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Server virtualization in higher educational institutions: a case study

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ABSTRACT

Virtualization is a concept in which multiple guest operating systems share a single piece of hardware. Server virtualization is the widely used type of virtualization in which each operating system believes that it has sole control of the underlying hardware. Server virtualization has already got its place in companies. Higher education institutes have also started to migrate to virtualized servers. The motivation for higher education institutes to adopt server virtualization is to reduce the maintenance of the complex information technology (IT) infrastructure. Data security is also one of the parameters considered by higher education institutes to move to virtualization. Virtualization enables organizations to reduce expenditure by avoiding building out more data center space. Server consolidation benefits the educational institutes by reducing energy costs, easing maintenance, optimizing the use of hardware, provisioning the resources for research. As the hybrid mode of learning is gaining momentum, the online mode of teaching and working from home options can be enabled with a strengthened infrastructure. The paper presents activities conducted during server virtualization implementation at RV College of Engineering, Bengaluru, one of the reputed engineering institutes in India. The activities carried out include study of the current scenario, evaluation of new proposals and post-implementation review.

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1. INTRODUCTION

Resources like servers, operating systems, desktop, network, storage and file can be created virtually and this concept is termed virtualization. Using virtualization, more scalability can be achieved. It also radically transforms traditional computing. Virtualization can be applied to various layers like hardware, operating system and network [1]. Virtualization has gained a lot of popularity with fortune 500 companies and its growth has caught the attention of universities as a solution to use information technology more effectively and efficiently. Higher educational institutes also need huge computing infrastructure nowadays to cater to the needs of stakeholders. To mitigate the costs, server virtualization is one of the strategies being used. Figure 1 shows different layers of server virtualization.

The benefits of virtualization in the educational institute include reduction in power consumption, effective hardware use, decreased maintenance costs, disaster recovery and data security. As the number of physical servers reduces, there will be less power consumption. The server hardware can be effectively used by proper resource allocation in virtualized setup. The cost of maintenance of servers at various locations on the campus is comparatively higher than maintaining servers at one place like a data center. If something goes wrong and critical data gets deleted, it is possible to retrieve the data using backup and disaster recovery techniques deployed at the data center. It will be convenient to configure data security measures if all servers are in one place rather than distributed at various locations across campus. However, if virtualization is not planned properly and if the institute does not choose the solution that best fits their landscape, the effort will have a high probability of failure. This paper discusses the step-by-step procedure RV College of Engineering adapted to virtualize the servers. Some of the previous related works are also discussed.

Misevicien *et al.* [2] presented details of virtualization implementation at Kaunas University of Technology. The virtualization enabled the staff and students at the university to access the application via the web from home as well as in computer classes. The researcher highlighted the benefits of virtualization technologies. To find out the problems with the infrastructure, the experiments conducted for load monitoring of the network were also presented. Virtualization technologies and their advantages for the education have been outlined. Klement [3] explained the status of virtualization used in school. The study dealt with the model design and theoretical bases which lead to its composition. The server virtualized environment can provide a lot of opportunities in crisis periods. As explained by Ray and Srivastava [4], the administrators of the educational institutes are now working toward ensuring that teaching should not be halted entirely during the crisis. Several esteemed institutes are trying to circumvent this crisis by migrating to the virtual environment. Simulated labs and virtual teaching are excellent alternatives while staying at a safe distance. The researchers also opined that the complete virtualization of educational missions overnight is not an easy task.

Mateljan *et al.* [5] opine that the virtualization types vary and they span from partial to complete. Most of them find a useful application in education. The application of implementing virtualization include remote connection, setting up new environments, faster backup, and easier maintenance. Soler [6] mentioned the various cases where virtualization is implemented. The first case discusses benefits for the university considering the parameters such as reproducibility and hardware cost reduction. The second and third cases deal with students benefits in terms of flexibility. The researcher has also provided a critical analysis of the solutions and the benefits. Ghorpade and Kamatchi [7] have explained how some virtualization and clustering technologies can be deployed to provide students, as well as instructors, with an optimized environment. Jingxian [8] proposed a virtual server based on virtual software to improve the efficiency of equipment and reduce the energy consumption and thus reducing the operating costs. Foo *et al.* [9] has explained the utilization improvement and enabling e-resource sharing among the departments by developing a computational grid test bed. Patel *et al.* [10] conducted comprehensive energy audit investigations for each site on the campus to determine existing infrastructure conditions and provided a solution. The detailed energy audit of server rooms on the academic campus was conducted by Gudluru *et al.* [11]. Cloud computing services for an interactive multi-campus university are discussed in [12].

