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Optimization of Virtual Machines in Cloud-Based Distributed Systems for Enhanced Performance and Cost Efficiency

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Abstract

The advent of cloud computing has revolutionized the management of computing resources within organizations, offering flexible access to scalable infrastructure on demand. This thesis delved into the realm of optimization techniques for Virtual Machines (VMs) in cloud-based distributed systems, with a focus on enhancing system performance and cost efficiency. The research objectives encompassed evaluating performance metrics, devising optimization strategies for workload balancing, dynamic provisioning, and fault tolerance, and scrutinizing the correlation between workload characteristics and resource utilization. The study employed a qualitative approach, conducting open-ended interviews with IT personnel at Bank and utilizing both primary and secondary data, with analysis performed using SPSS. The overarching goal was to furnish insights and recommendations for the adoption of efficient VM strategies. The conclusions underscored the significance of strategies aimed at maximizing resource utilization, integrating workload balancing and dynamic provisioning for Bank's data centers, and enhancing services such as core banking and agency banking. The recommendations put forward the deployment of the proposed algorithms and models, with due consideration for optimizing heat and cooling efficiency in data centers. Furthermore, future research should delve into exploring novel models, algorithms, and robust platforms, such as Microsoft Azure, to continually optimize virtual resources, thereby ensuring both cost efficiency and service performance.

Keywords: *Optimization of Virtual Machines, Cloud-Based Distributed Systems, Enhanced Performance, Cost Efficiency.*

1. Introduction

In recent years, researchers in developed countries like In the United States, Smith et al. (2017) conducted an extensive study on workload characteristics and resource allocation algorithms in cloud-based distributed systems. Their research focused on optimizing memory, CPU, and storage utilization, aiming to enhance system performance and cost efficiency, and have conducted extensive studies on the optimization of VMs in cloud-based distributed systems. These studies have explored various aspects, including workload characteristics, resource allocation algorithms, scalability, and cost optimization.

Johnson et al. (2019) conducted a notable study in the United Kingdom, exploring the impact of workload patterns on resource utilization in cloud-based distributed systems. Their research contributed to the development of advanced allocation algorithms to improve efficiency and optimize VM performance. Notable research conducted in developed countries includes Smith et al. (2017) who proposed an advanced allocation algorithm, and Johnson et al. (2019) who examined the impact of workload patterns on resource utilization.

These studies have contributed to the understanding of resource optimization in cloud-based distributed systems. Lee et al. (2020) conducted a research study in Canada, investigating scalability and elasticity aspects of virtual machine allocation in cloud-based distributed systems. Their research focused on optimizing resource utilization in dynamic cloud environments, ensuring efficient allocation and improved system performance.

Tanaka et al. (2021) conducted a recent study in Japan, analyzing performance metrics and benchmarking different resource allocation strategies in cloud-based distributed systems. Their research aimed to enhance cost efficiency by identifying and implementing effective allocation approaches.

In African countries, there is a growing interest in the optimization of VMs in cloud-based distributed systems to address the unique challenges and opportunities in the region. Research conducted by Kimani et al. (2018) conducted a study in Kenya, focusing on addressing infrastructure limitations and optimizing resource allocation in cloud-based distributed systems. Their research considered the specific workload characteristics prevalent in the region and proposed allocation strategies to improve performance and cost efficiency.

In Nigeria, Abu et al. (2019) conducted research on the optimization of virtual machines in cloud-based distributed systems. The study aimed to meet the high demand for computing resources in the country by exploring cost-effective solutions and optimizing resource allocation strategies. Therefore, for all above research, they have explored various aspects such as workload characteristics, resource allocation algorithms, scalability, and cost optimization, providing a foundation for further advancements in the field and tailored approaches to meet the specific requirements of each country.

In Rwanda on the optimization of virtual machines in cloud-based distributed systems may be limited, it presents an opportunity for researchers and stakeholders in the country to contribute to the body of knowledge in this field. There has been an increasing focus on the optimization of virtual machines (VMs) in cloud-based distributed systems to support the country's digital transformation and economic growth. Although specific studies in this area might be limited, Rwanda has made significant strides in embracing cloud-computing technologies and harnessing their potential. (Charles, 2021)

Virtual Machines in cloud-based distributed systems has played big role in resource allocation of using resource utilization in several institutions using cloud services however poses challenges in achieving optimal performance and cost efficiency. Smith et al. (2017) The Inadequate resource allocation practices result in underutilization or overutilization of resources, compromising system performance and cost efficiency. Moreover, it results reduced system performance, increased operational costs, decreased scalability, and hindered ability to meet with BK organizational goals and objectives.so as researcher should come up with the solution of to develop and implement effective resource allocation strategies and algorithms that optimize the performance and cost efficiency of virtual machines in cloud-based distributed system.

1.1 Objectives of the study

1.1.1 General objective

The general objective of this thesis is to Optimize Virtual Machines in cloud-based distributed systems to enhance performance and cost efficiency. The research aims to develop strategies that ensure optimal utilization of computing resources while considering workload balancing, dynamic provisioning, and fault tolerance requirements.

1.1.2 Specific Objectives

(i) To examine how memory upgrade will enhance performance and cost efficient of clod-based distributed systems.
(ii) To analysis the extent to which virtual machines techniques and system performance in cloud-based distributed systems.
(iii) To develop and implement effective resource allocation strategies and algorithms that optimize the performance and cost efficiency of virtual machines in cloud-based distributed systems.
(iv) To assess the impact of resource allocation on system performance, encompassing factors such as system optimization.

