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## Virtual Desktop Infrastructure in Higher Education Institution: An Application of Home and Mobile Computing Environment

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### Abstract

Currently, universities have rising demands to apply the incredible recent developments in computer technology that support students to achieve skills necessary for developing applied critical thinking in the contexts of online society. Medical and engineering subjects' practical learning and education scenarios are crucial to attain a set of competencies and applied skills. These recent developments allow sharing and resource allocation, which brings savings and maximize use, and therefore offer centralized management, increased security, and scalability. This paper describes the implantation of Virtual Desktop Infrastructure (VDI) to access the virtual laboratories that bring efficient use of resources as one of Al Balqa Applied University's (BAU) Private Cloud services. The concept of desktop virtualization implements the sharing of capabilities utilizing legacy machines, which reduces the cost of infrastructure and introduces increased security, mobility, scalability, agility, and high availability. Al Balqa Applied University uses the service extensively to facilitate in/off-campus learning, teaching, and administrative activities and continue performing their work and education functions remotely to cope with the COVID-19 pandemic.

**Keyword:** Virtual Desktop, Infrastructure, Hyper-V, Virtual labs, Private cloud, COVID-19.

### 1. Introduction

Currently, there is increasing demand for applying new technologies that help university college students obtain skills indispensable for developing applied critical wondering in the contexts of online society. This is possibly more applicable to Engineering subject education, where practical learning scenarios are essential to accomplishing a set of competencies and applied skills. In light of the lack of resources such as compu-

tational software; Cloud computing is recommended in educational progression while the university continues through digital transformations.

This research presents and discusses the results of a systematic analysis that addresses the implementation of Virtual Desktop Infrastructure (VDI) as a fundamental element of Al-Balqa Applied University Private Cloud (BAUPC). This private cloud consolidated thirteen scattered data centers into two data centers for optimal utilization of ICT resources. The BAUPC VDI service also aims to collaborate with other institutions to share a single expensive laboratory owned by and located in an individual university and/or supported by the higher education research funds. In addition, more people are embracing virtual machines (VMs) to aid the universities' teaching, learning, administrative, and health ICT infrastructure. The VDI helps the growth and flexibility of the BAUPC services and allows the university to take full benefit of its on-premises hardware (Alzoubaidi, A. R., 2016a; Alzoubaidi, A. R., 2016b; Alzoubaidi, A. R., 2016c).

The solutions were examined in the university's main campus office, personal computer systems (PCs), and laboratories. The main campus is the central administration campus of BAU multi-site across the country. It hosts one of the BAUPC data centers that deal with information and communication technology (ICT) services for 1500 faculty members, 2250 administrative and supporting staff, and 75 laboratories. The main campus was where the implementation was piloted, and the operating system Windows 7 and Office Microsoft Office 2013 requirements are used. Moreover, due to the concurrent license agreement with different vendors, the university requires that the infrastructure is available 24/7 for all sites on demand so that users could work anytime anywhere whenever needed, and the entire solution ought to put into place a virtual infrastructure that will provide high availability and business continuity.

Likewise, the university considers that the virtualized costly laboratories, such as chemical, Geographical Information System (GIS), and security, should have their virtualized applications infrastructure accessed remotely and distance education. Whether in the server or patron, virtualization science is largely used for sharing the capabilities of computer structures by splitting the assets between several virtual PCs.

The university school agrees with Microsoft technologies alongside the economic motives of existing solutions primarily based on Microsoft. The de facto choice is to use Microsoft technology, mainly Windows Server, Hyper-V® Server, System Center, and desktop operating system Windows Professional 8.1 and Microsoft Office Standard. Therefore, some client-server architecture applications or thin client, therefore without the need to installation, combine with remote login using presentation virtualization (Mercy L. et al., 2019).

For over two decades, Desktop Virtualization and Cloud Computing (CC) have transformed the ICT industry through reduced cost, simplified, centralized management, better security, flexibility, visibility, scalability, and higher availability. Several arrangements of desktop virtualization and CC can help educational institutions satisfy users' needs for mobility, agility, and flexibility while discharging the burden on ICT divisions to manage cost, security, and compliance. Additionally, desktop virtualization can empower more dynamic centralized management by separating the legacy desktop computing stack elements.

