Implementation of VDI based Computer Laboratory in University Education System to Save Energy, Cost, and Adapt Technology Upgradation

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Summary
Computing laboratories of universities face a crucial challenge due to technology upgradation. Generally, hardware and software have a few years of lifetime and get outdated after a certain period of time. Especially, the hardware lifespan is too short. Moreover, the maintenance and usage efficiency of the university laboratory is not up to the mark due to resource constraints. To cope up with the software and hardware upgradations, investing again and again for the same laboratory is very tedious and cost inefficient, especially for a developing country like Bangladesh. This paper recommends utilization of Virtual Desktop Infrastructure (VDI) under a cloud-based environment to improve the efficiency and maintenance of a computing laboratory. In this paper, we propose a cloud-based network map for the university computing laboratory alongside with its implementation. Several experiments were conducted to identify the energy efficiency, cost, and performance parameters statistics of the proposed solution. The experimental result establishes the proposed recommendation as a cost effective and efficient approach to tackle the aforementioned challenges as well as it increases the versatility of computing in university laboratories.

Key words:
Virtual desktop; Green Computing; Cloud computing; Virtualization techniques; Energy consumption;

1. Introduction

Computer Science (CS) is being identified as the compulsory education in today's curriculum [2] and computing laboratory is a focal demand of CS education strategy. However, the contents taught in CS courses are highly variable and the courses that are mentored using computers cover extensive corners and capacities. For this reason, modern day computer laboratories demand a model that satisfies both stability and elasticity. Furthermore, safety standards should be strictly followed in these laboratories since fundamental exercises like database design, assembly programming, shell scripting or networking exercises can damage laboratory infrastructures. File damage and system malfunction like hardware or software is a regular affair that is very difficult to recover as well as time consuming. Frequent maintenance and troubleshooting in laboratory can affect the regular course schedules. Alongside these, the traditional computer laboratories have scalability issues. For example, it is a tedious and time consuming task for a lab administrator to install software and hardware in every single machine. Moreover, if a software upgradation is needed, there is no alternative to visit each computer and update software. On the other hand, computing resources needed for research experiments are highly variable. As a result some computing machines remain idle with high computing environment while some run out of memories or other computing resources. In essence, implementation and management of current hardware centered computing laboratories is a tedious and cost inefficient approach.

For developing a comprehensive and scalable education system there is no alternative to virtual infrastructure based technology. It opens the door of versatility since same infrastructure can be used for different purposes. For example, some thin clients can be used for research and some can be used for UNIX based system in the same platform under same blade using Virtual Machine (VM) [3]. As it is implemented in datacenter blade, so performance and hardware capability issues are solved regardless of software or version due to central virtualized environment.

Computer virtualization technology includes server virtualization, application virtualization, and desktop virtualization. Other techniques like- Network virtualization, graphics virtualization technologies are also evolving rapidly [1]. In the near future, all the current physical device will support the virtualization technology to achieve the IaaS (infrastructure as a service) and the real meaning of cloud computing. Virtual desktop adopts virtualization technology and virtual desktop technology, thin client and data centers to provide users alternative to traditional personal computing solutions as well as achieve security and flexibility [1].

Desktop virtualization technology or Virtual Desktop Infrastructure (VDI) is a cloud-based computing technology that allows administrators and users to use virtual desktops that are hosted under a centralized control

Manuscript received July 7, 2020
Manuscript revised July 20, 2020

in the data center. Users can have the real personal computing environment through LAN or remote access. This supports multiple real-time virtual operating environment on a single physical machine and distributes the essential hardware resources. VDI is a grand choice to tackle aforementioned challenges For example, system or software upgradation for administrator can be executed very easily because all desktop can be upgraded from central server through Unified Management System. VDI offers a maintenance and management revolution that overcomes efficiency rigidity. On the other hand, it is also possible to use backdated computer to connect to cloud service as a client which can cut capital investment and improve the efficiency of laboratory usage [4].