2.1 Empirical Review

Examination and analysis of empirical studies, experiments, and real-world data related to Virtual Machines strategies. It focuses on studies that have implemented and evaluated Virtual Machines techniques in practical settings. The empirical review provides insights into the effectiveness and performance of various approaches and helps validate and refine Virtual Machines algorithms and techniques. As case studies play a crucial role in the empirical review as they provide detailed real-world scenarios where Virtual Machines strategies have been implemented. For example, a case study by Smith et al. (2017) examined the Virtual Machines techniques in a large-scale cloud data center, focusing on workload balancing and optimizing resource utilization. The study showcased how specific allocation algorithms improved system performance and reduced resource wastage. So, for the experimental evaluations involve setting up controlled environments or simulations to assess the performance of Virtual Machines strategies. For instance, a study by Zhang et al. (2015) conducted experiments in a simulated cloud environment with varying workloads and evaluated the performance of different allocation algorithms. The findings provided insights into the efficiency and scalability of the proposed strategies. Comparative studies are conducted to compare the performance of different Virtual Machines techniques. For example, a comparative study by Li et al. (2018) evaluated multiple allocation algorithms and compared their performance in terms of response time, resource utilization, and cost efficiency. The study helped identify the most effective strategy for a specific workload pattern. Performance Benchmarks: Empirical reviews often include the analysis of performance benchmarks that provide standardized metrics for evaluating Virtual Machines algorithms. For instance, the Cloud Suite benchmark suite proposed by Ferreira et al. (2015) provides a standardized set of workloads and metrics to assess the performance of Virtual Machines strategies. Such benchmarks enable researchers to compare their algorithms against established standards.

2.1.1 Memory upgrade and system performance

Memory upgrade plays a crucial role in enhancing system performance by increasing the available random-access memory (RAM). The gap in system performance arises when there is an inadequate amount of RAM to meet the demands of resource-intensive tasks and applications. Research conducted by Li et al. (2019) focused on the impact of memory upgrade on the performance of database systems. The study demonstrated that increasing memory capacity led to enhanced query execution speeds, reduced disk I/O operations, and improved overall database performance.

2.1.2 Virtual machine and system performance

Virtual machine (VM) performance is impacted by various factors, including the allocated resources and the optimization of resource utilization. The gap in system performance can arise when the virtual machine lacks sufficient resources to meet the demands of running applications and workloads effectively. To address this performance gap, optimizing resource allocation within virtual machines is crucial. Properly provisioning CPU, memory, and storage resources to virtual machines based on their workload requirements can help ensure optimal performance. Numerous studies have focused on investigating the impact of resource allocation and optimization on virtual machine performance. For instance, a study by Huang et al. (2018) explored the effects of CPU resource allocation policies on virtual machine performance. The research demonstrated that allocating CPU resources based on workload characteristics and priorities can significantly enhance performance and reduce resource contention.

2.1.3 Effect utilization and system performance

In contrast, poor resource utilization can result in underutilized or overburdened resources, leading to suboptimal system performance. Underutilization means that resources are not fully utilized, resulting in wasted capacity and decreased efficiency. Overutilization occurs when resources are overloaded, causing performance degradation and increased response times.

Several research studies have investigated the impact of resource utilization on system performance in cloud-based distributed systems. For instance, a study by Wang et al. (2019) examined the effects of resource utilization on the performance of containerized applications. The research highlighted the importance of efficient resource utilization in achieving high-performance containerized environments.

2.1.4 Resource allocation and system performance

In contrast, poor resource allocation can result in resource imbalances, where some components are underutilized while others are overloaded. This can lead to performance degradation, increased response times, and inefficiencies in resource utilization. Inadequate allocation may also result in resource contention, where multiple components compete for limited resources, further impacting system performance.

Several research studies have explored the relationship between resource allocation and system performance in cloud-based distributed systems. For example, a study by Li et al. (2018) investigated resource allocation algorithms in virtualized environments and highlighted the impact of different allocation strategies on system performance. The findings emphasized the importance of intelligent resource allocation techniques in achieving optimal performance.