This research extends ongoing research; Balqa Private Cloud (BPC) migration,

(Alzoubaidi, A. R., 2016a; Alzoubaidi, A. R., 2016b; Alzoubaidi, A. R., 2016c; Alzoubaidi, A. R., 2016d), which designates how to implement and create an institutional virtualization implementation that achieves the intended goals and introduces comprehensive desktop-virtualization solutions based on their performance evaluation. It provides a practical high-level direction to help companies develop and implement desktop virtualization. Moreover, CC implementation in the enterprises and institutions and the term "XaaS" was invented. XaaS, or anything-as-a-service, was used to describe the seemingly endless list of digital services that can be delivered via the cloud. Cloud computing allows for "infinite" on-demand resources and offers the aptitude to pay for resources on an as-needed basis (Guide, P., 2013).

Several universities, community colleges, schools, and public and private sector enterprises have several branches, where almost 50% of their staff are equipped with old PCs. Furthermore, current educational institution's legacy PCs cannot run Windows 8 and 10, and MS is dropping support for Windows 7; universities are looking at a Windows 10 refresh, which did not support migration to windows 10 to run the application for educational research, and administrative business.

Specialized laboratories used for starving resources such as Chemical, GIS (Kharouf, R. A. A., Alzoubaidi, A. R., & Jweihan, M., 2017; Eugen, P., Rahman, A. A., & Doina, P. P., 2014; Alzoubaidi, A. R., Kharouf, A., & Adnan, R., 2013), and Security, which requires high computing, storage, and connectivity requirements, are financially no longer afforded where needed. National educational institutions suffer plenty of financial shortages to replace their legacy physical computer PCs every 3-5 years.

Educational institutions community (faculty, staff, and students) will access applications and services in/off-campus from various devices, such as smartphones and Boyds, to fulfill the evolving need to enable anywhere, anytime, any device access which offloads the laboratories excessive demands and costs. More educational establishments are shortly to understand the many advantages of moving away from physical desktops prefer virtual desktops that aid improved user mobility and remote access. This allows employees who are regularly on the go and need to pull up a virtual laptop containing a full range of virtual applications and data. Furthermore, it matches right into organizations' digital workspace workflows that already function similarly, regular consumption of cloud, web, and mobile apps throughout multiple contexts, especially if it is persistent VD (TechRepublic, n.d.; Ace Cloud Settings, 2018).

Educational institutions in particular and organizations, in general, have been aware of the problems mentioned above for years, but virtualization is the tipping factor for transformation has attained. The migration to today's Windows versions, expanded mobile access devices, and tighter IT budgets has created the best storm for desktop computing change.

The primary objective of this research is to implement and use the virtualization technology solution that fits the university's needs, considering the benefits of the services to faculty, staff, and students with flexible, secure, and agile computing services. The VDI solution is a cost-effective solution to cope with the university's financial situation. The most significant point of this project is its overall analysis because the expression of Total Cost of Ownership (TCO) and Return on Investment (ROI) are based on it (Agrawal, S., Biswas, R., & Nath, A., 2014, April). Also, BAU VDI research ran to evaluate, test and implement, and continuously enhance the university's cloud computing migration strategy.

## 2. Literature Review

Cloud computing splits the applications from the hosting hardware machine. It provides educational institutions and organizations with the on-demand provision of computing services over the network. Service providers such as Balqa Private Cloud own and manage the cloud infrastructure, including the networking devices, servers, and storage devices housed in BAU data centers. Virtualization is the underpinning that supports cloud computing; virtualization automates system processes to allow hardware independence, improves stability, increases flexibility and scalability, and high availability for education, health care, GIS, etc. (Alzoubaidi, A. R., 2016a; Alzoubaidi, A. R., 2016b; Alzoubaidi, A. R., 2016c; Alzoubaidi, A. R., 2016d; Rockwell Automation Publication, 2013; IT Exam Answers, 2019).

Virtualization abstracts compute resources in the form of virtual machines (VMs) interconnected with associated storage. The cloud orchestrates how virtualized compute, storage, and connectivity resources are assigned, provisioned, and offered. Virtualization is not necessary to create a cloud environment, but it enables rapid scaling of resources in a way that physical non-virtualized environments find hard to accomplish (Rockwell Automation Publication, 2013; Guide, P., 2013; Amanze B.C., Nwoke B.C., AmaFule I.A., Chilaka U., 2016).

