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Extending the use of Virtualization Technologies to Improve the Datacenter Resource Utilization in On-premises Datacenters

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ABSTRACT: Recently, the increasing demand for computation and storage has significantly driven the global expansion of Datacenters. Historically, it was common to execute applications directly on physical servers. However, within a decade the use of virtualization which improves efficiency in Information Technology environments became the norm in many organizations. By allowing multiple virtual machines (VMs) to share physical resources such as Servers, Storage, and Networks, virtualization technologies seek to improve the utilization of Datacenter resources. In this paper we compared two most popular virtualization technologies, Microsoft Hyper-V and VMware and proposed virtualization deployment strategies which will help in reducing the energy and maintenance cost and optimize the resource utilization.

KEYWORDS: Datacenter, Virtualization, Multi-Criteria Decision Making, Analytic Hierarchy Process, Resource utilization.

I. INTRODUCTION

Virtualization Technologies are rapidly transforming the way many Organizations are managing their Information Technology (IT) resources in their data centers. Organizations are leveraging on virtualization technologies to enhance their IT infrastructure, maximize their resources such as CPU and RAM while minimizing the infra-structure cost. In this context, extending the use of virtualization technologies to improve the Datacenter utilization in on-premises Datacenters by considering power consumed by the Datacenter infrastructures and cost is an essential step towards achieving this objective. Virtualization is the creation of virtual rather than actual version of something such as Operating System (OS), Server, Storage device or network resources [1]. Virtualization is an increasing efficient as of the existing re-sources that delivers huge cost savings in a brief amount of time. It offers organizations new models of application deployment for greater uptime to meet the user's expectation or customer's needs. Virtualization provides new services in minutes instead of days, provides load balancing and scalability without downtime [2]. The aim of this paper is to enhance the virtualization deployment strategy by considering the following criteria: Power, Cost, CPU and RAM in choosing the best Virtual-ization solution among Hyper-V and VMware and based on the criticality of the ap-plications. We leverage on Multi-Criteria-Decision Making based on the Analytic Hierarchy Process (MCDM-AHP) method to make accurate decision on which Technology to adopt.

This paper is organized as follows. Section II describes the related work of other researchers, explain MCDM-AHP method. We then discuss the criteria considered to be able to arrive at the accurate decision on which virtualization to deploy in Section III. We discuss and present our simulation results in Section IV. Finally, Section V presents conclusion.

II. RELATED WORK

Virtualization enables the creation of virtual instances of computing resources such as servers, storage, and networks, which can be used to run multiple workloads simultaneously. For example, the server virtualization enables multiple virtual servers to run on a single physical server which can improve CPU and memory utilization. Storage virtualization can enable the creation of a single pool of storage utilization. The use of virtualization technology can result in reduction of cost of hardware and software licenses. By enabling the consolidation of



multiple workloads into a single server, less physical hardware will be required which will reduce the cost of purchasing and maintaining the hardware and Operating system software licensing cost and subscriptions will reduce [3]. Server virtualizations provide the ability to expand, scale out critical applications, easy management, and automation of some of the administration tasks. many organizations rely on a heterogeneous set of applications to deliver critical services to their customers and partners. To efficiently utilize the computing power of their Datacenters, the organizations allow these heterogeneous workloads to execute on the same set of hardware resources and need a resource management technology to determine the most effective allocation of resources to workloads [4].

Hyper-V is a type-1, native hypervisor developed by Microsoft that allows for the development and control of numerous virtualized versions of a computer known as virtual machines (VMs). Hyper-V provides a virtualization framework on which one can build any level of complexity IT architecture. Each VM runs in its own distinct space, unaffected by the processes of other VMs. VMware is a hypervisor-based virtualization technology that enables the concurrent operation of multiple virtual machines on the same physical hardware. VMware ESXi is a type-1, native hypervisor that is at the heart of VMware vSphere. It is used to directly control host servers while running multiple guest VMs. VMware ESXi gives running virtual machines direct access to the working resources of the physical machine [5, 6].