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2.2 Conceptual framework

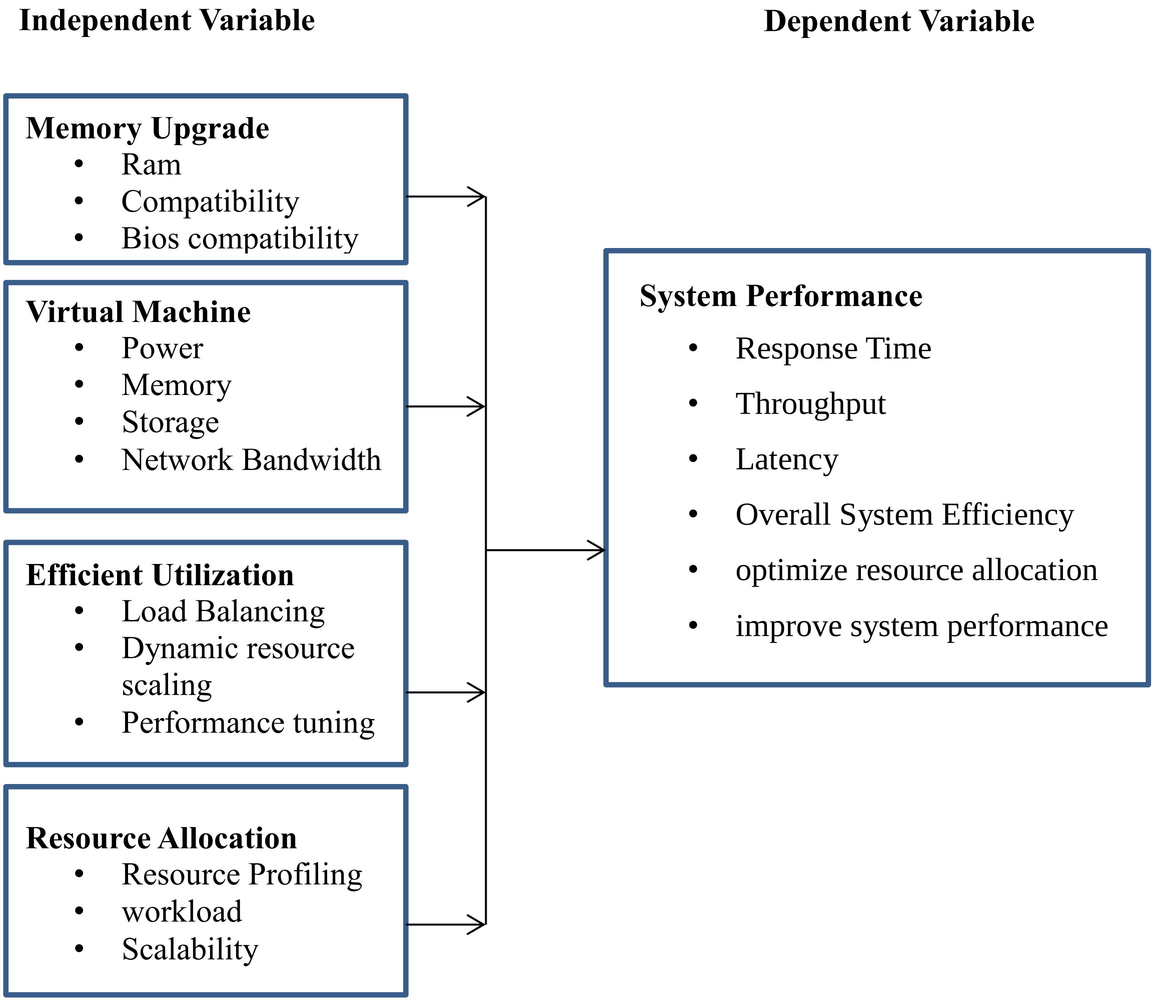

Figure 1: Conceptual Framework

Source : Researcher, 2023

The conceptual framework in the Figure 1 above demonstrates the relationship between memory upgrade, virtual machine, effecient utilization and resource allocation with system performance which is measure in terms of reponse time throughtput, latency, overall system effeiciency, optimize resource allocation and improve system performance.

3. Materials and Methods

In this study, a combination of quantitative and qualitative research methods, including a survey conducted in the field, aimed to optimize virtual machines in cloud-based distributed systems for improved performance and cost efficiency. The study focused on Bank of Kigali (BK), Rwanda, with a target population of 120 individuals from the IT and Datacenter departments. Using stratified and purposive sampling techniques, the researcher selected a sample size of 92 respondents, incorporating a mix of genders and ages ranging from 23 to 65. The research instruments included a questionnaire and a focus group guide. The questionnaire, with both open-ended and close-ended questions, was distributed to 36 staff and IT members from BK to gather quantitative data. Simultaneously, qualitative insights were obtained through face-to-face interviews using the focus group guide. The data collection process involved the use of Zabbix software, an open-source monitoring tool for IT components like networks, servers, and virtual machines. Zabbix facilitated the collection and storage of data for analysis.

The validation, pilot, and reliability of instruments were considered essential in ensuring the accuracy and consistency of data. A pilot study involving 36 participants was conducted to identify potential weaknesses and enhance the questionnaire's effectiveness. Reliability was assessed using Cronbach's Alpha, and factor analysis was employed to establish internal consistency. Validity considerations encompassed content, construct, and external validity. Additionally, the study incorporated ethical considerations, emphasizing the need to preserve the confidentiality and integrity of Bank's information. To adhere to ethical standards, the researcher obtained a research letter and approval from the HR office at Bank, demonstrating a commitment to conducting the research with integrity and respecting the dignity of the organization.

For data analysis, Zabbix software was employed to set triggers, manage alerting and notifications, and visualize data through graphs and dashboards. Furthermore, SPSS (Statistical Package for the Social Sciences) was selected for statistical analysis, data management, and visualization. Descriptive statistics, including measures of central tendency and variability, were used to interpret the collected data. The mean values were categorized into intervals to facilitate interpretation, reflecting the respondents' perceptions. The study maintained a strong ethical stance, ensuring adherence to ethical guidelines throughout the research process.

4.1 Presentation of findings

This chapter presents and interprets the research findings in alignment with the study's objectives, focusing on optimizing virtual machines integration into Bank's competency in distributed systems for improved performance and cost efficiency. The findings address goals such as evaluating the impact of memory upgrades on cloud-based distributed systems, analyzing virtual machine techniques and system performance, developing resource allocation strategies, and assessing the influence of resource allocation on overall system optimization. The presentation includes background information, descriptive statistics, and a thorough examination of the study's defined objectives.

4.2 Response Rate for the Questionnaire and Interview Guide

This is the outcome of the respondents working together to communicate their thoughts on a specific question, which is expressed in several topics. 120 participants were sought for the study. Three interviewing guides and 92 questionnaires were successfully gathered by the researcher. A return rate of more than 70% is regarded as appropriate for study, per Saunders and Lewis (2012). This suggested that the data that had been gathered was adequate to carry out the analysis.

4.3 Data Visualization

The graphic display of information and data is known as data visualization. Data visualization tools give an accessible approach to examine and comprehend trends, outliers, and patterns in data by utilizing visual components including charts, graphs, and maps.

4.3.1 Respondents' Demographic Profiles

The researcher opted to start with the background characteristics of the respondents before delivering the data analysis results. The profile is based on Data Center skills abilities, age, gender, and years of experience.

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4.3.2 Respondents' Age

Analysing respondents' age is essential for understanding the demographic composition of a survey sample and its implications for various domains, including marketing, policy planning, and behavior analysis. Age data allows for the profiling of respondents into generational cohorts, enabling insights into generational trends, attitudes, and preferences. The graphic display of information and data is known as data visualization. Data visualization tools give an accessible approach to examine and comprehend trends, outliers, and patterns in data by utilizing visual components including charts, graphs, and maps.

Table 1: Distribution of Respondents by age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-30	40	43.5	43.5	43.5
	31-45	25	27.2	27.2	70.7
	46-55	20	21.7	21.7	92.4
	55-65	7	7.6	7.6	100.0
	Total	92	100.0	100.0	

Source: Primary Data 2023

According to the findings in the table above, the age distribution of employees in the datacenter sector reveals a diverse workforce. The majority of respondents, approximately 43.5%, fall within the 18-30 age range, suggesting a strong presence of younger, tech-savvy professionals. This youthful demographic can bring innovation and adaptability to the organization. Additionally, the age group of 31-45 accounts for 27.2% of respondents, indicating a significant presence of mid-career professionals with valuable experience and expertise. Moreover, nearly 29.3% of respondents are aged 46-65, showcasing a substantial number of experienced employees contributing their knowledge to datacenter operations.

