of mainframe computing in the 1960s and it has evolved over the years. At that time, the computer could perform one task through a single application one at a time. As a matter of fact, the 1960s marked the start of memory virtualization research at Michigan University. The memory virtualization system utilized was an IBM System 360 which allowed users to perform several tasks simultaneously in a single machine [1]. After that, the idea of time sharing emerged as a virtualization technology. Basically, it is a physical machine that can be accessed remotely by many users simultaneously and independently [1][18].

Virtualization was popular in the market until the 1970s when personal computers superseded virtualization in terms of cost effectiveness; and hence, the focus in the market on virtualization decreased. Still, the mainframe was used to meet enterprise computing needs. In 1972, the hypervisor, called the Virtual Machine (VM-CP) came to the market. The hypervisor is a controlling program which operates in a machine to create a virtual computing environment. The hypervisor is considered the main driver leading to the advent of cloud computing, server virtualization and desktop virtualization [1].

B. Desktop Virtualization Technology

One of the virtualization applications is Virtual Desktop Infrastructure (VDI) which emerged after hypervisor invention (e.g. EXS or other technologies). Mainly, hypervisor is intended to separate operating systems and applications from the underlying hardware "Server" and to virtualize hardware resources (e.g. CPU, GPU, Memory, Network, Bandwidth, etc). Its operating system is installed in a physical server to create a virtual environment that allows concurrent operation of multiple instances called virtual machines (VMs) [17].

VDI is a Server based Computing (SBC) technology which differs from Personal Computers. The computing processes in VDI are carried out in Data Center and all the desktops are hosted on server. In this case, users connect to their desktops through Remote graphical Protocol such as Remote Desktop Protocol (RDP) from any device as shown in "Fig. 1" [2].

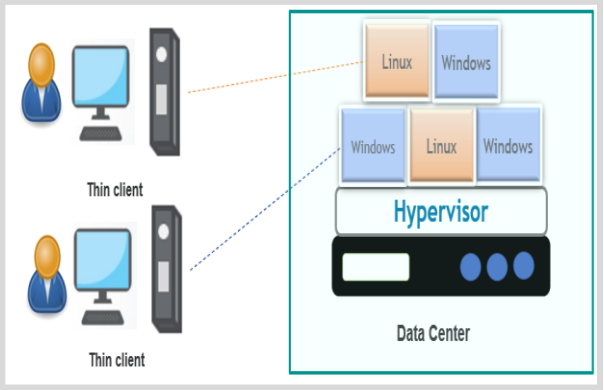

Figure 1. Users Connect to Virtual Desktops Through a Protocol such as RDP.

The idea of reserving a virtual machine (VM) for each user in the data center is not practical and considered poor resource utilization. However, with the introduction of Controller or Connection Broker as a management tool, user connections are based on the available VMs instead of having a dedicated connection to a specific VM. Connection broker has additional features like connecting a user to the right group of machines, deploy more desktops, monitor the performance and status of machines to indicate which VMs are in use, load balancing, troubleshooting and automatic reconnection to disconnected sessions[2]. Still the concept of broker is evolving and more features are being added such as Virtual desktops supporting Windows 10, NVIDIA GRID, multimedia redirection and 4K monitors [17].

Desktops and applications in VDI run remotely on server and user profiles are kept in a centralized storage location. Thus, users can seamlessly access desktops and work on applications as if they are running locally on their machines. This provides mobility features to desktops [2].

Like any technology, desktop virtualization has its strengths and weaknesses given different use cases. Hence, assessing the use case and feasibility of VDI application is essential. It follows that determining whether VDI meets training center requirements in Oil and Gas companies must be through a proper evaluation.

3. The Benefits of Desktop Virtualization

Virtual Desktop Infrastructure (VDI) proved to be a great advantage and of value to the academic sector [3]. Its benefits included centralized workstation management, minimized cost of power consumption, efficient resource utilization, simplified process of desktop deployment and maintenance, and streamlined OS migration [2][3]. "Fig. 2" presents the benefits of VDI deployment in brief.

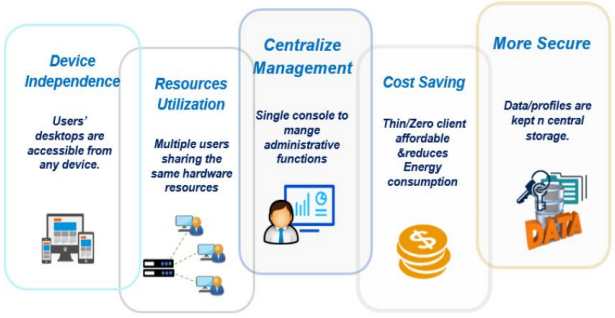

Figure 2. Summarized Benefits of Implementing VDI

A. *Centralized Workstation Management*

One key feature of VDI technology is the centralized management of workstations. Rot and Chrobak [3] indicated that centralized desktop management decreases the complexity associated with desktop maintenance and increases efficiency. In such an approach, all desktops can be easily administered, supervised, and tracked along with their installations (updates, software, etc) through a single console run by one person in technical support [2].