Virtual desktop infrastructure setup in higher education has been explained in [13]. Asabere *et al.* [14] discussed green information and communication technology (ICT) implementation strategies in polytechnic education in Ghana. Cloud-based educational systems and their challenges are discussed in [15]. Najm *et al.* [16] discussed cloud computing security for e-learning, while Aziz *et al.* [17] analyzed available technology in the market to integrate into e-learning using the technology evaluation process. Similar works can be seen in [18]–[20]. In some of the previous research works [21]–[25], a detailed discussion of the virtualization concept can be found. The study of related works indicates that server virtualization in educational institutes is one of the current trends and there is a scope for deploying server virtualization in a better way.

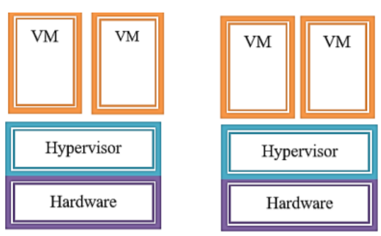

Figure 1. Server virtualization environment

2. THE PROPOSED MODEL

Server virtualization provides flexibility and scalability. It is possible to achieve the mail, web, academic, research, exam-related, counseling and study material services using server virtualization. Figure 2 represents the server virtualization model.

Figure 2. Server virtualization model

2.1. Drawbacks in the system

The strategy was to understand the drawbacks of the current system which consisted of various servers located in all departments. The outcomes of the analysis of the environment are explained in brief. Figure 3 shows the scenario before virtualization.

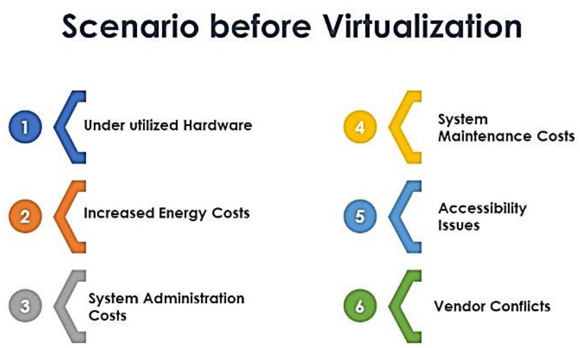

Figure 3. Scenario before virtualization

2.1.1. Under-utilized hardware

RVCE consisted of 36 physical servers located at various departments apart from operational servers. The processing capability was underutilized as some of the servers were meant for the execution of one or two applications in a specified time. It was observed that some of the servers were using only 20% of the resources. Servers to provide the license to invoke the software in client desktops were underutilized.

2.1.2. Energy-costs expenditure

Nowadays, one of the major expenditures incurred by any organization is energy costs. It ranks as one of the top three costs in operational expenses. The major contribution to this is the use of computing devices across campus. When the servers are located at different places, the air conditioners (AC) provisioned for each of them add to these operating costs.

2.1.3. Cost of system administration

Servers need to be kept running 24/7 without failure. To achieve this, servers need to be monitored to ensure it is working. The server administration costs include hardware status monitoring, operating system, and patches installation, updating of security patches. Some of the software-related issues like software aging are to be addressed at runtime. The software rejuvenation is to be executed without any downtime of critical services. The expenditure for all these system administration costs is a matter of concern. The hardware maintenance of servers adds to the operating costs.

2.1.4. Accessibility issues

The servers housed in various departments were isolated and accessing by other departments was not easy because of virtual local area network (VLAN) architecture. As interdisciplinary projects are increasing, there was a need to access the applications in one department by other department students and faculty. These accessibility issues were a major concern. This created a need for a holistic access plan.

2.1.5. Vendor conflicts

The computing power of various servers located in different departments is underutilized. The solution was to build a cluster of servers which was tried but the effort was not much successful. This is because of the limited support from the vendors and also the technology incompatibility of different original equipment manufacturers (OEMs).