Table 5: Distribution of Respondents by Qualifications

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Undergraduate	60	65.2	65.2	65.2
	Masters	30	32.6	32.6	97.8
	PHD	2	2.2	2.2	100.0
	Total	92	100.0	100.0	

According to the findings in the table above, the educational background of the respondents in the datacenter sector reveals an interesting distribution: the majority of respondents, accounting for 65.2%, hold undergraduate degrees. This indicates that a substantial portion of employees in datacenters have completed their undergraduate education, which is likely to include relevant technical knowledge and skills. Approximately 32.6% of respondents have attained a master's degree. This suggests that a significant number of datacenter employees have pursued advanced education, potentially equipping them with specialized knowledge that can be beneficial for complex tasks and leadership roles within the organization.

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Table 6: Distribution of Respondents by Experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	20	21.7	21.7	21.7
	1-2 years	10	10.9	10.9	32.6
	3-5 years	55	59.8	59.8	92.4
	More than 5 years	7	7.6	7.6	100.0
	Total	92	100.0	100.0	

Approximately 21.7% of respondents have less than 1 year of experience in this domain, suggesting a relatively inexperienced group in this particular field. About 10.9% of respondents have gained 1-2 years of experience, indicating a small but growing group of individuals who are

The majority, accounting for 59.8% of respondents, have accumulated 3-5 years of experience. This group represents a significant portion of data center employees who likely possess a solid foundation in this area and may be considered mid-career professionals. A smaller proportion, roughly 7.6%, have more than 5 years of experience. These individuals can be seen as seasoned experts in managing cloud-based distributed systems and virtual machines, likely providing valuable insights and leadership within the organization.

4.3.3 Relationship of respondent's age and experience matters

Tests of Between-Subjects Effects

Dependent Variable: Respondent's qualifications

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20.006[a]	4	5.002	80.156	.000
Intercept	7.969	1	7.969	127.719	.000
Experience	.000	1	.000	.000	1.000
Age	11.950	3	3.983	63.836	.000
Error	5.429	87	.062		
Total	198.000	92			
Corrected Total	25.435	91			

R Squared = .787 (Adjusted R Squared = .777)
The R-squared value of 0.787 indicates that approximately 78.7% of the variance in "Respondent's qualifications" can be explained by the combination of "Experience" and "Age" in the model. This suggests that the model is quite effective at explaining the variations in qualifications based on these predictors

This analysis demonstrates that Age has a significant effect on respondents' qualifications, while Experience does not have a significant effect in this context. The overall model is highly significant, and the R-squared value indicates that a substantial proportion of the variance in qualifications can be attributed to the age of the respondents.

Table 7: How often do you encounter challenges related to resource allocation when optimizing virtual machines in the cloud?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Occasionally	10	10.9	50.0	50.0
	Frequently	10	10.9	50.0	100.0
	Total	20	21.7	100.0	
Missing	System	72	78.3		
Total		92	100.0		

From the above table shows the results from datacenter staff where they have been emphasising for daily work challenges likely to meet during allocation of optimization of virtual machines in the cloud.

Table 8: How important is it, in your opinion, to implement automatic scaling (auto-scaling) of resources for virtual machines to optimize performance and cost efficiency?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very important	4	4.3	20.0	20.0
	Absolutely essential	16	17.4	80.0	100.0
	Total	20	21.7	100.0	
Missing	System	72	78.3		
Total		92	100.0		

Table 9: Virtual machine optimization is crucial for enhancing the performance of our cloud-based systems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	31	33.7	33.7	33.7
	Strongly agree	61	66.3	66.3	100.0
	Total	92	100.0	100.0	

4.4 Analysing the Relationship between Cost Optimization Strategies and Performance Enhancement in Cloud-Based Virtual Machines

In this analysis, we aim to explore the correlation between the effectiveness of current cost and optimization strategies for virtual machines in our cloud environment and their impact on performance enhancement and cost efficiency.by conducting a correlation analysis, we aim to uncover potential patterns and relationships. Specifically, we will explore whether a strong positive correlation exists between the effectiveness of cost and optimization strategies and the perceived importance of auto-scaling, as well as the extent to which VM optimization contributes to cost efficiency and performance enhancement. Understanding these correlations can provide valuable insights into the interplay between cost optimization and performance considerations in our cloud-based virtual machine environment, guiding future strategies and decisions for resource management.

Correlations

			How effective do you find the current cost optimization strategies employed for virtual machines in our cloud environment?	How important is it, in your opinion, to implement automatic scaling (auto-scaling) of resources for virtual machines to optimize performance and cost efficiency?	what extent do you believe that virtual machine optimization can contribute to achieving our organization's overall cost efficiency goals?	Virtual machine optimization is crucial for enhancing the performance of our cloud-based systems?
Spearman's rho	How effective do you find the current cost optimization strategies employed for virtual machines in our cloud environment?	Correlation Coefficient	.	.	.	.
		Sig. (2-tailed)	.	.	.	.
		N	20	20	20	20
	How important is it, in your opinion, to implement automatic scaling (auto-scaling) of resources for virtual machines to optimize performance and cost efficiency?	Correlation Coefficient	.	1.000	.	.
		Sig. (2-tailed)	.	.	.	.
		N	20	20	20	20
	what extent do you believe that virtual machine optimization can contribute to achieving our organization's overall cost efficiency goals?	Correlation Coefficient	.	.	1.000	.701**
		Sig. (2-tailed)	.	.	.	.000
		N	20	20	92	92
	Virtual machine optimization is crucial for enhancing the performance of our cloud-based systems?	Correlation Coefficient	.	.	.701**	1.000
		Sig. (2-tailed)	.	.	.000	.
		N	20	20	92	92

**. Correlation is significant at the 0.01 level (2-tailed).

This means there is a strong statistical relationship between the variables. There is a positive and statistically significant correlation (0.701) between "To what extent do you believe that

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virtual machine optimization can contribute to achieving our organization's overall cost efficiency goals?" and "Virtual machine optimization is crucial for enhancing the performance of our cloud-based systems?" This suggests that respondents who believe that VM optimization contributes significantly to cost efficiency also tend to consider it crucial for enhancing performance.as virtual machines won't need to have much resources to running, by using Splunk software to vm machines will low cost and system performance keep efficiently as needed by the organization.