Fig. 1 Cloud Based Laboratory (Conceptual)

2. Related Works

There are several approaches can be found in literature that justifies the implementation feasibility of VDI in university laboratory. Agrawal et al. [5] designed the VDI infrastructure to establish energy saving green computing within low cost. For these they showed experimental statistics to prove the institutional and economic reasons of VDI in education industry. Lee Yong et al. [6] used desktop virtualization and identified that it certainly improves security and reduces power consumption. The use of VDI in e-learning is explained by Makoto et al. in [7]. All of the approaches described here executed their experiments on emulator. In this paper, we have executed all the experiment in a real data center environment that will be discussed later in experimental setup section.

Some interesting debates by Miseviciene et al. [8] and DaSilva et al. [9] about the IT facilitated service challenges in University education system has established our proposed solution with a stronger base. Because, VDI technology is seamless solution comparing to other IT properties as those will be powerless and unfit within few years due to fast changes of hardwire devices.

3. Application of VDI to Save Energy and Green Computing

Technologies that are friendly to the environment and help to maintain ecological balances refers to Green. It comprises with the relations, steps, and practices of personal computer uses and any customs of Information Technology (IT) [10]. To minimize greenhouse gases and e-waste while using data centers, networks, and personal computers is a green computing practice. After all, it is an efficient way of implementing IT that saves ecology, energy, and money [12]. For instance, capabilities of today's PC is too high. If we share this PC to many clients it will help to utilize the additional abilities. Thin Client for virtual desktop does the same thing that discussed above and just use 8 watts (ZTE- CT321 for our experiment). In general, the lifetime of thin client is more than ten years compare to traditional PCs [13]. It saves energy and produces very little e-waste. This technique is effective and makes a simple way to solve composite problem.

Thin Client saves 75% on hardware [13]. It consumes less power, so it cuts energy usage about 85% for each user [13]. As it produces actually no heat, cooling solution is not appreciated. Now it is clear that VDI saves energy and reduces cost. In order to save cost and energy, estimation competency of required server and clients is a vital step. Datacenter provides integrated environment of hardware and software to deploy VDI based application. It enables multiple users to share a single operating system instance concurrently.

In our experimental each server (EC600 G3 CPU: Intel 2-L5 252a v4 18-core, 2 10 GHz; 13 cache; Memory-240OMhz 6'32G=192G DDR4; HDD: 2*600G (SAS 12G 2.5" hard drive: 10kpm); Port: 2.GE, 2-10GE; 3.1 GHz, 12 GB RAM / 500GB HDD) was connected to 1:10 thin-client devices (Model-CT321- CPU Intel D2550, dual-core, 1.86G Hz, Storage 8G/16G/32/64G SSD). The operating system on each VM is Windows 7. The energy friendliness of the above-used server is given below:

- Each fan can recognize service pressure. So, dynamically it speeds up when pressure is high.
- Frequency conversion ability control the CPU working frequency by reading service pressure
- Devices are green and ecological
- Transformation adeptness up to 94% [16] [17]

Saving energy through versatile technique and way is a broad research area in computing industries nowadays. As a VDI hardware we have used blade server and disk array (KU5200) in our experiment. The consumption and saving

Table 1: Power saving and consumption details

Consumption and savings of VDI with respect to a typical Lab (PCs) [5]						
Power calculation in **watts**					%age comparison between Thin Client w.r.t. a PC	
Blade	(Thin Client)	No of terminals	Total	Per terminal	Power exhausted	Saving
41.25	8	10	121.25	12.12	28.99	71.01
41.25	8	11	129.25	11.72	28.03	71.97
41.25	8	12	137.25	11.43	27.34	72.66
41.25	8	13	145.25	11.17	26.72	73.28
41.25	8	30	281.25	9.37	22.41	77.59
41.25	8	40	361.25	9.03	21.60	78.80
41.25	8	50	441.25	8.82	21.10	79.90
41.25	8	70	601.25	8.58	20.52	79.48
Approximate typical power of a PC is 41.8						

of VDI with respect to traditional university laboratories is shown in Table-1 and Table-2 shows the usual power consumptions of different devices.