Both Hyper-V and VMware have their Strength and weaknesses. Some of the considerations to consider when choosing the right technology are the following: Both Technologies have their own management tool, each equally up to the task. However, they differ significantly on their ability to scale to serve large organizations. In terms of storage deployment, VMware's Virtual Machine File System (VMFS) has a minor advantage over Hyper-V's Resilient File System, especially regarding clustering. The VMFS enables the rapid addition and removal of hosts to and from the cluster without interfering with the operation of other processes. Hyper-V's Cluster Shared Volume is more complex and difficult to use than VMware's equivalent, even though both have clustering capabilities [7]. Table1 depicts the characteristics between VMware and Hyper-V

Table 1. Key characteristics between VMware and Hyper-V

Characteristics	VMware	Microsoft Hyper-V
Maximum Virtual CPUs per physical Host	786	512
Maximum RAM	16 TB	24 TB
Memory Management features	-Support Memory sharing between VMs -Memory Virtualization -Support for large page size	-Support Dynamic memory -Support smart paging using hard disk as extra memory
Storage Deployment	-Can define all types of physical storage as virtual disk on the host. - uses VMware vSAN to virtualize physical hard disk - VMFS holds a slight edge when it comes to clustering	-Support direct attached storage, Network attached Storage and SAN Storage. -Hyper-Vs Cluster Shared volume is more complex and more difficult to use.
Snapshots	Transitory Snapshots cannot be performed in production	Persistent Snapshots can be performed in production
Management utilities	Uses VMware tools	Uses Microsoft integration tools
Migration tools	VMware vMotion	Hyper-V Live Migration
Operating System Support	Windows, Unix, MacOS and many others	Windows, Few Linux distributions, and FreeBSD



III. METHODOLOGY

Multi-Criteria Decision-Making (MCDM) is one of the most important decision-making methods [8]. The goal of MCDM is to find the best option by taking into account more than one criterion. That the process can be thought of as picking the best option from a set of options. It can also be thought of as putting together different options and then choosing a small set from them. in Infrastructure as service model (IaaS), MCDM methods are of extreme importance since customers are responsible for installing and maintaining the operating systems, databases, security components and applications. The most MCDM method used in IaaS is called Analytic Hierarchy Process (AHP) which is the most efficient method for managing information security in cloud computing as well as task scheduling and resource allocation [9]. The AHP developed by Saaty, is a multiobjective, multicriterion decision-making approach which employs a pairwise comparison procedure to arrive at a scale of preferences among sets of alternatives [10]. In our research, we look at the main problem which is virtual machine resource management and what technology to adopt for effective resource management. The research explores the use of AHP process for Decision-making. The proposed model is offering the following four (4) criteria: Cost, Power Consumption, CPU resources, and Memory (RAM) utilization. This method has added values for each criterion and ranked them by order of importance. our objective is to select the best solution among alternatives. In AHP, a pairwise comparisons are made with the grade ranging from 1 to 9 as indicated by the table for Scale of Relative importance made by Saaty.

Table 2. Saaty’s Scale of relative importance

Intensity of importance	Definition	Explanation
1	Equal importance	Two contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favor one over the other
5	Much more important	Experience and judgement strongly favor one over the other
7	Very much more important	Experience and judgement very strongly favor one over the other Its importance is demonstrated in practice
9	Absolutely more important	The highest possible order of affirmation
2,4,6,8	Intermediate values	When Compromise is needed

MCDM-AHP method creates a systematic approach to decision making, priority setting, and resource allocation. The Development of clear goals, selection of criteria and evaluation of alternatives help improve the decision-making process. In this research we use a basic but more reasonable assumption for comparing alternatives. If the attribute A is absolutely more important than Attribute B, A is rated 9 and B will be graded 1/9.

Multi-Criteria Decision-Making based on Analytic Hierarchy Process for Virtual Machine Resource Management (MCDM-AHP-VMRM)

In MCDM-AHP-VMRM, we use four criteria such as Cost, Power, CPU and RAM and the alternatives are VMware and Hyper-V.