4.5 ZABBIX Data Analysis

Zabbix is an open-source, enterprise-class monitoring and alerting solution designed to track and monitor the performance and availability of network devices, servers, cloud resources, applications, and other IT infrastructure components. It provides a comprehensive set of features for monitoring, alerting, visualization, and reporting, making it a popular choice for IT administrators and DevOps teams

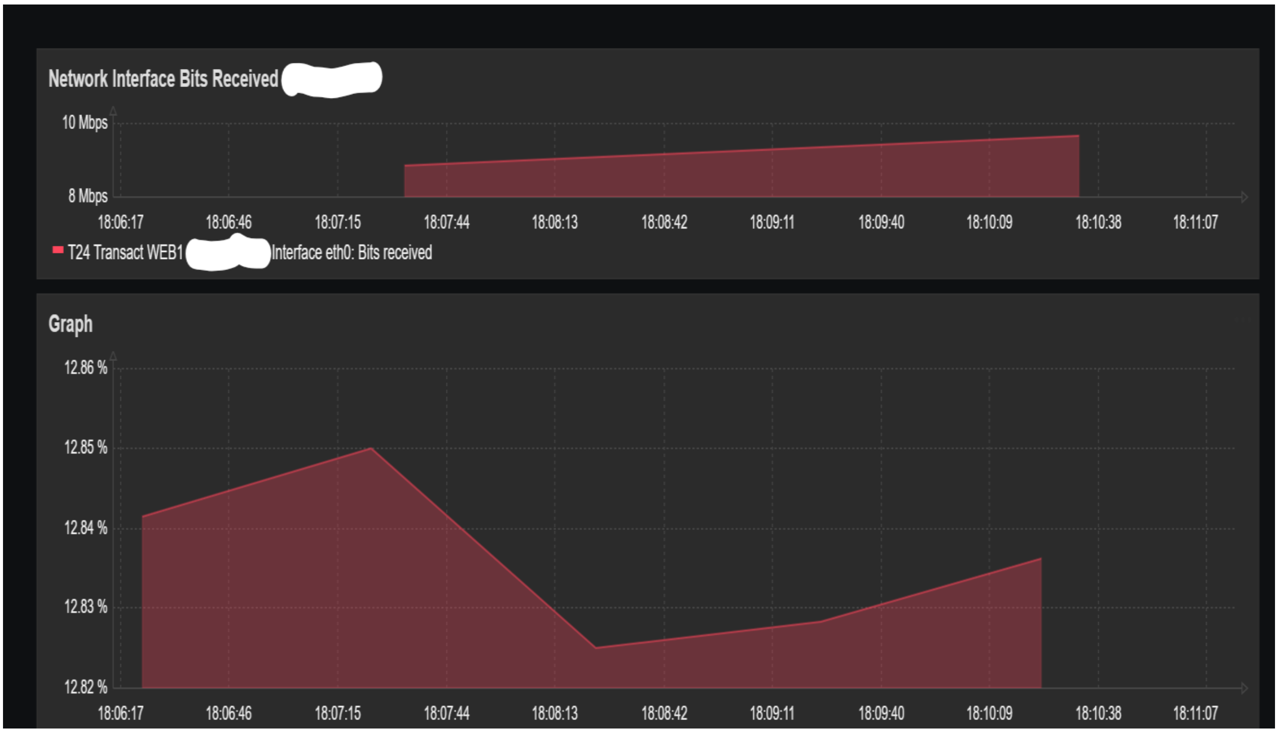

Figure 2: The variation of the resource utilization

Based on the above graph shows the variation of CPU utilization in real time, this will collects data through various methods, including agent-based and agentless monitoring, SNMP (Simple Network Management Protocol), JMX (Java Management Extensions), IPMI (Intelligent Platform Management Interface)