Table 2: Power consumption

Sl. NO	Node	Power Consumption	
		Watts	Amperes
1.	Blade	41.25w/blade	0.187
2.	Thin client	8	0.036
3.	PC	41.8	0.190
4.	Monitor-15”	22.44	0.102
5.	Monitor-18.5”	25.08	0.114

According to our setup, each blade can connect with 10 thin client. So, for ten virtual desktop, total power consumption is 121.25 watt. But for traditional computer, by following the Table-1 total power consumption for ten PC is 418 watt. Since, we can conclude that a VDI terminal saves 3.44 times than a traditional PC. In addition, it is also possible to control VM for saving energy by DC administrator. In other corner, it is also possible to increase the number of terminal for each blade by calculating vCPU and memory. On that special cases, the power consumption rate will vary more than the figured calculation. Fig. 2 demonstrates the power consumption versus saving rate of VDI users.

From the nature of the graph, we may take a decision that energy consumption and saving is about to constant with 20 terminal and above. If we consider a computer laboratory with 70 desktops of a University then the power consumption is 23408/8hours (Watts) in a day. But for VDI with 70 clients the consumed power will be 5611.667/8hours (watts) in a day. So, VDI energy saving is about 89%.

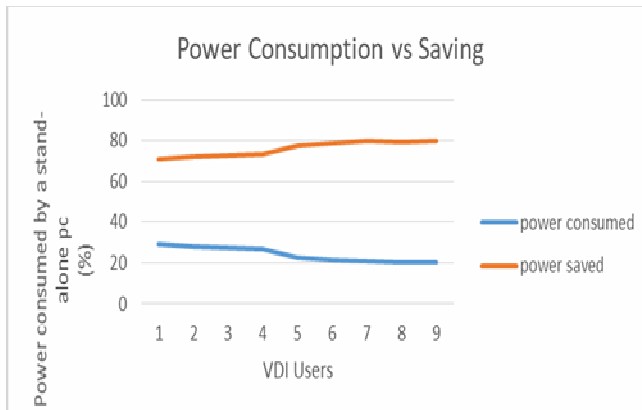

Fig. 2 Power consumption versus saving

4. Cost Comparison between Traditional Desktop and VDI based Solution

To calculate the cost of the VDI based solution for one terminal over a period of time, we used the following formula defined by [14] and it was also used by [20].

VDI Solution Cost = (No. of years * VDI Charges/Year) + Thin Device Price + Electricity Usage/Year * No. of Years

The VDI charges comprises the licenses for the applications, VM and the rent for the servers and IT infrastructure.

For the full power desktop, there is another formula. This formula contain only the price of the desktop and the electricity costs and charges for licenses for applications and operating systems, as follows:

Traditional Desktop Cost = Full Desktop Price + (Charges for Licenses/Year + Electricity Usage/Year) * No. of Years

The Table-3 is the result of the comparison.

Table 3: Cost comparison between common desktop and VDI

Power Analysis	Power Consumption		
	Common Desktop		VDI(Thin)
Power Usage(Watts)	Desktop(70)	Screens(70)	Clients(70)
Power Consumption Per Day	23408/8 hours	14044.8/8 hours	4810/8 Hours
Cost per Year($)	4200		500

5. Experiments and Performance Analysis

To implement VDI based laboratory we separated test environment into two architectural part as software architecture and hardware architecture. This is basically the VDI architecture of ZTE Corporation. By revising this we proposed VDI based university laboratory architecture. We also proposed storage and resource calculation for seventy terminal.

5.1 Hardware Architecture

A systematic procedure has been adopted in this paper to implement VDI based computing laboratory and performance of virtual desktops. In the first phase, seven servers, control domain server, and infrastructure server were installed. The hardware specifications of all servers are listed in Table-4.
On the other hand, the control domain server has three VMs installed. The first VM is the active directory. It is used to keep the records of users and authenticate the user credential whenever a user requests the virtual desktop. VMC (Virtual Management Center) is also used for performance statistics. All the operation is software controlled. All the allocation and system reservation is performed using proper channel. The below table is showing the hardware specification of control domain and infrastructure.
The following is the logical network map for experiment. This network map has secure design and checked by cloud and network experts and made up of by the suggestion of uptime institute. It also provide the message of experimental hardware architecture including all other optional devices.
The hardware architecture used for this experimental setup is described as follows:

Table-4: Experimental Hardware Specification

Name	Model	Specification
VMC Manager Server	EC600 G3	CPU: Intel Xeon E5-2620 V4(8core,20M Cache,2.10 GHz,with Heat sink) Memory: 4*32G (DDR4-2400 memory) Hard drive: 2*600G (SAS 2.5" hard drive: 10kprm) NIC: 2*GE, 4*10GE
ZXVE hosts (Common + high performan ce)	EC600 G3	CPU:Intel Xeon E5-2620 V4(8core,20M Cache,2.10 GHz,with Heat sink) Memory:4*32G (DDR4-2400 memory) Hard drive: 2*600G (SAS 2.5" hard drive:10kprm) NIC: 2*GE, 4*10GE
DISK ARRAY(I P+FC-SAN)	ZXCLO UD KU5200	Multi-core processor with X86 architecture, 2*800G SSD harddisk, 60*600G SAS hard drive 4*10GE optical port, with 5 expansion enclosure

Storage resource layer
In our experiment we used KU5200 disk array with controller as storage layer device. It has high price/performance ratio. The KU5200 storage support parallel extension and dynamic resource adjustment. Multiple KU5200s can make up a storage resource pool to provide flexible and effective data storage for cloud desktops.

Computing resource layer
The computing resource layer deals with computing resources for cloud desktops, including CPU and memory resources. The cloud desktop system virtualizes resources and delivers cloud desktops to the outside world through servers. We have used the following servers (blades) in our experimental setup:

E9000 Blade: It is a high-density and highly integrated blade computing server applicable to large-scale and integrated cloud desktop scenarios. The cloud desktop management and cloud desktop pool are configured with 330 blade servers, which are combined into 28 chassis. Each chassis has the 2*10GE*2 service and 2*10GE*2 storage, which are uplinked to the 9904 aggregation Switch; the 2*GE port is connected to two ZXR10 5950 management access switches in active/standby mode, and the 1*GE*2 IPMI port is connected to one ZXR10 5950 IPMI access switch.

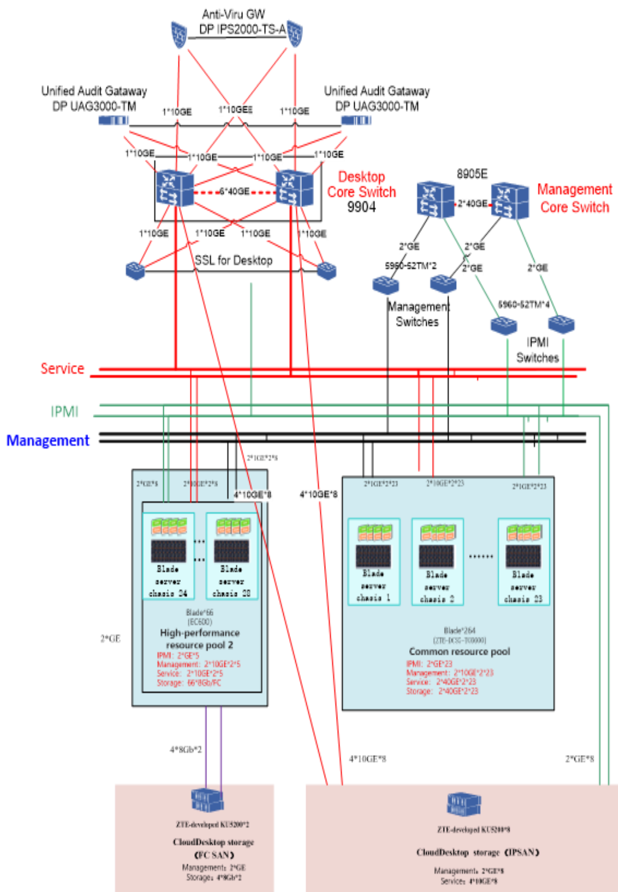

Fig. 3 Logical network map for Cloud Desktop

Acknowledgments Access Terminals:

Mobile Terminals:

For users to access intranet cloud desktops from external networks, DP SSL VPN gateways are used in the system. Through DP SSL VPN gateways, mobile terminals can perform Single Sign-On (SSO) to intranet cloud desktops.

Cloud terminals:

CT321 thin terminals are used in our laboratory. It is ZTE product and support Citrix ICA, RDP, ZTE RAP, VMware PCoIP, SPICE remote desktop protocols.