This fact leads to several enhancements in the way of handling operational activities efficiently. The reason being that an administrator applies customizations and modifications as a master image and the changes are reflected to targeted desktops via one command. This concept significantly reduces the time and effort involved in administrative functions [2][3]. Sacha Karbginski IT operations group leader describes central management as a great benefit because it helps his team to easily administer 2000 workstations distributed over 560 branches from a single location. He shared his experience when the team was able to increase all desktops RAM successfully from a central console in one day [4].

Thus, regardless of the number of managed desktops, it can be performed remotely and simultaneously [5]. In a typical workstation environment, desktop deployment and OS installation are deemed tedious and lengthy tasks since they are repeated on each machine individually.

With VDI, desktop provisioning takes minutes instead of hours [6]. For example, Rahman et al. [7] stated that KFUPM was successfully able to deploy 120 virtual machines in less than 40 minutes in their evaluation of VDI technology.

Furthermore, centralized management ensures effective monthly patching since the updates are distributed to all VMs at once with no exceptions [5]. Thus, it helps avoid vulnerabilities or unreached updates. Pushing monthly patches using remote software tools (e.g. Norton) is difficult to handle [2]. Such tools are agent based; and therefore, updating all workstations cannot be assured at one time and requires multiple attempts to address all vulnerabilities due to many reasons such as disconnected machines from network, machines being powered off, etc.

In addition, upgrading the Operating System on multiple machines by disseminating replicas of a single OS image from one console is an attractive advantage of VDI. As mentioned in [2], upgrading the OS through the typical method (i.e. non VDI) involves considering hardware components (e.g. RAM and hard disk) and software upgrade and compatibility for each workstation. Such processes incur high cost of manpower and time.

It can be understood from the previous facts that all vital functions including OS upgrades, desktop implementation and maintenance are performed utilizing the concept of "*apply once and deploy to many*". This concept is creating replicas of images from a single master image which includes all software installations, applications, updates and OS upgrades. These replicas can be updated and modified at any time easily to suit the operational requirements with minimum effort from one central console.

This helps the administrator to create a library of master images tailored according to different user needs [3]. This facilitates desktop preparation for training classrooms based on different application/courses requirements by deploying the appropriate master image. "Fig. 3" shows in brief the advantages of utilizing VDI centralized management feature in administrative tasks.

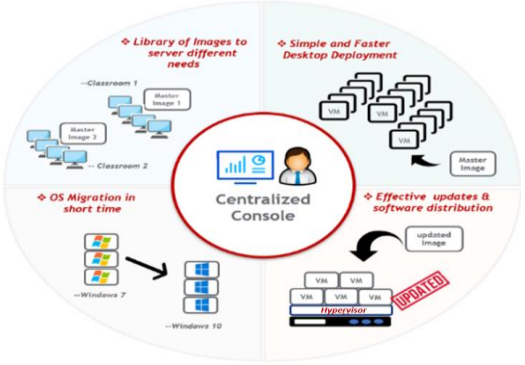

Figure 3. Summary of key Activates Performed through Centralized Management.

B. *Mobility and Desktop Independent Access*

The intent of desktop virtualization is to offer a substitute for the Personal Desktop [7]. In fact, all virtual desktops (VMs) are hosted in one centralized location and accessed by user through remote graphical protocol (e.g. ICA, PCoIP). This makes the VDI independent from the utilized device by the users [2]. VDI can be accessed securely from anywhere and by any type of device (e.g. thin client, smart phones, etc).

In education/training centers, the device independency feature of VDI makes it possible to use any type of device to conduct training regardless of its computing capabilities. This is because the main purpose of end-user devices is to

only connect user to VDI infrastructure where desktops are hosted. With this feature, instead of utilizing a dedicated workstation for each student in the classroom, students have the freedom to move while accessing their desktops from different devices.

C. *More Secure*

In fact, user data in VDI is located in a centralized storage location which reduces the susceptibility of data leakage or loss. Hence, VDI has adequate data security as the user profiles and files are kept in the data center fully isolated from the local user devices as shown in "Fig.4". Based on that, losing user device does not cause data leakage[5]. The administrator can define policies to prevent copying data to local devices which makes accessing desktops via different types of devices a secure option [3]. In case end-user devices are corrupted, replacing the hardware with a new device takes only a few seconds because no data is stored on user devices.