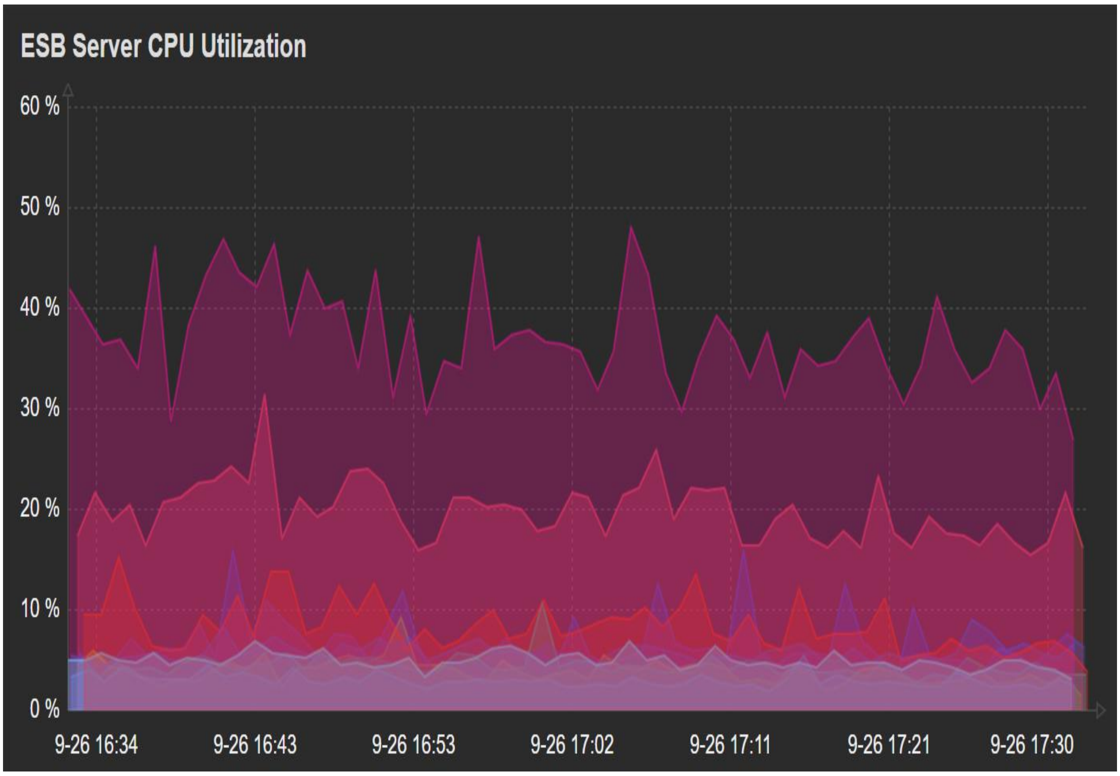

Figure 3: Variations of CPU from Enterprise Service Bus

From the above figure shows the variations of CPU utilizations from ESB Servers as we are optimizing the virtual machines in cloud based distributed systems, we will have to keep monitoring and enhance performance and cost efficient by doing monitoring and make scalability of the resources during the time we have high request from the customers from several services they are requesting then we make configurations and exceeds the necessary resource to avoid the downtime of the services.

The above figure shows the variations of CPU resources to the bank Application service running its own server with necessary resources such Ram, Storage and Processor are being consumed by app service to keep our virtual machines being optimized and also enhancing performance we apply several techniques such optimization of drives, scheduling clearing temp files in certain period of time and monitoring.

4.6 Splunk Data analysis

Splunk Enterprise is a data analytics and monitoring platform designed to help organizations collect, index, search, and analyse machine-generated data. It is widely used for log and event data analysis, providing insights into various aspects of an organization's IT infrastructure, security, and business operations. (George A. Fry's departure in 1942)

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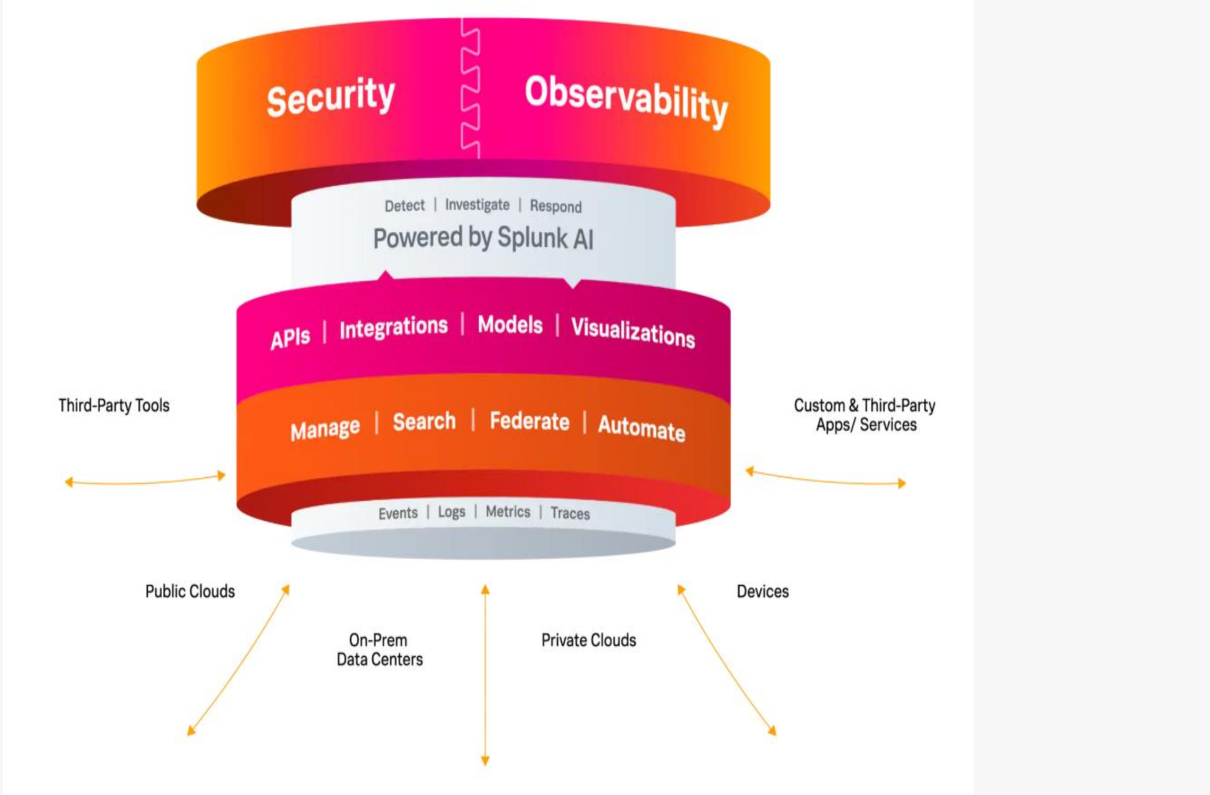

Figure 4: Shows functionality of Splunk

Some key features and capabilities of Splunk Enterprise: Data Collection: Splunk can ingest data from a wide range of sources, including servers, applications, network devices, sensors, and more. It can collect and index structured and unstructured data. Search and Query: Splunk's powerful search and query language allows users to search and analyze data in real-time. It supports complex searches and filtering to quickly identify patterns, trends, and anomalies. Real-Time Monitoring: Splunk can monitor and alert on events and conditions in real-time. This is valuable for security monitoring, system health checks, and proactive issue detection. Data Visualization: Splunk provides visualization tools to create dashboards and reports. Users can create custom visualizations to represent data in a meaningful way. Machine Learning: Splunk offers machine learning capabilities for predictive analytics and anomaly detection. It can automatically detect deviations from normal patterns in data. Security Information and Event Management (SIEM): Splunk is often used as a SIEM solution to monitor and analyze security events, helping organizations detect and respond to security threats. Compliance and Reporting: Splunk can assist with compliance reporting by collecting and analysing data relevant to regulatory requirements. Customization: Users can create custom applications and add-ons to extend Splunk's functionality to suit specific use cases and industries. Scalability: Splunk Enterprise is scalable and can handle large volumes of data. Organizations can deploy it on-premises or in the cloud, depending on their needs. Integration: Splunk integrates with a wide range of third-party tools and services, making it a versatile platform for data analysis and correlation.