5.2 Software Architecture

Software architecture of our experiment involves virtualization software, cloud desktops, and O&M management.

Software architecture of our experiment is centrally based on uSmartView. The uSmartView is based on uSmartOS. Therefore, the software architecture of the uSmartView involves virtualization software, cloud desktops, and O&M management.

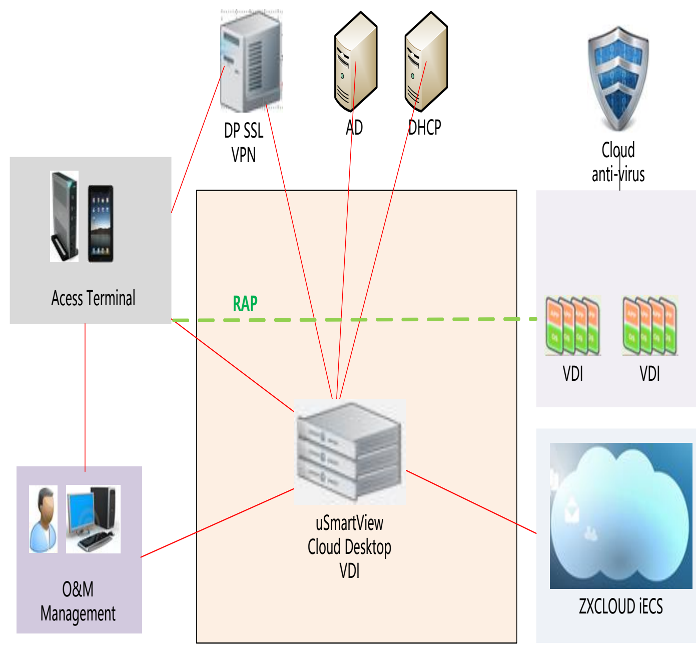

Fig. 4 Software architecture of the uSmartView

The software architecture of the uSmartView is described as follows:

ZXCLOUD IECS

iECS is a virtualization platform software that provides virtualization resources for VDI desktops, including CPUs, memory computing resources, storage resources, network resources, performance statistics, and system alarms.

uSmartView:

The uSmartView has two modules:

Desktop O&M management module: It supports desktop management, user management, data reports, and involves the following components: VDI desktops.

Desktop user application module: It provides access entries for different terminals. Users can access through clients, mobile phones, and tablets based on IOS or Android system.

O&M management

Performs O&M management for the entire system, and involves the cloud terminal management subsystem and cloud desktop management subsystem:

ZTE cloud terminal management subsystem
O&M management subsystem for thin terminals, providing thin terminal system update, software update, device control, terminal monitoring, security control, and other functions.

Cloud desktop management subsystem
It deals with O&M management subsystem for cloud desktops, providing resource pool management, cloud desktop management, alarm management, performance statistics management, permission management, log management, and other functions.

Security gateway module
With this module, users in external networks can access intranet could desktops through SSL VPN gateways, the gateways can be controlled, tunnels can be encrypted during transmission, and users can perform single sign-on to cloud desktops.

AD domain control module
This module is an optional system component of Windows Server of Microsoft. It can perform unified and integrated control for users and computers and perform integrated user authentication.

Basic functional service module
DHCP: DHCP service: supports dynamic IP address allocation.

Cloud antivirus module
Provides cloud antivirus functions for each virtual desktop user, and uses agent-free antivirus technologies to reduce VM performance cost due to antivirus to a great extent. This module is optional.

Proposed Laboratory Logical Map:
Figure-5 demonstrates the proposed network map of cloud based virtual desktop University laboratory. By revising the above discussed architecture we proposed the following calculations for target laboratory.

List of physical resources for each virtual desktop in proposed University Laboratories:

CPU of a single user: 2vCPU
Memory of a single user: 4G
Storage of a single user: 200G

The system supports statistics of physical machine's CPU use rate, memory use rate, disk use rate, port flow in/out speed, disk read/write times per second, disk read/write rate, and disk IO delay.