Figure 4. Users Files and Profiles are Stored in Data Center and Can be Accessed from Any Device

D. *Resource Optimization*

Workstations, in general, are not fully utilized and VDI ensures better overall use of resources. As Agarwal and Nath [8] stated, less than 5% of computers capabilities are utilized per the normal use of a personal computer. However, virtualization capitalizes on server resources and guarantees maximum use by distributing resources among many users [8][7].

E. *Cost Saving*

In VDI, end-user devices are used as a means to access desktops through network connectivity. With any VDI solution it is recommended, as a cost effective alternative, to use devices with low computing specifications such as thin-clients. Thin clients are small devices that do not have a hard disk, RAM and CPU similar to typical workstations [3][5]. These devices consume less energy (about 40-50 W) compared to the minimum power consumption of workstations (about 200W) [2][3].

Thin client is an inexpensive device and its price is approximately three times less than an average workstation. In addition, it has a longer life span than a Workstation since there are no moving parts or software incompatibility issues over the time [8].

4. System Design:

In 2018, a small scale VDI evaluation was conducted within the company premises for better control and stability. The infrastructure consists of Hyper Converged Infrastructure (HCI) nodes, and each node has the following specifications:

- 192 GB RAM.
- Intel Xeon Silver 12 Core 2.1 GHz Processor.
- Hybrid hard disk 14 X (1 TB) HDD and 2 X (1.92 TB) SSD.
- Two (2) NVIDIA Tesla M60 graphic cards.

"Fig. 5" shows the testing environment with the minimum hardware required to operate VDI. HCI is an x86 server in which computing, network and storage are gathered in a single system to allow resource sharing and better scalability [13]. As shown in the Figure below, the system design was built from three distinct software technologies: Hypervisor, Storage and Desktop Virtualization Solution.

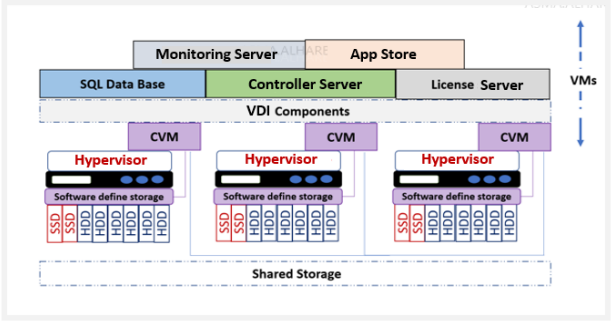

Figure 5. VDI Evaluation Infrastructure

A. *Storge Technolgy in VDI Infrastrucure:*

The storage, integrated in the testing infrastructure, is a combination of SSD and HDD disk drives attached to server as presented in Figure 5. This type of storage is called *All flash drives*, and managed by software-define technology.

In this evaluation, the storage technology relies on installing its software in a virtual machine on every server. The virtual machine that is managing the storage is known as Controller VM (CVM) software which provides central storage management by virtualizing all disks locally attached to HCI servers [14]. In addition, it provides a centralized single console for administrators to monitor the performance and resource utilization of multiple clusters in

different sites. The solution facilitates performing system health checks and generating alerts which help in troubleshooting and reducing resolution time [15].

B. *Desktop Virtualization Components and Architchture:*

In this study, desktop virtualization is based on Xendesktop solution. "Fig. 6" shows how VDI components interact with each other to deliver desktops to end-users. VDI is based on client-server architecture. Thus, end-user devices must run a software agent to establish communication to VDI infrastructure through ICA/HDX remote graphic protocol where virtual machines are hosted. In the beginning, users login to an App Store web server to select their entitled resources (e.g. Windows 10 desktop). If the selection is identified, a request is sent to Controller or the broker server. The broker is deemed the main component in VDI because it is responsible for user authentication, monitoring the status of virtual machines, and connecting users to the available VMs. In other words, it is communicating with other components which are Licenses server, Active Directory, and SQL databases to provide desktops to users [10].