3. METHOD

Prior to the implementation of server virtualization, some tasks are executed to ensure the implementation is cost-effective and productive. The opinion of various stakeholders was taken during this stage. Figure 4 depicts the strategies followed before implementation.

Figure 4. Pre-implementation strategies

2.1 Product support evaluation

Various parameters were considered for the evaluation of the virtualization product. The factors evaluated are recurring costs, ease of maintenance, vendor support, and application support. The evaluation was done on whether the existing hardware can be utilized. IT administrators at RV College of Engineering® shortlisted popular virtualization products like Xen, VMWare, Microsoft, and Citrix. Open-source platforms were also evaluated.

2.2 Evaluating the cost

The financial implications of migrating to virtualization were analyzed. This was one of the most needed aspects because the clarity on cost-benefit analysis helps to convince the management. The cost-benefit analysis was carried out considering the parameters like energy savings and maintenance costs.

2.3 Conducting proof-of-concept (PoC)

The IT team conducted a PoC using various virtualization products like Citrix, VMware, Microsoft and Xen to evaluate whether the less expensive product meets the requirements. Feedback was taken from similar other organizations where server virtualization is already in use and information on which tools, they are using is obtained. The requirements for the next few years were estimated before finalizing the capacity. As technologies are dependent on one another, along with servers, networking and firewall were also to be upgraded to cater to the projected computing requirements.

2.4 Pre-implementation activities

Pros and cons of the server virtualization process are documented, and approval was requested from the management. A pre-implementation discussion was carried out by the information technology (IT) team and the identified vendor. A detailed plan of action was prepared which included tasks like identifying the services to be virtualized, departmental and operational servers to be virtualized.

Pilot implementation of server virtualization is done to mimic the proposed server virtualization solution. The technical glitches encountered were resolved and a detailed study was done to understand the impact on other components in the campus IT infrastructure. Initially network-attached storage (NAS) box was used to hold the virtual machines. The existing rack server with an AMD processor and 64 GB of RAM was used for installing the hypervisor. The synthetic load was generated to study the fault tolerance of the system.

3.5. Migration to the new setup

As all the services were in use, the production systems migration to the new setup was planned carefully so that there is the least possible downtime. Physical machines were converted to virtual machines (P2V) and moved to the new platform. The servers used in the departments, servers for operational activities like dynamic host configuration protocol (DHCP), servers hosting web applications are moved to new setup in a short span of time with minimal technical glitches. Once the virtualized environment is stabilized, the servers are migrated to hyper converged infrastructure (HCI) environment. Figure 5 shows the components of the new HCI environment. HCI provides stable platform which has built-in intelligence that enables the easy administrators for IT team. The new setup does not need additional backup facility.

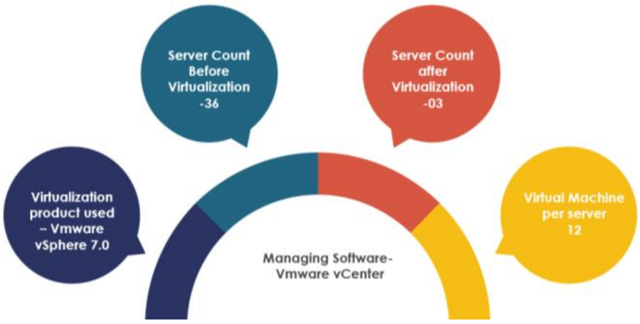

Figure 5. Server virtualized environment

4. RESULTS AND DISCUSSION

Optimized use of server hardware was one of the main intentions of the server consolidation project. The total number of physical servers is to be reduced from 36 to 3. This results in benefits like reduced system administration costs, reduced energy costs, ease of maintenance and scalability.

4.1. Server consolidation

All the servers used across departments are removed and hosted as virtual servers in the data center. A total of 42 servers were made available on an immediate basis after the virtualization setup. This includes departmental licensing servers, operational servers like DHCP, active directory service, web applications deployed for automation of various activities. Figure 6 shows the number of servers in an HCI cluster.