A virtual laboratory is implemented to provide a training environment for practical exercises (Lee, K. H., Kwon, S. W., Shin, J. H., & Choi, G. S., 2015; Sianipar, J., Willems, C., & Meinel, C., 2016). Three types of virtualization can assist with desktop strategy, application virtualization, presentation virtualization, and desktop virtualization (DocPlayer, n.d.).

Virtual desktop infrastructure (VDI) is a desktop-centered service that hosts user desktop environments on remote servers and/or blade PCs; the hosts can access VDI over a network using a remote display protocol. Desktop virtualization solutions are software packages consisting of several programs, and these solutions are based on the hypervisor. There are various desktop virtualization solutions; Citrix, VMware, and Microsoft are the most popular, and they will be the focus of our research. Each solution has its hypervisor: Citrix uses XenServer, VMware uses ESX/ESXi Server, and Microsoft uses Hyper-V. Here, we construct a VDI that consists of a hypervisor and a desktop virtualization solution. The solution enables centralized servers to virtualize users' desktops on demands. Software applications and data are stored on a server, not on the local device (Citrix, n.d.; Cloudwards, 2020; Ace Cloud Settings, 2018).

Because the data resides in a central location, it is more secure than data housed on individual devices. Management is simplified, with patches, updates, and application deployment handled once from a centralized location. Storage needs are reduced, and with a single "command center" for all desktop management, compliance requirements are more easily met.

The VDI technology has been introduced to the e-learning system due to its features, such as flexibility and availability. However, the proposed solution is a network-based technology, and therefore its performance will be subject to the bandwidth of the network used (Rahman, H., Azzedin, F., Shawahna, A., Sajjad, F., & Abdulrahman, A. S., 2016, August).

The COVID-19 risk to the international businesses and industries, including edu-

ditional businesses, is feasibly worse than the health impact. The necessary isolation policy that was implemented to contain COVID-19 has a devastating effect on economic activity. Small and midsize businesses (SMB) are linked to large businesses, government departments, health organizations, and educational institutions as both suppliers and customers. Technology has an essential share in the daily operations of conducting business across all departmental functions, including sales, marketing, operations, finance, and customer support. Accordingly, we believe that the recent pandemic-triggered economic crumbling acts as a catalyst for IT investment priorities among SMBs. HOWEVER, the IT impact concerning small and midmarket firms is accelerating new PC purchases to be deployed for unexpected growth in work-at-home employees. The new Windows 10 operating system and underlying security procedures will create an opportunity as many SMB IT executives plan to integrate, support, and secure these assets. Mobility solutions plans will accelerate. Business decision-makers will aggressively move past devices to a mobile solution strategy - inclusive of mobility infrastructure, employees' applications and services, management, analytics, security that will exploit the capabilities of new endpoints.

As users express desires to embrace more mobile tools for teaching, learning, and treat patients more efficiently and have better access to digital tools, the opportunity to implement virtualization is significant to every employee within an organization. In addition, organizations may have skills and/or able to identify local expertise to focus on deploying VDI or DaaS or SD-WAN" solutions (Channel Futures, 2021).

The average person uses less than 5% of the capacity of their PC. The rest is wasted. The Desktop Virtualization solution is based on the simple fact that today's PCs are so powerful that the vast majority of applications only use a small fraction of the computer's capacity (Agrawal, S., Biswas, R., & Nath, A., 2014, April).

This research investigates the current setup for faculty, staff, and specialized laboratory PCs and workstations and evaluates different scenarios to support the direction and tipping points for the change. Meanwhile, migration to the latest Windows versions, increased mobile access devices, security concerns, and tighter IT budgets are considered. Moreover, currently, the outbreak of COVID-19 has created the perfect storm for desktop computing change, which needs responsive actions to facilitate distance learning, blended learning, and working from home.