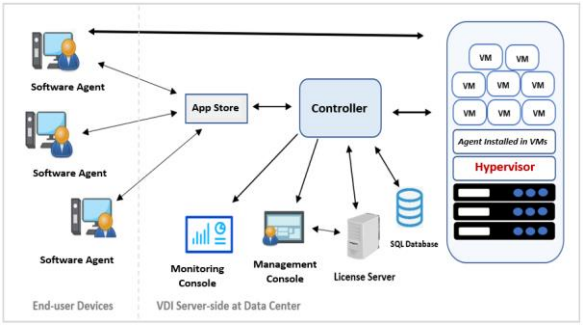

Figure 6. Desktop Virtualization Components

In this evaluation, Management console used to perform administration, and configuration tasks. The console helps technical support in troubleshooting activities, tracking licenses, and configuring roles [12]. One of the key features is the ability to create groups of machines (pool of desktops) with the same configuration and assign desktops to a group of users. As shown in "Fig.7", an administrator selects "*Deploy*" command from the console to create a group of cloned machines with the same configuration of the master image. After that, selecting "*Assign*" command will identify these VMs to a group of users. Using this method an administrator can prepare different pools of machines to serve different courses' requirements in short time.

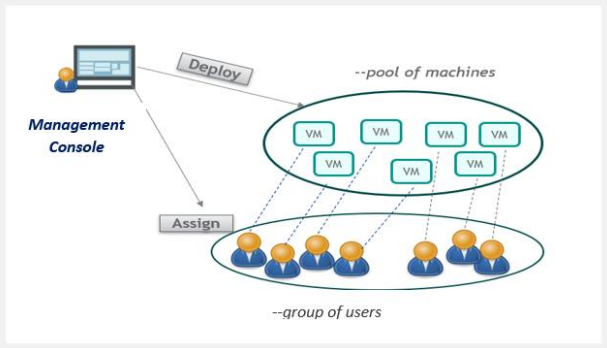

Figure 7. Presents How to Deploy Group of VMs and Assign Them to Users Through VDI Management Console.

C. *Operating System and Applications Requirements:*

The focus in this study was to assess the use of Windows 10 as the Operating System in provisioned desktops. As a noteworthy point, Windows 10 requires higher CPU consumption (32% more) than any other Operating System. The applications running on Windows 10 platform require additional GPUs compared to Windows 7 [9]. Therefore, VDI hardware is equipped with NVIDIA graphic cards to ensure better performance for intensive graphics applications with Windows 10.

Moreover, the type of applications utilized by professionals are demanding, and require advanced workstation configuration with special CPU, GPU and Memory (e.g. models' interpretations, 3D simulations, seismic applications) to run properly. Thus, there are three different workstation' configurations classified as General-use , Mid-range and High-end workstations to address applications requirements as shown Table 1.

TABLE 1. TRAINING CENTER WORKSTATION CONFIGURATIONS

PC configurations	CPU	GPU	Memory
General-use	4 Cores	2GB	16GB
Medium-range	8 Cores	4GB	32 GB
High-end	16 Cores	8 GB	64 GB

D. *Desktop Provisioning Method:*

The factor that makes VDI deployments faster than conventional is Desktop Provisioning service. The utilized provisioning module in this study is Machine Creation Services (MCS). Through MCS, VMs are cloned form a master image and the created machines are called "*linked-clone*" [11]. In this process, the master image is set as read-only and the replicated VMs do not copy the whole image. Thus, all data will be cleared out from the VM upon log-off but it will be saved on another disk called *differential disk*. Any change or update made to the master image can

be reflected onto the cloned VMs accordingly by selecting the update option in the Management console.

MCS also contributes in saving disk space. As Chrobak [2] mentioned, this type of implementation saves approximately 75 % of disk space. This is because the cloned machines initially have 1 GB of space and the capacity increases as needed until it reaches the maximum storage capacity. For example, let us say the capacity for a master image is 20 GB and there are 100 cloned machines with the same disk size. The total disk space required is 2TB. However, with MCS, each machine has 1 GB for saving its data which means that the 100 machines consume 120 GB of disk space altogether [2][3].

E. End-users Devices:

To assess the performance of VDI in regards to the end-user devices, thin clients were used in this study. Thin client devices run light versions of Operating Systems such as Windows 10 IOT, which is the smallest Windows 10 edition. During the assessment, Windows 10 IOT and Linux-based thin client were utilized. Note that there are differences between Windows and Linux devices in terms of the maximum supported monitors and VDI accessibility method. Table 2 shows the features of Linux and Windows thin clients.

TABLE 2. FEATURES OF THIN CLIENTS

Attributes	Thin client	
	Windows 10 IOT	Linux
Supported monitors	4	3
Access	Agent/ Internet Browser	Internet Browser

5. PRACTICAL EXPERIMENT SETUP

The assessed system was placed in production for five months. Two classrooms were reserved to conduct training sessions using VDI technology. As seen in "Fig. 8", the capacity of each classroom is six students and each device is connected with two monitors. During the evaluation, Windows 10 IOT and Linux thin clients were put in two separate classrooms.