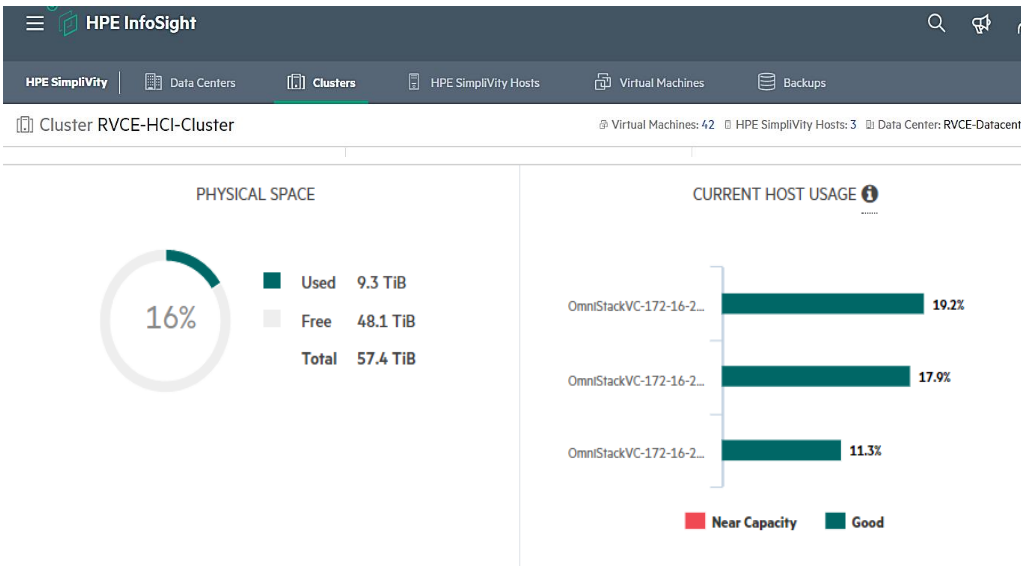

Figure 6. Virtual Servers count and storage utilization status

4.2. Optimized utilization of hardware

The server consolidation resulted in the optimized utilization of computing resources. With the thin provisioning of computing resources in a virtualized environment, the processing power and memory usage came down drastically. Figures 7 and 8 depict the screenshot from the dashboard.