### ***3. BAUPC and VDI Environment***

Besides the economical factor for introducing this service at the multi-campus or a consortium of universities, we build an environment where users can access and process tasks everywhere. They use their physical end system at the laboratory or office in the university. In addition, users are up to process tasks and jobs by accessing personal virtual desktop environments in other faculties or remote BAU sites. Furthermore, VDI guarantees students have access to resources, technology, and software required to complete lab work asynchronously. Al Balqa Applied University PC is a computing model that uses resources dedicated to BAU multi campuses. A private cloud utilizes many of the characteristics of the other cloud deployment models, including resource pooling, self-service, elasticity, and agility delivered in a standardized manner with the additional control and customization available from dedicated resources. The VDI is a

private, on-premises, internally hosted model regarding security, control, scale, cost, and availability of resources. The VDI is an extension to BAUPC services. The solution service to be implanted as part of the university ICT cloud computing strategy aiming at provision VDI as a Service. Using BAU Microsoft school agreement for products and services usage and the necessary calls to run off-campus remote desktops, the web and application platform, and more (Alzoubaidi, A. R., 2016a; Alzoubaidi, A. R., 2016b; Alzoubaidi, A. R., 2016c; Alzoubaidi, A. R., 2016d).

#### **4. Implementation**

In the COVID-19 environment, modern business, work from home, and distance learning all need access to services when and wherever they are needed. A clear-cut use case for proactive building and implementation can answer any use case that comes up in the future. The actual implementation process was divided into the following steps: Environment analysis and the requirements of the newly created infrastructure focused primarily on user requirements (Tulloch, M., 2010). The ability to implement flexible work by conducting VDI with their end systems used for their work. The system considerations for configuring VDI can be categorized into the following three factors: system configuration, user configuration, and data configuration, as detailed in (Lee, K. H., Kwon, S. W., Shin, J. H., & Choi, G. S., 2015). This research describes the design and practical implementation to accomplish another milestone of implementing the BAUPC strategy. To support the university's multi-campus environment in teaching, learning, and research to facilitate local and remote access to computing resources for educational and administrative purposes. This service is piloted for medical and engineering individuals and laboratories' local and remote access and medical doctors' rounds at the university's hospital. This allows medical students to access educational data and material according to a specialty by ethical guidelines.

The server specifications include (Intel Xeon E3 series, Quad-Core, 3.1 GHz, 12 GB RAM / 500GB HDD) was connected to 20 numbers legacy-client devices under Windows OS. Eventually, the Desktop PC environment (ranging from low specs P4 to Core i3, 2 GB RAM, 500 GB HDD).

The implantation was validated in a virtual laboratory, using 20 VMs to access remotely and locally AutoCAD 2016 on traditional legacy PCs, as well as GIS, chemical, and Medical laboratories, created on a visualized server hosted at BAUPC to provide VDI as a Service to BAU community. The implantation also extended access using any device anywhere for faculty, students, and staff at a reduced cost and other mentioned above benefits to use traditional PCs to run the latest operating systems and applications.

The VDI general system architecture for local and remote access includes home workers, students, and faculty. Also, patient care uses the system in the physician's round, which uses the hospital information system on a virtual desktop with intelligent devices. The VDI setup comprising of virtual private networks (VPN) or Software-defined Wide Area networks (SD-WAN), virtualized networks, VDI servers, access and management servers, and storage area network (SAN) switches. The system architecture was established to accomplish high availability and stability of the VDI service through the physical and logical redundant implementation of all servers such as a

management server, an access server, an active directory (AD) server, switch servers, and VPN or SD-WAN. Moreover, the VDI server was clustered so that the virtualization service can function even with hardware failure.

The success of this research is due to many reasons; the team's dedication to implementing VDI in reality, the utilization of BAU MS school agreement, which enables the university to use windows server, MS virtual layer software Hyper-V, and finally,, to achieve the university's Cloud strategy.

The university plans to deploy a comprehensive solution to serve its multiple campuses based on Windows Server 2012-19 with Hyper-V. The required components to deploy a Windows Server 2012-19 VDI environment, and the used VDI technology through enabling the following roles:

Remote Desktop Virtualization Host, Desktop Session Host, Desktop Connection Broker, Desktop Gateway, Desktop Web Access, and Remote Desktop Licensing (Nakivo, 2019).

VDI environment, including the model, experimental setup to run the required tests, is implanted at the computer center laboratories in different campuses. The setup provides students with virtual desktops where applications and client desktops run on a remote server and are delivered to client devices locally and over the Internet. CC in general and VDI, in particular, may be deployed utilizing either Greenfield or Brownfield deployment Options; Greenfield is typically used when infrastructure does not exist, and an organization has to build the cloud infrastructure starting from the physical layer, and brownfield is used when some of the infrastructure entities exist, which can be transformed to cloud infrastructure by deploying the remaining entities required for the cloud infrastructure.