The infrastructure for the study has limited resources. Thus, the hardware was sized based on the highest workstation configuration and designed to accommodate Six High-end VMs. Accordingly, VMs can be configured to run Six Medium-range or Twelve General-use VMs. User profiles and data were kept in a shared folder within the solution to avoid slowness. The network connectivity for VDI server is 10 GB while the network connection to each end-user devices is limited to 1 GB.

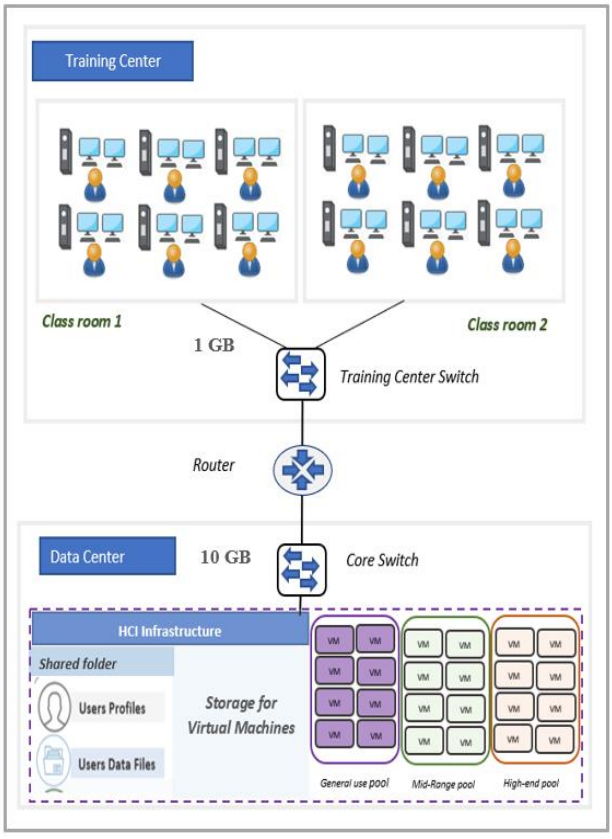

Figure 8. VDI Evaluation Setup.

6. RESULTS AND DISCUSSION

Nowadays, there is a wide range of tools to automate workstations' administration and, usually firms' recruitment for workstation administrators is based on an estimate of 500+ workstations per administrator [5].

Regardless of the number of supported desktops, one VDI administrator can remotely manage many desktop activities from centralized location at the same time. Hence, VDI simplifies the process of managing operational activities such as desktop deployment, software updates and maintenance especially for an academic environment [7].

From the study, both VDI and conventional environments' update process were monitored for a period of five consecutive months. "Fig. 9" presents the readings that have been taken from reporting tools after one day of applying Windows 10 monthly updates.

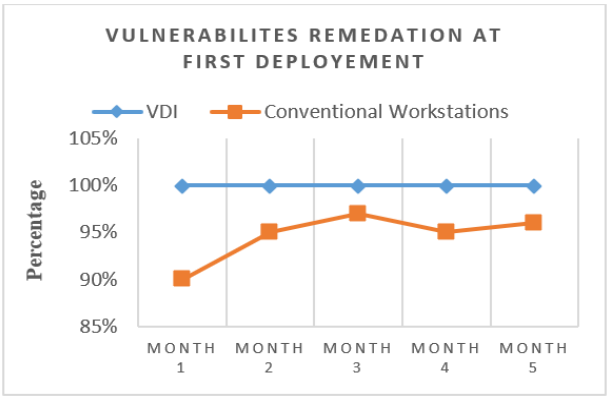

Figure 9. Output of Reporting Tool after One Day form VDI and Typical Workstation Environment.

It is clear that VDI is efficient in remediating all desktop vulnerabilities since 100% of targeted desktops received updates at once the very first time. On the other hand, conventional workstation approach relies on automated software/tool which is gradually updating workstations with a maximum achieved percentage of about 95%. Thus, administrator manual intervention is required to achieve 100% workstation remediation and ensure no vulnerabilities remain.

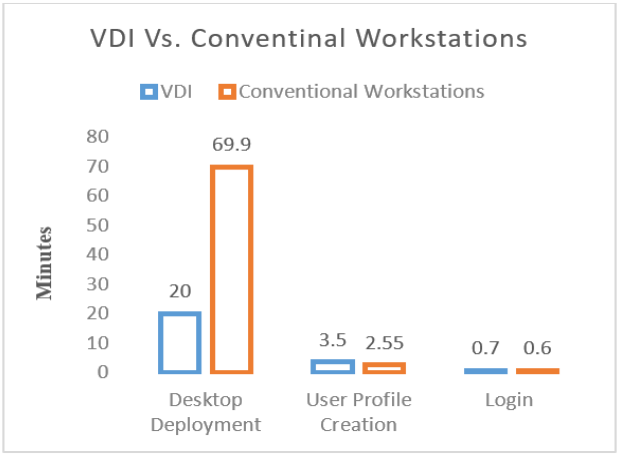

Figure 10. Recorded Time While Performing Activities (Desktop Deployment, User Profile Creation and Login) in One VM and One Workstation.