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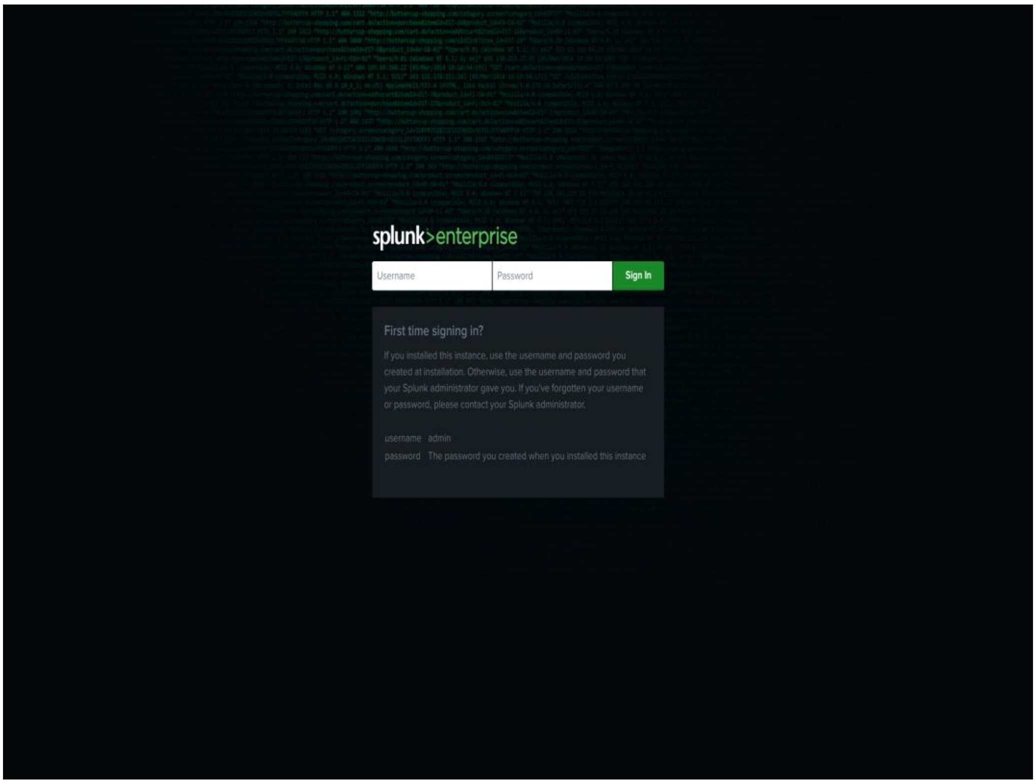
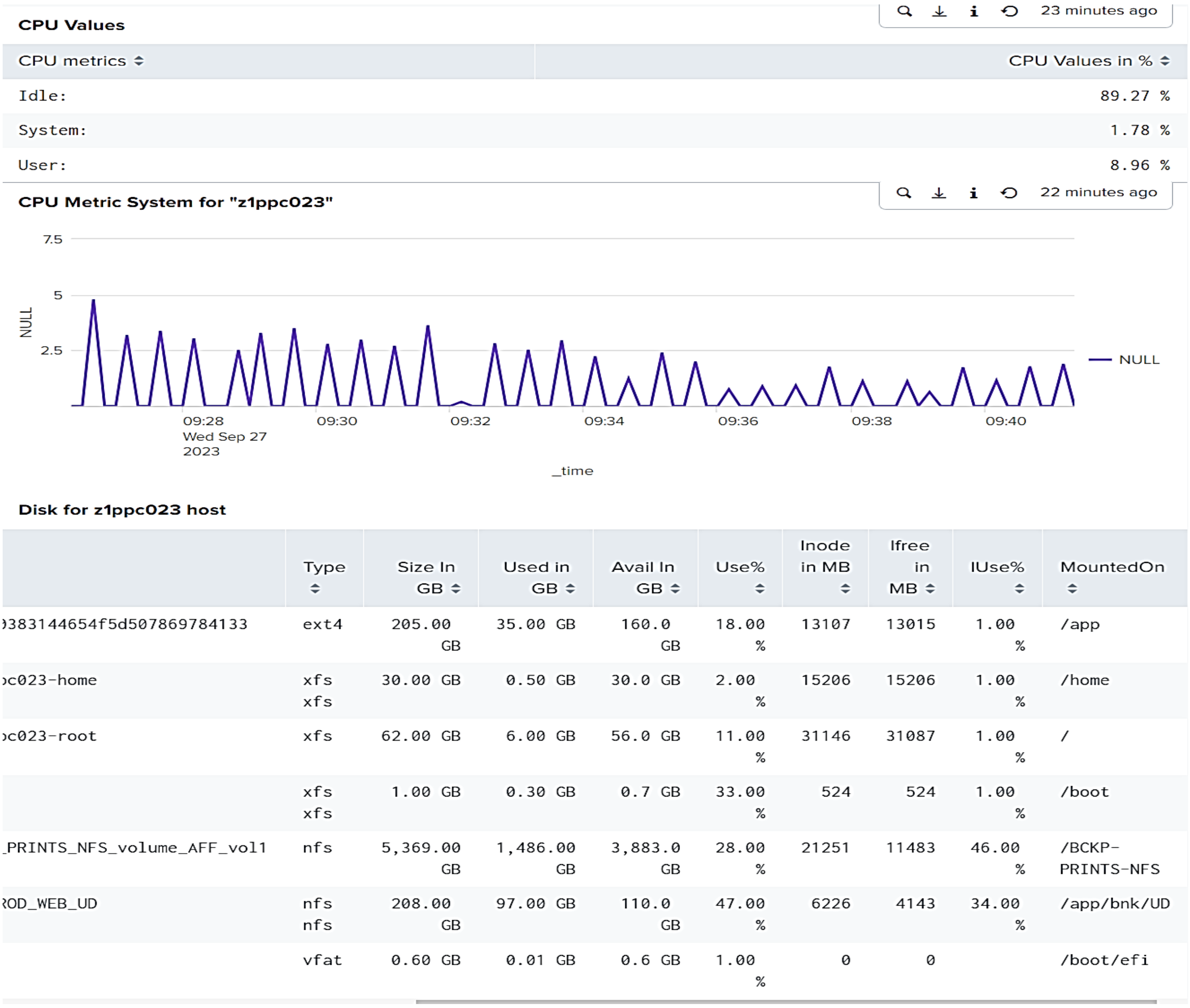


Figure 5: Splunk enterprise login

The above figure shows the login interface of Splunk enterprise from the above you put the credentials have been created. We are going to the next for server and its utilization where we’ll have to monitor and alert on events and conditions in real-time. This is valuable for security monitoring, system health checks, and proactive issue detection.