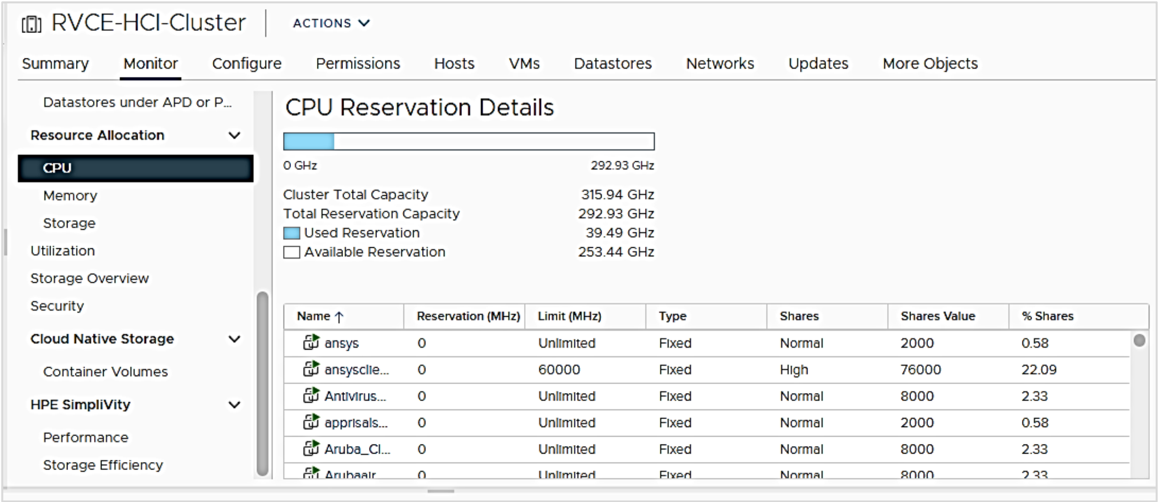

Figure 7. Random CPU utilization status

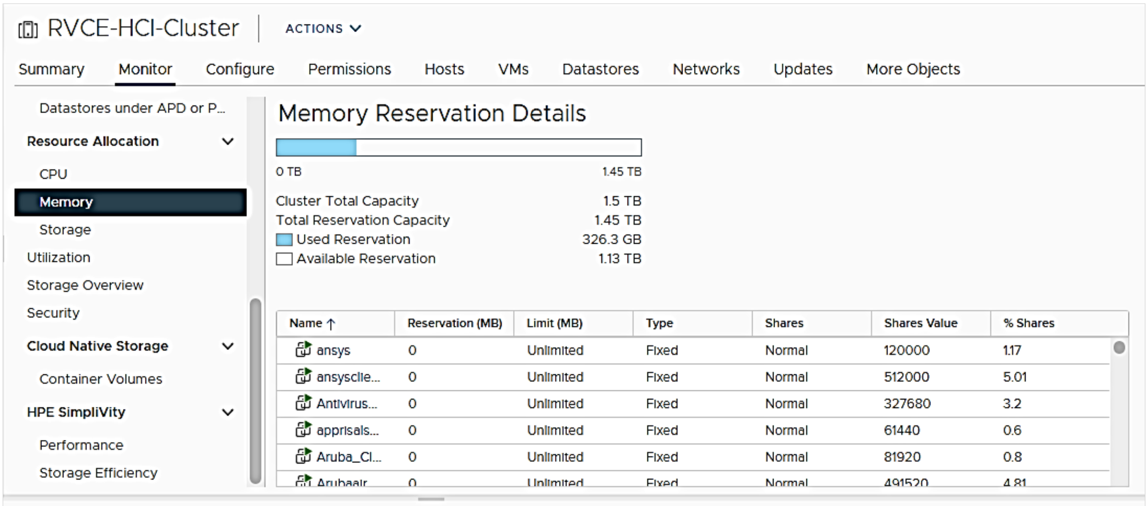

Figure 8. Random memory utilization status

4.3. Proactive maintenance

The server consolidation helped the IT administrators with proactive maintenance of servers. The resource utilization of various servers is monitored and alerts are generated if the server is in a failure-prone state. Figure 9 shows one such screenshot.

4.4. Strengthening the research infrastructure

The research scholars are provided with dedicated virtual servers for their research works as and when requested. The resource-intensive research works are provided with a virtual machine with better resources. Apart from this, some researchers request data sets of resource consumption from operational servers for building machine learning models. Figures 10 and 11 show the random CPU and memory utilization of a server that can be provided to researchers conducting research in the areas like software fault prediction and resource consumption prediction. Figure 12 shows an example of an outlier. An outlier is an observation that lies an abnormal distance from other values in a random sample.

4.5. Energy savings

Another significant benefit is the energy savings achieved by the consolidation of servers. Figures 13 and 14 show the random screenshot of the power consumption of departmental servers. After the consolidation of servers, there is a considerable reduction in power consumption. Figure 15 shows the power consumption of one of the HCI nodes. Table 1 shows the comparison of power consumption before and after consolidation. It can be seen that the average power consumption of the departmental server is 160 watts whereas the average power consumption of HCI nodes (3 nodes) is 425 watts.