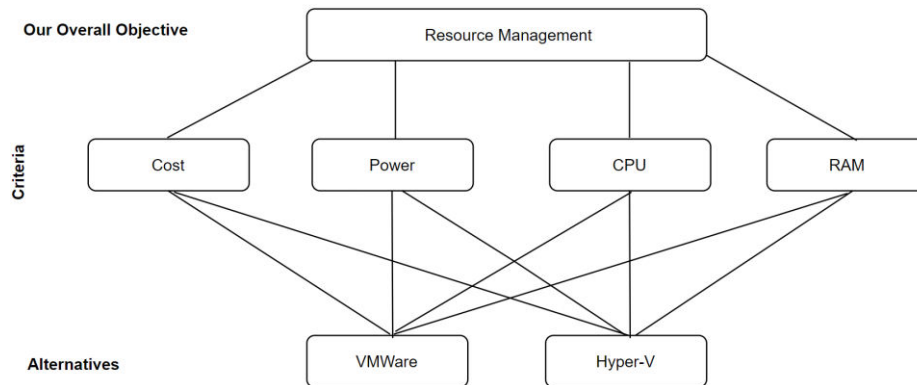


FIG. 1. MCDM-AHP-VMRM

The MCDM-AHP-VMRM involves 4 steps to be able to arrive at the optimal alternative. The first step is to identify the problem which in our case is the resource management, the second step involves the pairwise comparison whereby two elements will be compared each time. If we have N factors (criteria) the total number of comparisons will be $N * (N-1)/2$. For Example, if we have 4 factors we will be having 6 comparisons $[4*(4-1)/2]$. The size of our Matrix M will be NxN. They will be compared and the diagonal or our matrix will unity, that $M_{ii} = 1$. The cells in upper diagonal will be the reciprocal relationship with the cells in the lower diagonal. This is to say the values in the upper diagonal will be calculated by $M_{ij} = 1/ M_{ji}$ where $j>i$. The Normalization is then done by dividing each element by the sum of the elements in its column. The Eigen Vector is obtained by adding the sum of the normalized elements and must be equal to 1. The third step involves calculating the criteria weight which are the results of the normalized values. The fourth step involves rating the alternatives and aggregate them with the criteria weight obtained in the third step.

A consistency check is then performed using the following equations:

The consistency matrix (λ_{max}) or largest eigen value for each M_{ij} matrix is:

$$\lambda_{max} = \sum_{j=1}^N [W_j \sum_{i=1}^N M_{ij}] \tag{1}$$

Where M_{ij} will be the summation of all criteria in each column in the matrix M and W_j the criteria weight value. To calculate the Consistency Index (CI), the following formula is used:

$$CI = \frac{\lambda_{max} - N}{N - 1} \tag{2}$$

Finally, the Consistency ratio is calculated using the following formula:

$$CR = \frac{CI}{RI} \tag{3}$$

Where, RI is the Random Index (RI) of the matrix M established by Saaty, as a function of n values as shown in the table below:

Table 3. Random Index for different values of the number of criteria by Saaty

n	2	3	4	5	6	7	8
R.I	0.00	0.58	0.90	1.12	1.24	1.32	1.41

If the CR is less than 0.10, the result of the pairwise comparison is sufficient. Therefore, our matrix M is:

$$M = \begin{bmatrix} \mathbf{M1} & \mathbf{M2} & \mathbf{Mi} & \mathbf{Mn} \\ \mathbf{M1} & \frac{w1}{w1} & \frac{w1}{w2} & \frac{w1}{wi} & \frac{w1}{wn} \\ \mathbf{M2} & \frac{w2}{w1} & \frac{w2}{w2} & \frac{w2}{wi} & \frac{w2}{wn} \\ \mathbf{Mi} & \frac{wi}{w1} & \frac{wi}{w2} & \frac{wi}{wi} & \frac{wi}{wn} \\ \mathbf{Mn} & \frac{wn}{w1} & \frac{wn}{w2} & \frac{wn}{wi} & \frac{wn}{wn} \end{bmatrix}$$