The time required to complete desktop deployment, user profile creation and login into a machine is another factor to gauge the effectiveness of having VDI as an alternative to conventional. With reference to "Fig.10", the average duration of executing each activity (i.e. Desktop Deployment, Profile Creation and Login) indicates that the desktop deployment using VDI technology was significantly faster by 71.5%. With VDI, the process of desktop deployment and building image takes around 20 minutes compared to 69.9 minutes when re-imaging a desktop using the conventional approach. It is proven that VDI shortens desktop implementation from hours to minutes [6].

The image size of VDI desktop was reduced by 42% compared to conventional workstation environment. This is due to the fact that VDI is device independent; and hence, there is no need to include additional hardware drivers on Windows image. Accordingly, updating and rolling back VMs to previous state are time efficient processes [5]. For the other two covered activities in the analysis; namely, User Profile Creation and Log-in, they are comparable between both environments.

During the study, it was clear that the average time required for an administrator to reimage workstations or rebuild VMs is increasing as the number of devices grow. The process of reimaging the conventional workstations is lengthy and requires manual work. By comparing the recorded time intervals, building VDI desktops was more efficient and faster than reimaging conventional workstations for the same number of devices.

The evaluation shows that the time required to prepare desktop in VDI gets slightly longer as the number of VMs increases. This is because the infrastructure utilizing the hybrid (SSD and HDD) which makes the activities related to rebuilding image or refreshing VMs a bit slower. However, the master image should be kept on speed storage (SSD) to have the optimum performance using MCS provisioning technique [2].

VDI depends on sharing hardware resources with multiple users. It is important to calculate the VDI performance with concurrent connections to know the endurance of the system. User opinions were surveyed after each training session about their experience with the VDI. The feedback covers key questions about their satisfaction with VDI as a viable alternative to the conventional desktop, applications performance and the utilization of thin client devices. Table 3 presents the end-users survey results based on which the analysis of VDI performance on the targeted areas/aspects.

TABLE 3. USERS FEEDBACK COLLECTED AFTER EACH TRAINING SESSION.

Attributes	Partially (*Half of Users or 50% connected to VDI*)	Completely (*All users or 100% connected to VDI*)
Login time Duration 1) Similar to PC. (= *PC*) 2) Different than PC but less than 1 min. (< *1min*). 3) Different than PC but more than 1 min. (>*1min*.)	- 75% (<*1min*.) - 25% (= *PC*)	- 90% (> *1 min.)* - 10% (< *1min.)*

Experience of Applications' performance 1) Similar to PC. (= *PC*) 2) Different with Acceptable slowness (*Acceptable app Slowness*) 3) Different with unacceptable slowness (*unacceptable*)	- 85% (Acceptable app Slowness) - 15% (= *PC*)	- 96% (*unacceptable*) - 4% (Acceptable app Slowness)
Experience of end-user devices' performance 1) Linux thin clients 2) Windows 10 thin clients	- 100% (Prefer Linux devices)	-100%(Prefer Linux devices)

Considering the concurrent login capabilities in VDI environment, the process of logging in to a normal workstation at the training centre takes 30-35 seconds while it takes 40 seconds in VM which is slightly slower. The login time of one VM is taken as a reference to calculate the log-in time as the number of connected users increases as shown in "Fig. 11".

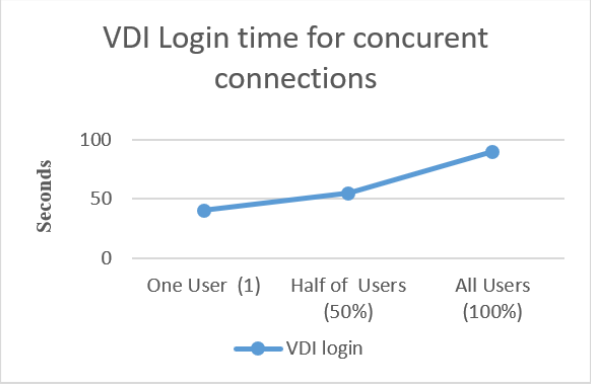

Figure 11.Login Time for Concurrent Connection based on Users Utilization.