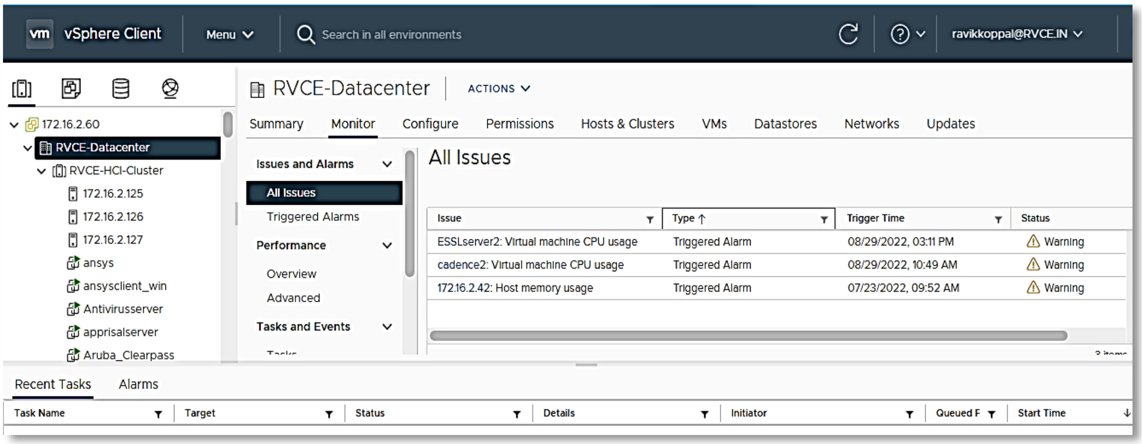

Figure 9. Alerts generated in the monitoring application

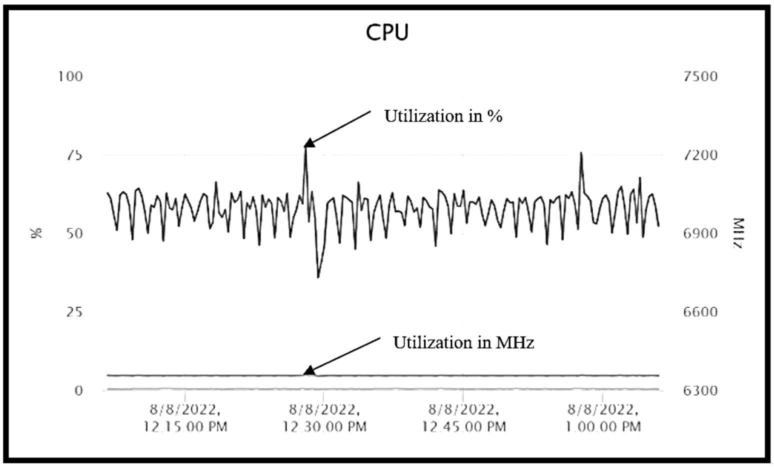

Figure 10. Random CPU utilization status

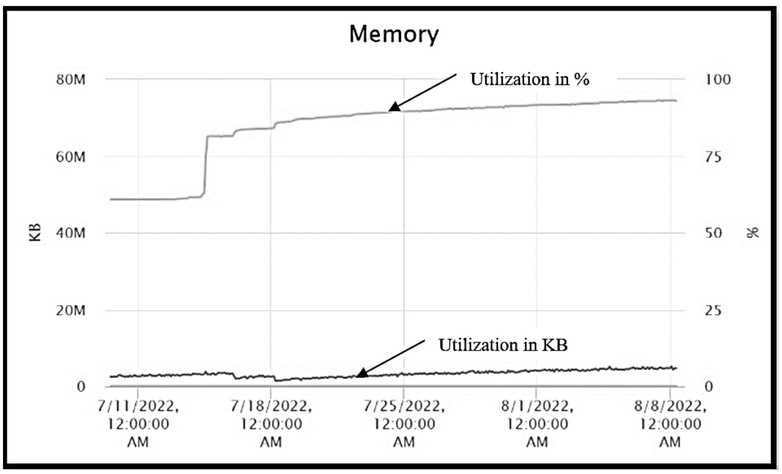

Figure 11. Random memory utilization status

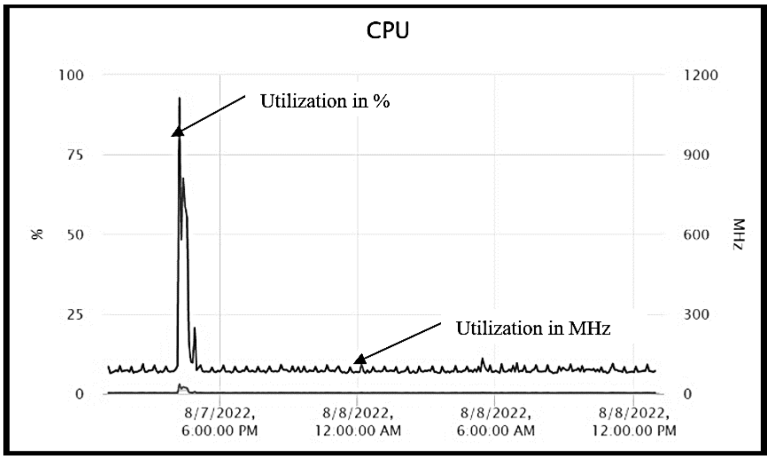

Figure 12. An example of an outlier

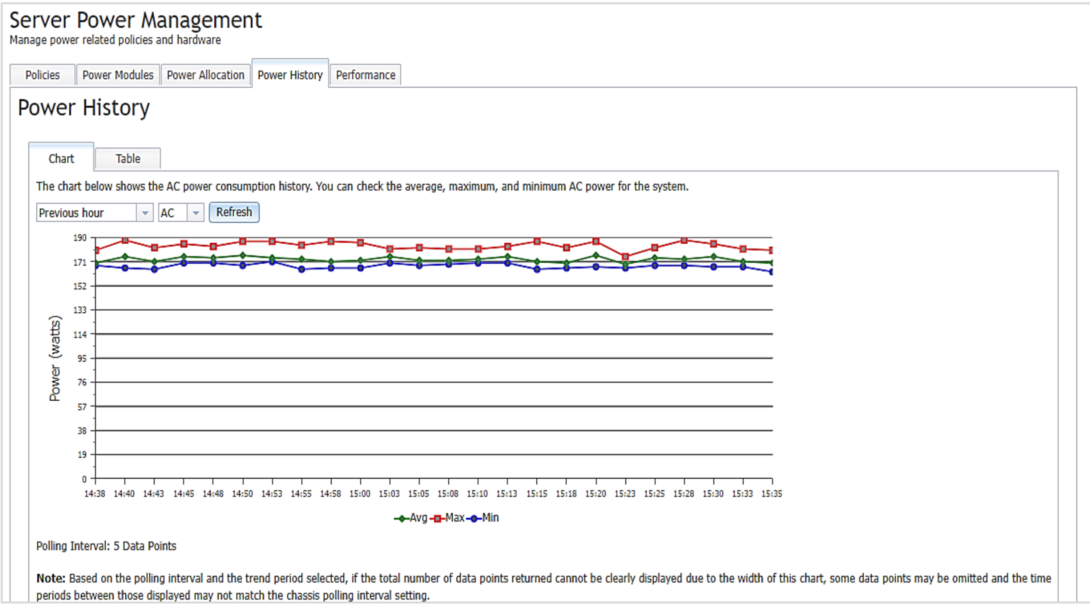

Figure 13. Screenshot of power consumption of two of the departmental server-1

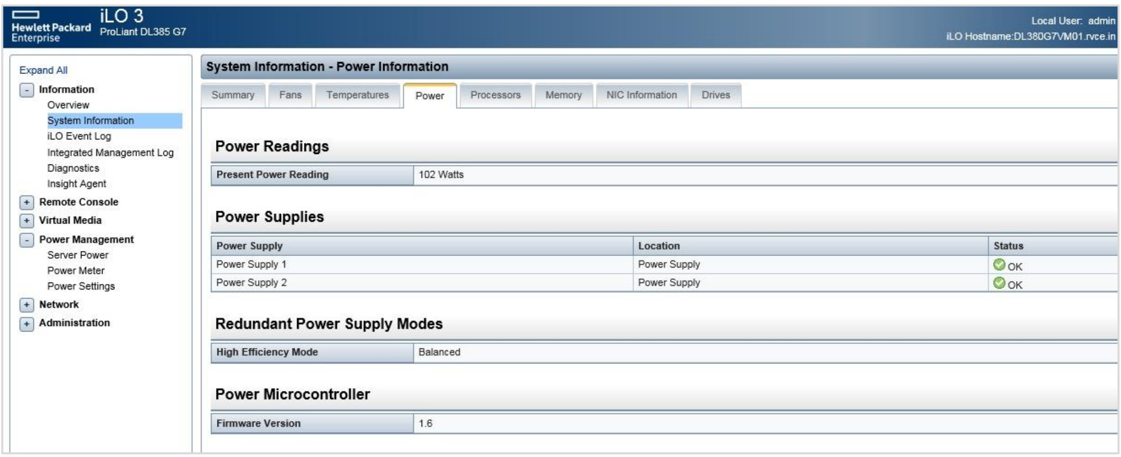

Figure 14. Screenshot of power consumption of two of the departmental server-2

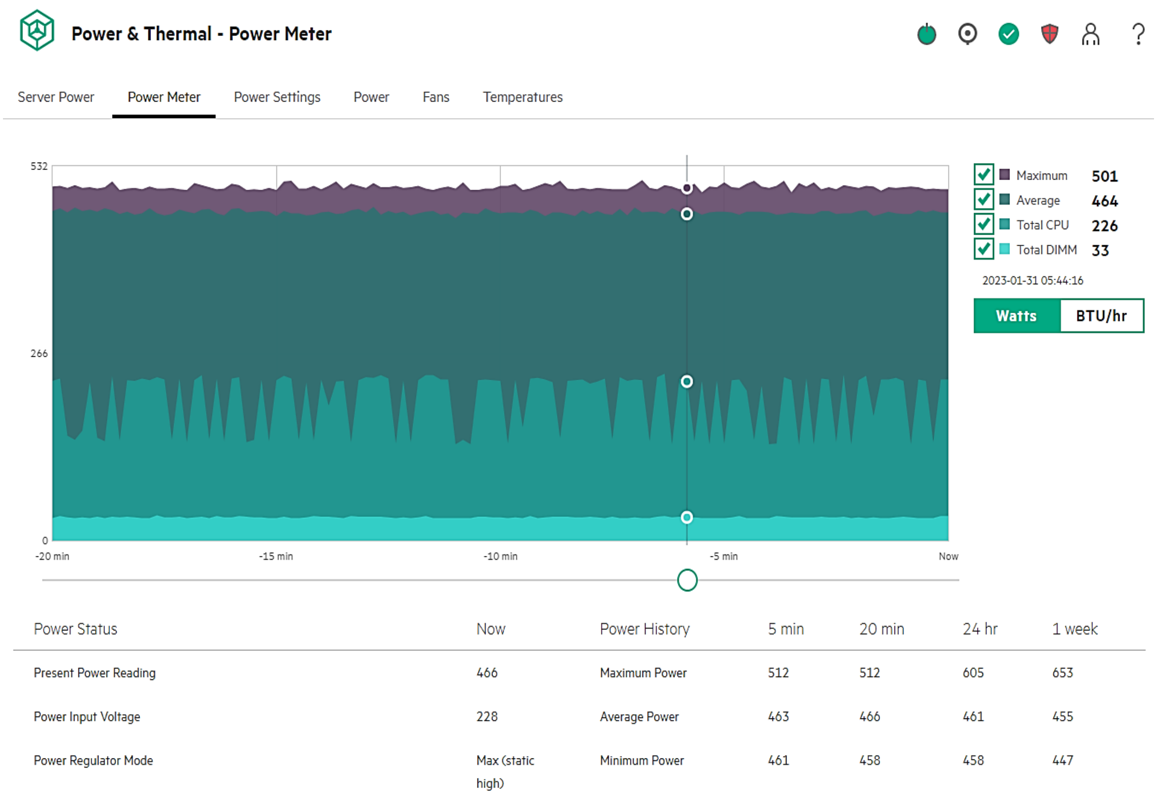

Figure 15. Screenshot of power consumption of one of the HCI nodes

Table 1. Power consumption comparison

	Before server consolidation	After server consolidation
No of servers	36	03
Average power consumption per server	160 Watts	425 Watts (One physical host on which multiple VMs are running)
Total power consumption	5760 Watts	1275 Watts

5. CONCLUSION