Where $w_1, w_2, \dots, w_i, w_n$ are the weights given to the criteria or factors. The factor weights are obtained based on the analysis of how the resources are needed by the systems. The sum of the extracted weights is equal to 1. The result is elaborated using the process below:

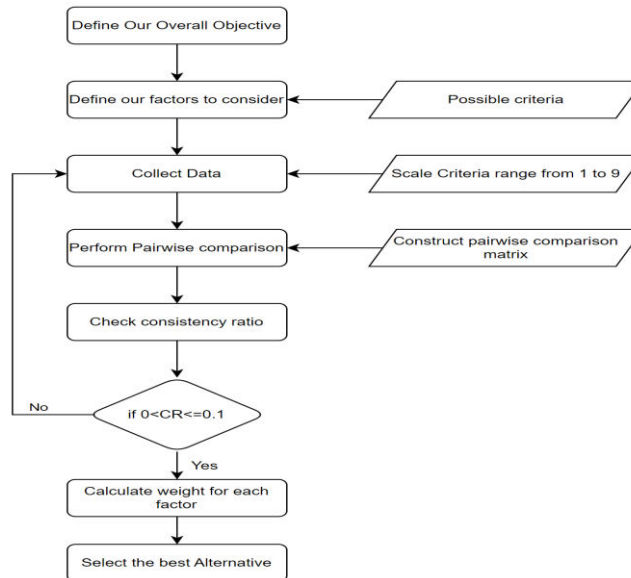


Fig. 2. Process flow for our MCDM-AHP-VMRM

In the analysis of CMDM-AHP-VMRM, we are ranking the criteria of the resources such as CPU, RAM, Power, and Cost by assigning the scores based on their importance. We rank the resources as follows: Cost is given score 1, Power is given score 2, CPU is given score 3 and RAM is given score 5. The alternatives are Hyper-V and VMware as Virtualization technologies. Our goal is to choose the best Solution among these two popular Virtualization technologies.

IV. EXPERIMENTAL RESULTS

We have used the SpiceLogic Analytic Hierarchy Process software to Evaluate 4 criteria for the Virtual machine Resources to be able to choose among the two Virtualization solutions. Each criteria has its individual weight as shown below and a matrix is created based on Saaty scale. The cost is given less importance and has less impact on service availability, Power is relatively important than cost, and CPU is more important than Power and Cost and RAM has strong importance.

Table 4. Priority trade-offs results using SpiceLogic

	Cost	Power	CPU	RAM	Priorities
Cost	1	0.5	0.33333333	0.2	0.07963517
Power	2	1	0.33333333	0.2	0.11552033
CPU	3	3	1	0.2	0.21587919
RAM	5	5	5	1	0.58896531
* Consistency Ratio calculated as	0.081				

The figure below shows the criteria weight; the Cost has approximately 0.08, Power has 0.116, CPU has 0.216 and RAM has 0.89

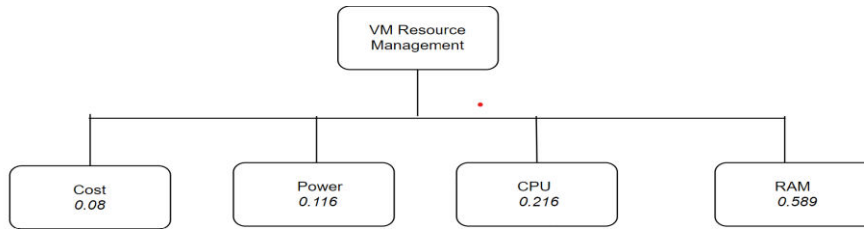


Fig. 3. Criteria weight

The pairwise Comparison of Options for Criteria

A pairwise comparison has been done for each criterion (Cost, Power, CPU, RAM) with the mentioned alternatives (VMWare and Hyper-V) as shown in the table below:

Ranking Alternatives:

Table 5. Pairwise Comparison of Options for criteria: Cost

Cost	VMWare	Hyper-V	Priorities
VMWare	1	0.33333333	0.25
Hyper-V	3	1	0.75

Even though the cost has low weight (least reliability) on Hyper-V is somewhat more important than the cost on VMWare (Table 5). Therefore, the Cost of Hyper-V is higher than VMWare.