Cluster resource statistics: Include virtual CPU and memory use rate in the cluster, quantity of physical hosts and VMs in the cluster, and the top 5 physical hosts bearing the highest load in the cluster. The statistics will be displayed in the form of dashboard in the later section. [14][18, 19]

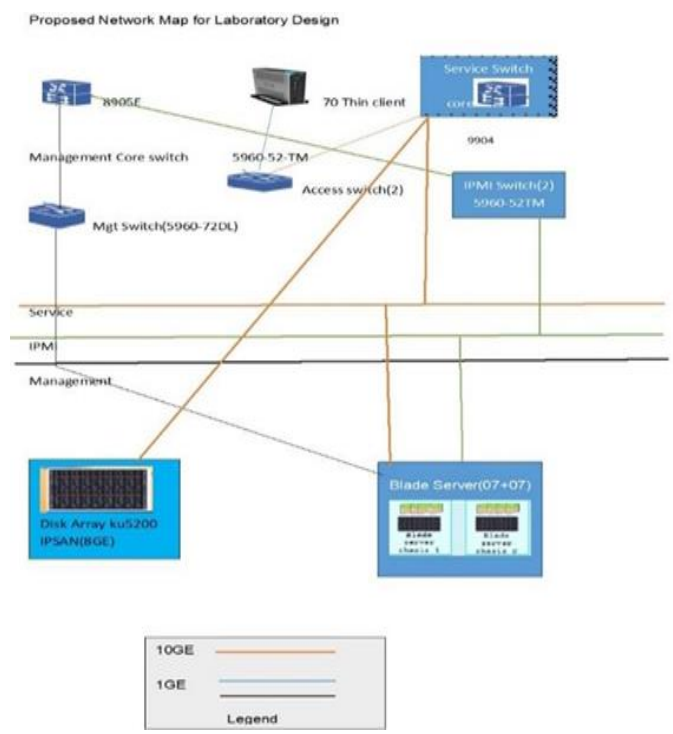

Fig. 5 Proposed Laboratory Network Map

The Table-5 below is the software list for proposed lab.

Table-5 Proposed lab Software list

Software Name	Model and Version	Qunatity
Desktop Cloud Authorization	iRAI VDI authorization/user	70
Cloud desktop management server Operating System	CGSL linux_64-bit(V4)	1 set
Management Server DB software	MySQL	1 set
Microsoft Authorization	Microsoft VDA latest version(Ultimate)	70 set
Terminal management software	Terminal Mgt. Software	1 set
	Terminal Mgt. Authorization	70 set

Storage and blade calculation for proposed Lab: As we considered total desktop number will be 70, so recommended storage and blade calculation are as follows: For 70pcs of Desktop, with 200G/Desktop using blade server and disk array we need the following blade calculation.
10Cloud Desktop /Blade *7=70 Cloud Desktop 7 blades for redundancy. The following figure is showing the blade in E-9000 including MAC, IPMI IP and gateway address.
Disk Array: By the configuration of our proposed disk array (ZXCLOUD KU5200) each expansion array has 28(each 600G) disks. So, for 70 machine including 200G (HDD) storage the recommended calculation is:
1 Disk Array*28 HDD/ Disk Array*600G/HDD=16800G=16.8T
16.8T/70 Cloud Desktop /1.2 raid==0.2T=200G /Cloud Desktop