In this evaluation, users encountered slowness in navigating their desktops, launching applications and getting inputs from keyboard keystrokes when the number of VMs reaches its peak (i.e. all users connected to VMs). The poor performance was related to scalability (limited system resources) of the system because VDI infrastructure depends on resource sharing. If storage or memory could not handle the load, unacceptable performance resulted. As a remedy, the memory and storage were increased and the performance was enhanced.

The study also showed that the performance of running standard applications (e.g. Microsoft office suite), and heavy intensive applications graphics with high CPU utilization used by geological and geophysics applications were similar in both environments. However, it was found that increasing the number of users in VDI infrastructure would cause slowness and poor resolution due to limited resources of memory, CPU and GPU. Frequent freezing and slow graphic movement was experienced in cases where applications were used by more than four users simultaneously. Quality issues in real-time transmission (video and audio) were detected if the load increased. Such observations were considered common issues of VDI system in CPU and GPU intensive applications [5].

For the performance of thin clients in VDI, it was found that Linux thin clients were fast and meeting the user expectations but they were not supporting agent-based applications. Meanwhile, Windows thin clients demonstrated noticeable slowness. In addition, Linux thin clients had less administration overhead as they needed less device updating frequency compared to Windows 10 IOT. In fact, Linux thin clients were required to be updated for only one time during the five months study while Windows 10 IOT thin clients were updated on a monthly basis.

7. CHALLENGES

Although VDI has many benefits for different organizations (e.g. education, hospitals and banking sectors), its deployment has many challenges [3].

One of these challenges is the high initial cost. The capital cost associated with the hardware, licenses and software is expensive compared to procuring new workstations. In addition to the hardware initial cost, this high cost is also attributed to the fact that each VDI user needs to have licences to access the VMs and for the use of VDI system components. Thus, the hardware cost can dramatically increase. However, considering the long-term operational benefits; VDI is an effective solution in some use cases [3].

Another challenge is providing the required training prior to the adoption of VDI as replacement for workstation environment. It is important to ensure that the administrators are prepared with the right skills to deal with VDI environment. As a minimum, this would cover system deployment, troubleshooting, and daily operations. In order to avoid user reluctance in accepting a VDI environment, proper user training must be conducted. These attribute to higher costs which should be accounted for [3].

System complexity is another challenge that requires forming a team with skilled members possessing diverse expertise including network, storage, and security. Hence, the employed personnel are required to possess the background and discipline covering all VDI system components [3].

Moreover, it is observed from the study that the VDI does not support Windows 10 biometric authentication (e.g. fingerprint, smart card and face recognition). This

limitation will not allow full utilization of Windows 10 available features that are widely used in the conventional environment.

Last but not least, VDI is a network dependent technology. Users without network connectivity cannot access their desktops. To ensure system reliability, it is recommended that organizations have a strategy to consider redundancy and eliminate single points of failures such as network, electricity, VMs, servers, etc. [2].

8. Conclusion

VDI technical evaluations revealed that the capabilities of this technology can serve different type of users' requirements covering advance computations and visualization rendering. This can be provided as long as the system is properly designed for scalability and equipped with the right resources. Although the initial investment for VDI is costly, but the return of investment will pay back over a period of time by overcoming the cost of operations and maintenance, leading to high efficiency and time effectiveness. Furthermore, current VDI implementations impose different technical challenges that will be overcome as this technology rapidly advances to meet the market needs.

References

[1] R.Padhy, M. Patra and S. Satapathy, "Virtualization Techniques & Technologies: State-of-the-art," *Journal of Global Research in Computer Science*, vol. 2, no. 12, pp. 29-43, Decomber, 2011. [On-line]. Available: www.jgrcs.info [Accessed: Jun. 12, 2019].

[2] P. Chrobak, "Implementation of Virtual Desktop Infrastructure in academic laboratories ," *in 2014 Federated Conference on Computer Science and Information Systems*, Warsaw, Poland , IEEE, Sept. 2014, pp. 119-1146.

[3] A. Rot and P. Chrobak, "Benefits, Limitations and Costs of IT Infrastructure Virtualization in the Academic Environment. Case Study using VDI technology," in *13th International Conference on Software Technology, ICSOFT 2018*, Porto, Portugal, Jul. 2018, pp. 704-711.

[4] J. Brendel, " The pros and cons of a virtual desktop infrsatrucrue Desktops off the Rack". *Admin Magaizine*, 2013.[On-line]. Available http://coh.duckdns.org/ADMINMagazine/html/2013/16/056-061_VDIBasics/056-061_VDIBasics.html [Accessed: 15 Aug. 2019].