Table 6. Pairwise Comparison of Options for criteria: Power

Power	VMWare	Hyper-V	Priorities
VMWare	1	5	0.83333333
Hyper-V	0.2	1	0.16666667

Table 6 above shows that the power consumed on VMWare is much more important than on Hyper-V though the Power has also less reliability (from User’s perspective do not know and do not value the importance of energy).

Table 7. Pairwise Comparison of Options for criteria: CPU

CPU	VMWare	Hyper-V	Priorities
VMWare	1	0.33333333	0.25
Hyper-V	3	1	0.75

Hyper-V utilizes more CPUs than VMWare, as depicted in Table 21. This indicates that CPU management is easier on VMWare than on Hyper-V.

Table 8. Pairwise Comparison of Options for criteria: RAM

RAM	VMWare	Hyper-V	Priorities
VMWare	1	5	0.83333333
Hyper-V	0.2	1	0.16666667

Table 8 demonstrates that VMware receives a higher resource management priority for RAM than Hyper-V as it gives 83 % priority over 17% respectively.

Below is a graph depicting the relative importance of the two alternatives VMWare and Hyper-V. The result demonstrates that VMWare is prioritized over Hyper-V.

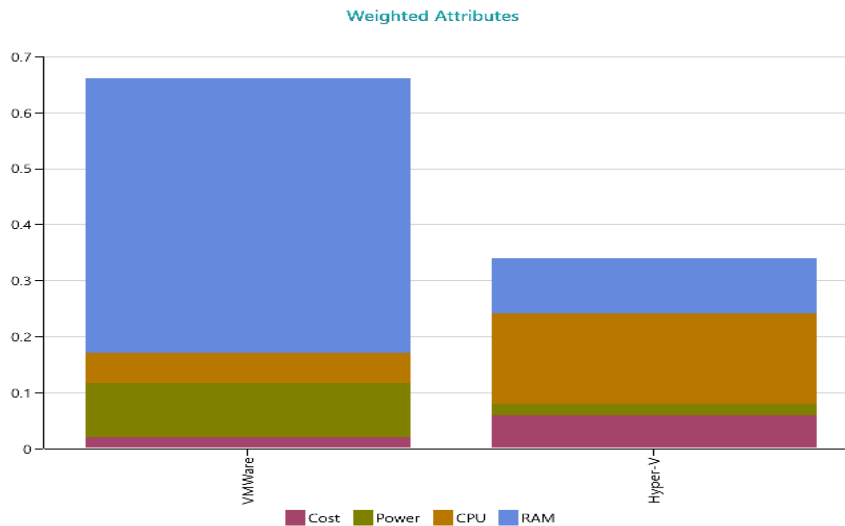


Fig. 4. Weighted Attributes for VMware and Hyper-V

The result from SpiceLogic shows that the recommended Virtualization Technology to adopt is VMWare as shown in the Figure 31 above. Having an adequate Virtualization technology implemented will result in proper resource Management. This will have an impact on reducing the maintenance cost and scalability.

Proposed Virtualization Deployment model based on MCDM-AHP-VMRM

The Microsoft Hyper-V Virtualization has shown its limitation in terms of resource allocation, effective management, and scalability. This results in poor performance of the organization Critical Systems that run on Hyper-V. The new Deployment model would base on the criticality of the applications and Organization type and size, infrastructure hardware and licenses acquired, and future deployment and plans for expansion in the Organizations planning to maintain the On-premises Datacenters.