## **5. Results and Discussion**

Academic and administrative applications hosted at the VDI server are accessed anywhere. Through this research, many Virtual labs are tested and built; AutoCAD virtual lab for Civil and architecture engineering dept., GIS for the department of Surveying and Geomatics Engineering, faculty, staff, and students, enabling them to use licensed applications during and after university hours at all BAU campuses. An implementation that reduced the cost of utilizing many copies of the software, at many campuses, on/off university schedules. BAU VDI will eliminate business needs to purchase new computers in order to achieve new Windows version migration. VDI as a Service, as intended, is one of the BAU private cloud services; it is a significant component designed, tested, and implemented to provide VDI services as follows:

1. In/Off University working program users' access. VDI community services; Students, faculty, and staff may securely connect to the VDI service domain resources to access authorized applications. They are using any device anytime, anywhere.

2. In/Off working program laboratories access. VDI services for on/off-campus to access educational and administrative IT resources, hardware, software, and specialized labs and applications, making full utilization of the expensive resources with no redundancies or extra license fees and specialized simulation labs (Chemical, GIS, Medical, Security and Forensics, etc.) according to a predefined schedule for in/off University working hours and using any device anytime, anywhere.

3. VDI's initial implemented phase covered one chemistry, AutoCAD, and one Security laboratory, equipped with 20 P4 legacy PCs each, running Windows latest licensed versions under Microsoft school agreement and software to create virtual desktops which enable multiple users to share a single operating system instance simultaneously. This setup substitutes, procuring new PCs stack to process high processing operations, graphics applications, store data and related applications in dedicated compute, storage, and internetworked secure setup. This initial implementation included 10 legacy PCs for administrative staff to access the university information systems.

BAUPC VDI as a Service initial phase supports virtual desktops and virtual labs using low specs legacy PCs running windows clients, with its maximum cost approximately 100 JD each compared to 700-3000 JDs for medium to high specs stations requirements for different users ranging from browsing to Matlab, GIS, CAD and simulations applications, adding the cost of servers for each lab which are centralized in the BAUPC. There is a clear cost-saving; the cost decreases by 30-50% beside the other benefits of VDI.

This completes the Virtual Desktop Managed Pool deployment, and now you are off to the races. Our research has two VM pools, one for the virtual lab we had created and 10 PCs we will create for staff & faculty works.

Virtual desktop infrastructure implementation will eliminate businesses' need to purchase new computers to achieve Windows migration of the PCs. PCs can consume 7-10% of IT budgets yet provide no competitive advantage. With continued economic volatility, businesses are keeping a closer rein on IT expenditures. Wholesale PC refreshments and Windows 7 upgrades are no longer feasible, and the cost of supporting an increasingly distributed user base needs to be reduced.

## **6. Conclusions**

In the current information age, it is important to deal with IT and personnel resources effectively. Efficient resource allocation brings savings and maximizes their use and thus increases the possibilities for competition. This study economically analyzed the investment effects of VDI implementation at BAUPC services, virtual labs that are gaining attention for their use of emerging technologies. The results of our study confirmed that VDI could have an economic impact on virtual labs operation. Also, currently, the new option for students and staff working remotely during covid-19.

As a result, the service is available for students, faculty, and staff looking for e-learning and working in remote computer labs through BAUPC VDI service as an application portal that allows authorized users to access individual applications available in the University regardless of its hosting BAU campus. The beginning of a pilot suite to make many licensed applications available to all University students via the VDI. The VDI application access provision to campus and department home directory as well, so that your work can be stored in your designated storage. This should allow you to work on projects in virtual labs or via VDI in central storage.

This implemented VDI provides on/off-campus access for educational and administrative resources, hardware, software, specialized labs, and application services through BAUPC for all the university campuses. This implantation is the first of its kind in Jordan in general due to BAU's campus distribution. Based on these research re-



sults, BAU plans to deploy and utilize VDI services to cut costs of hardware, software, and licensing for laboratory applications and improve employee productivity and student needs, simplify IT management, and save costs.

The benefit from the implemented VDI as Service through better security, flexibility, scalability, and higher availability. It is an actual VDI on-demand, anywhere, anytime, using any device as a real leapfrog in the ICT services in the university. The ongoing research work aimed at studying the performance evaluation and analysis of the implemented BAU PC VDI as a Service using the Riverbed simulation tool.

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