[5] *Top 10 Benefits of VDI*, Mavenspire, Jun. 2016.[On-line]. Available: http://www.mavenspire.com/blog/top-10-benefits-of-vdi/ [Accessed: 2 Aug. 2019].

[6] K. Hess, " Desktop Virtualization vs Virtual Desktop Infrasturuxre," Jun. 2011.[On-line]. Available: https://www.zdnet.com/article/desktop virtualization-vs-virtual-desktop-infrastructure/ [Accessed: 16 Aug. 2019].

[7] H. Rahman, A. Shawahna, F. Azzedin, A. Alyahya and F. Sajjad, "Performance evaluation of VDI environment," *in: 2016 Sixth International Confrance on Innovative Computing Technology (INTECH)*, Dublin, IEEE, pp. 104-109, Aug, 2016. [online]. Available : https://www.researchgate.net/publication/313539824_Performance_evaluation_of_VDI_environment [Accessed: 27 Aug. 2019].

[8] S. Agarwal, A. Nath and R. Biswas, "Virtual Desktop Infrastrucure in higher Education Instituation: Energy Efficiency as an Application of Green Computing ," *In:2014 International Confrance on Communication systems and Network Technologies (CSNT)* , Bhopal,IEEE, pp. 601-605, Apr.2014. [online]. Available : https://www.researchgate.net/publication/271498006 [Accessed: 27 Aug. 2019].

[9] "See the difference for yourself: how to set up your own Windows 10 VDI test environment with NVIDIA Virtual GPUsoltions," *Whitepaper*, nvidia corporation [Online]. Avilable: http://images.nvidia.com/content/grid/pdf/HowToSetUpWIN10TestEnviroment.pdf [Accessed: 6 Sep. 2019]

[10] *Citrix XenDesktop 7.15 LTSR Architecture and Components*, Note of an IT Pro, Nov, 2017.[On-line]. Available: https://shabaztech.com/citrix-xenapp-xendesktop-7-15-ltsr-architecture-components/ [Accessed: 2 Jul. 2019].

[11] M. Rouse,"Citrix Machine Creation Services (Citrix MCS)," *in Citrix Synergy 2016 confrance coverage*, Mar. 2017 .[On-line]. Available https://searchvirtualdesktop.techtarget.com/definition/Citrix-Machine-Creation-Services-Citrix-MCS [Accessed: 18 Jul. 2019].

[12] Inside Citrix chapter eleven – The one with Citrix Studio," E-Book Inside Citrix- the flecast mangment architecture.[Online]. Avalilavle: https://www.basvankaam.com/inside-citrix-chapter-eleven-the-one-with-citrix-studio/ [Accessed: 10 Jul. 2019].

[13] A. Bednarz, " What is hyperconvergence?,"Network World from IDG, Feb. 2019. [online]. Avilable : https://www.networkworld.com/article/3207567/what-is-hyperconvergence.html [Accessed: 17 Jul. 2019].

[14] *Nutanix Plantofrm overview*, Nutanix Web Console Guide NOS 4.0, May. 2015. [Online]. Avalilavle: https://portal.nutanix.com/#/page/docs/details?targetId=Web_Console_Guide-NOS_v4_0:app_about_nutanix_complete_cluster_c.html [Accessed: 17 Aug. 2019]

[15] " What is Nutanix Prism Central," *Nutanix Prism Central:Pro Vs Starter Features*,Aug,2019.[Online].Avalilavle: https://hyperhci.com/2019/08/11/nutanix-prism-central-prism-pro-vs-prism-starter-features/ [Accessed: 20 Sep.. 2019]

[16] Chelsie ,"Virtualization Desktop Infrastrucures: The History, Benefits and Drawbacks," *InfoSec Digest Blog TS Factory*, Jul. 2019. [Online]. Avalilavle:https://www.tsfactory.com/forums/infosecdigest/2019/07/25/vdi_basics/ [Accessed: 27 Sep.. 2019]

[17] P. Oven and B. Coombs, "A complete history of VMWare and VDI," E-Book, *Mastering VMware Horizon 7*, Oct. 2016. [Online]. Avalilavle: https://subscription.packtpub.com/book/virtualization_and_cloud/9781786466396/1/ch01lvl1sec9/a-complete-history-of-vmware-and-vdi [Accessed: 10 Aug.. 2019]

[18] S. Conroy, "History of Virtualization," *I Don't Know, Read The Manual*, Jan. 2018.[Online]. Avalilavle: https://www.idkrtm.com/history-of-virtualization/ [Accessed: 4 Sep.. 2019]

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