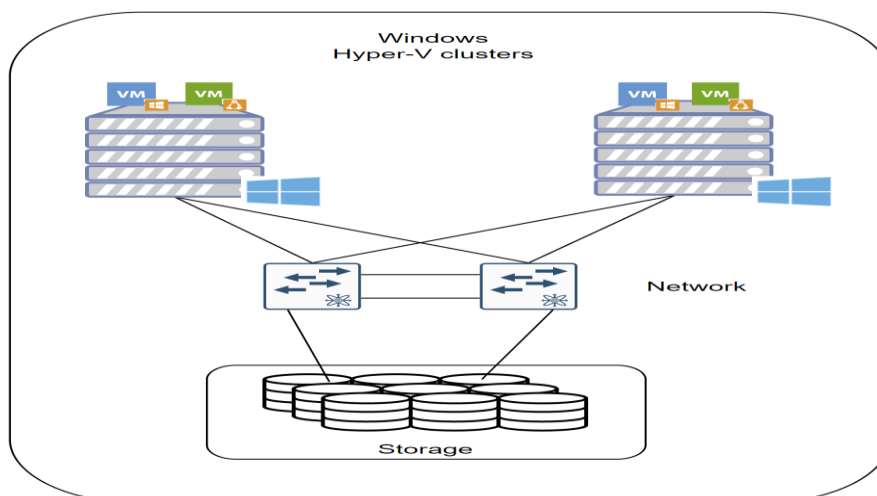


Fig. 5. Deployment of tests and development Systems

The Figure above depicts the virtualization technology the researcher is proposing for tests and development systems. The deployment is based on the current Hardware systems and licenses acquired for the virtualization. For the Tests and Development Environments, Deploying Hyper-V in clusters as created VMs can be shutdown any time and put back online when needed. This can reduce the dramatically the resources being utilized.

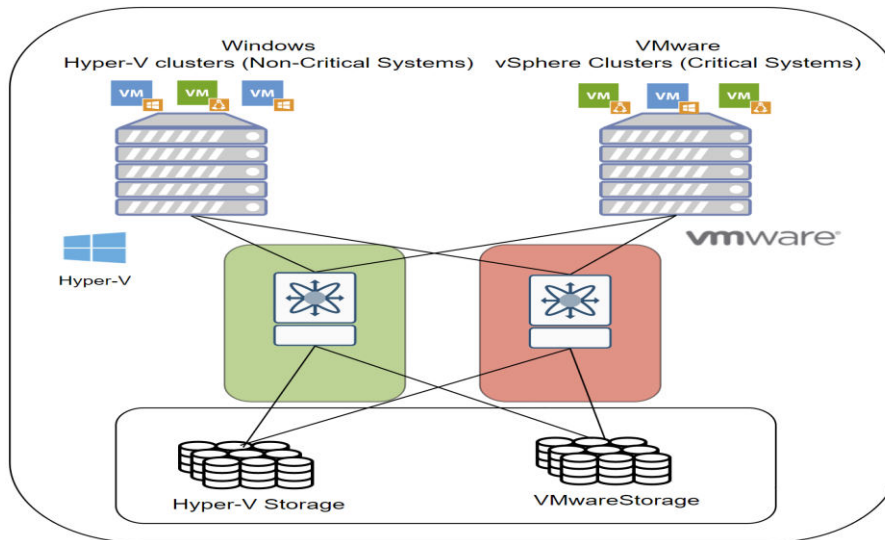


Fig. 6. Deployment of Production Systems

The Figure above describes the virtualization deployment strategy proposed by the researcher for production systems, it will include the organization mission-critical systems such as customer-facing applications and non-mission -critical applications such as support-to-business applications. The critical systems will be deployed on VMWare platform as it is suitable for providing high availability for critical workloads and other capabilities such as expand or reduce resources as the VM is online without compromising the availability of services. Non-Critical Systems such as support-to business applications or other can be deployed on Hyper-V Virtualization platform.

V. CONCLUSION

We have considered the issue of decision-making procedure to deploy the virtualization technologies that are suitable for the organizations to improve the resource utilizations in the On-premises Datacenters. We used the MCDM-AHP Method to develop the MCDM-AHP-VMRM for decision making. We represented 4 criteria to consider such as Cost, Power CPU and RAM. We presented 2 virtualization technologies: VMware and Hyper-V as alternatives in choosing the appropriate virtualization technology to deploy. While Virtualization technologies have been widely adopted in many institutions, its implementation is still a challenge. This research paper will help many organizations implementing properly the virtualization technologies.

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