The outcomes of the server virtualization project are ease of scalability, reduction in the cost of operation and optimized utilization of physical resources. The new servers can be provisioned in minutes and can be put to use immediately. The server consolidation project upgraded one of the critical requirements on the campus. This work enables the upgradation of other components in the huge IT infrastructure currently the institute has.

The server consolidation project created a ready platform to set up a private cloud. Upon implementation and configuration of the provisioning software, the computing resources can be provisioned wherever and whenever needed. The resources of the private cloud like processing power, memory and storage can be provisioned to meet academic requirements, operational activities and to host software to automate institutional activities. A self-service portal for users is in consideration. The concept of isolating an operating system instance from the client accessing it is called desktop virtualization. As the departmental requirements in an engineering institute are heterogenous, it is challenging to deploy virtual desktop infrastructure (VDI). The institute has VDI in the infrastructure Roadmap.

Currently, the new setup is capable of serving user requirements by allocating processing, memory, and storage requirements. Some of the requirements are highly resource intensive i.e., the need for graphic processing units (GPU) for the execution of deep learning algorithms or similar works. Provisioning of such resources is not possible in the current setup and is in consideration as a future requirement. Desktops and laptops are widely used for computing on campus in the current scenario. Apart from these, various devices like tablets, mobiles are being used by students. If the private setup is complete, the students can connect to the institution servers and perform the computing they want. This requirement is in consideration.

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