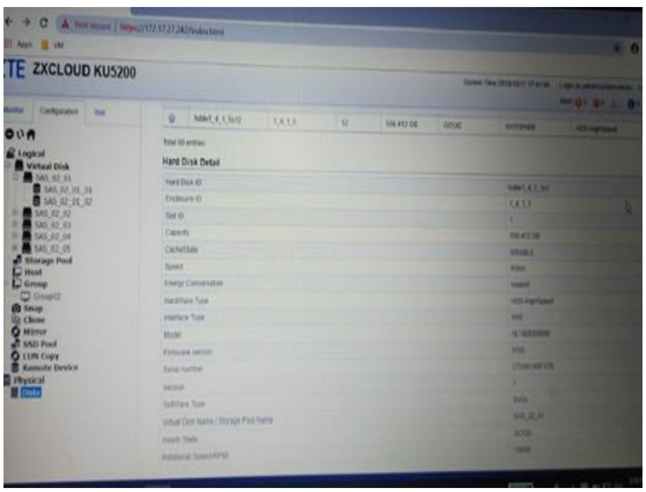

Fig. 6 ZXCLOUD KU5200 with hard disk details

Mass storages are divided into logical or virtual disk. All the virtual disk is then included under a pool. After making desired pool every host is divided under pool and group. Then each pool is inserted into a VMC. Then it is time to create single user desktop with credentials. For more details, the disk array and server is connected through IPSAN. Blade and storage is integrated using IQN (iSCSI Qualified Name) number. iSCSI protocol is used to ensure storage via blade communication. Now the VDI system is ready for service and test. To test the quality of service we tested from different location by using thin client and SSL VPN from laptop. All the connection and work environment were succeeded. For checking better performance multiple network were used. For example, using LAN the performance was best. The packet delay time was 35ms (average). The packet delay time from remote network like Dhaka, Bangladesh to Gazipur (kaliakior), Bangladesh is approximately above 90ms and packet loss varies on time to time. When it was checked the packet loss was null.

Supported User:

116 User*60% online Concurrency

116 User*60%=70 User online Concurrency.

Physical host performance analysis:
Performance parameter comprises CPU uses and memory usage. So, performance analysis can be easily done by using query. Fig. 7 and Fig. 8 demonstrates a sample for CPU usage statistics.

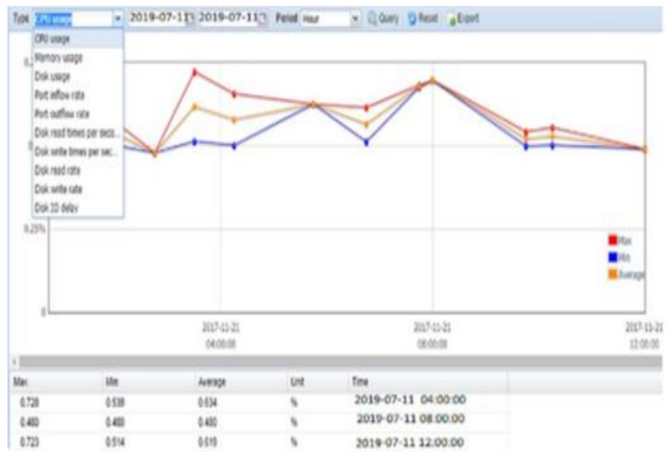

Fig. 7 Physical Host Performance Analysis of the experimental network

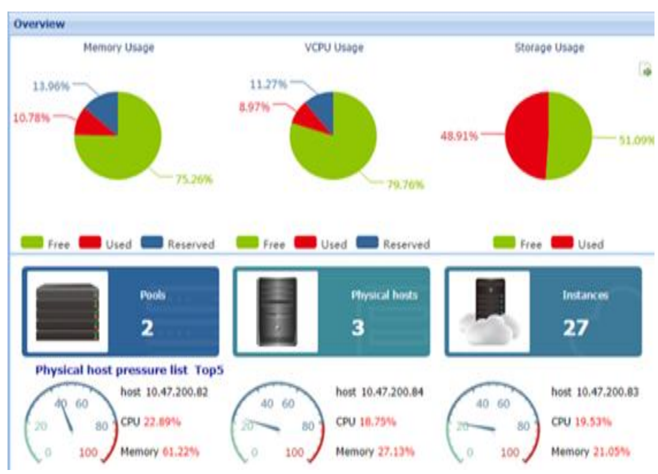

Fig. 8 physical host statistics

6. Conclusions

In this paper, we propose a VDI based laboratory for University. In the core of the proposal, there are a network map, software and hardware architecture, storage calculation and implementation details. Besides, we have compared the existing desktop environment with virtualized desktop. We have concluded that the maintenance cost can be reduced by the VDI environment. It can also reduce energy consumption and improve its security. In this paper, the energy savings of VDI affects from 45 watts to 26 watts using single desktop. If adjusting the power in the terminal of VDI then energy consumption reduces only 5 watts. So we can conclude with a remark that VDI is called the part of green environment and computing method that saves power consumption.

Acknowledgments

We are very grateful to Bangladesh National Data Center and Bangladesh Computer Council to carry out the research during its PAT (Project Acceptance Test).

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