CPU metrics	CPU Values in %
Idle:	89.27 %
System:	1.78 %
User:	8.96 %

	Type	Size In GB	Used in GB	Avail In GB	Use%	Inode in MB	Ifree in MB	IUse%	MountedOn
3383144654f5d507869784133	ext4	205.00 GB	35.00 GB	160.0 GB	18.00 %	13107	13015	1.00 %	/app
c023-home	xfs xfs	30.00 GB	0.50 GB	30.0 GB	2.00 %	15206	15206	1.00 %	/home
c023-root	xfs	62.00 GB	6.00 GB	56.0 GB	11.00 %	31146	31087	1.00 %	/
	xfs xfs	1.00 GB	0.30 GB	0.7 GB	33.00 %	524	524	1.00 %	/boot
_PRINTS_NFS_volume_AFF_vol1	nfs	5,369.00 GB	1,486.00 GB	3,883.0 GB	28.00 %	21251	11483	46.00 %	/BCKP-PRINTS-NFS
ROD_WEB_UD	nfs nfs	208.00 GB	97.00 GB	110.0 GB	47.00 %	6226	4143	34.00 %	/app/bnk/UD
	vfat	0.60 GB	0.01 GB	0.6 GB	1.00 %	0	0		/boot/efi

Figure 6: Shows CPU Metrics

As we're concerned with optimization of virtual machines in cloud-based distributed systems for enhanced performance and cost efficiency we'll keep monitoring our resources to make sure the enough performance and emphasize the cost efficiency are being respected and our systems hosted to the servers are working very effectively so here Splunk enterprise will be the greater tool to support our main goal to optimize our virtual resource allocations are on the hybrid cloud.

4.7 Analysis Optimization of virtual machines techniques, algorithms and cost efficiency in distributed systems

There are several techniques and algorithms may apply on the virtual machine to optimize it and measure the cost metrics to keep enhancing the performance of our distributed systems,

Right-sizing VMs: Choose VM configurations (CPU, RAM, storage) based on workload requirements. Avoid overprovisioning or under provisioning resources. Resource Allocation: Use resource reservations and limits to control resource allocation. Employ CPU and memory affinity/anti-affinity rules to manage resource placement. Hypervisor Optimization:

Stay updated with the latest hypervisor updates and patches for performance improvements. Enable hardware virtualization support (VT-x/AMD-V) in the BIOS/UEFI settings. Use a

Type 1 hypervisor for better performance compared to Type 2. Storage Optimization: Use thin provisioning to allocate storage dynamically. Implement storage deduplication and compression where available. Utilize high-speed storage options like SSDs for I/O-intensive workloads. Networking Optimization: Implement VLANs and network segmentation for improved network performance and security. Use paravirtualized (PV) or virtio drivers for network adapters for better performance. Guest OS Optimization: Use the latest OS versions and patches. Disable unnecessary services and features. Install and configure VM-specific drivers/tools provided by the hypervisor vendor. CPU Pinning: For performance-sensitive workloads, consider CPU pinning, which assigns specific physical CPUs to a VM to reduce contention. Memory Ballooning: Use memory ballooning techniques to reclaim unused memory from VMs and allocate it to others when needed. Monitoring and Performance Tuning. Continuously monitor VM performance using tools like VMware vCenter, Hyper-V Manager, or open-source solutions like Grafana and Prometheus. - Analyze performance data to identify bottlenecks and adjust resource allocations accordingly. Backup and Snapshot Management: Implement efficient backup and snapshot strategies to minimize I/O impact during backups. Avoid keeping excessive snapshots, as they can consume storage and impact performance. Host Maintenance and Patching: - Regularly update and patch the underlying hypervisor and host OS to address security vulnerabilities and performance enhancements. Load Balancing and High Availability: - Distribute workloads across multiple VMs for load balancing and redundancy. Implement high availability configurations to ensure uptime and failover capabilities. SSD Caching - Use SSD caching solutions, like vSAN caching or Storage Spaces Direct (S2D), to improve storage performance. Power Management: - Adjust power management settings to balance performance and energy efficiency, especially in non-production environments. Documentation and Capacity Planning: - Maintain detailed documentation of VM configurations and performance tuning efforts. - Perform capacity planning to ensure resources are allocated optimally as workloads evolve.

4.7.1 Facts of Optimization virtual machines and cost efficiency in distributed systems

4.7.1.1 Energy Reduction for Ant-Colony Optimization (ER-ACO) Algorithm

Our optimization goal is to adopt a virtualization technology which will allow the effective management of resources (CPU and RAM) and minimize the Energy consumed by Bank of Kigali Datacenters which in turn will reduce the maintenance cost for the bank by effectively placing the VMs to the hosts with lower Energy consumption and with enough CPU, and Memory to accommodate the VM. Therefore, the pheromone shall consider the following additional factor: the system energy utilized by the physical host.

4.7.1.2 Proposed Energy Reduction for Ant-Colony Optimization algorithm

Our proposed ER-ACO algorithm is shown in the Figure 21 below and it can be stated as follows:

Input:

Virtual machine required resources R_i, Physical Machine resources S, Power utilized by the physical host $P_{(u)}$, the algorithm parameters α, β, ϱ

Output:

The Virtual machine VM_j mapped to the Physical host i, if $P_{(u)} < P_{max}$ then the algorithm ends, otherwise, compute the Physical machine resources S and allocate the VM_j to the Physical host i.

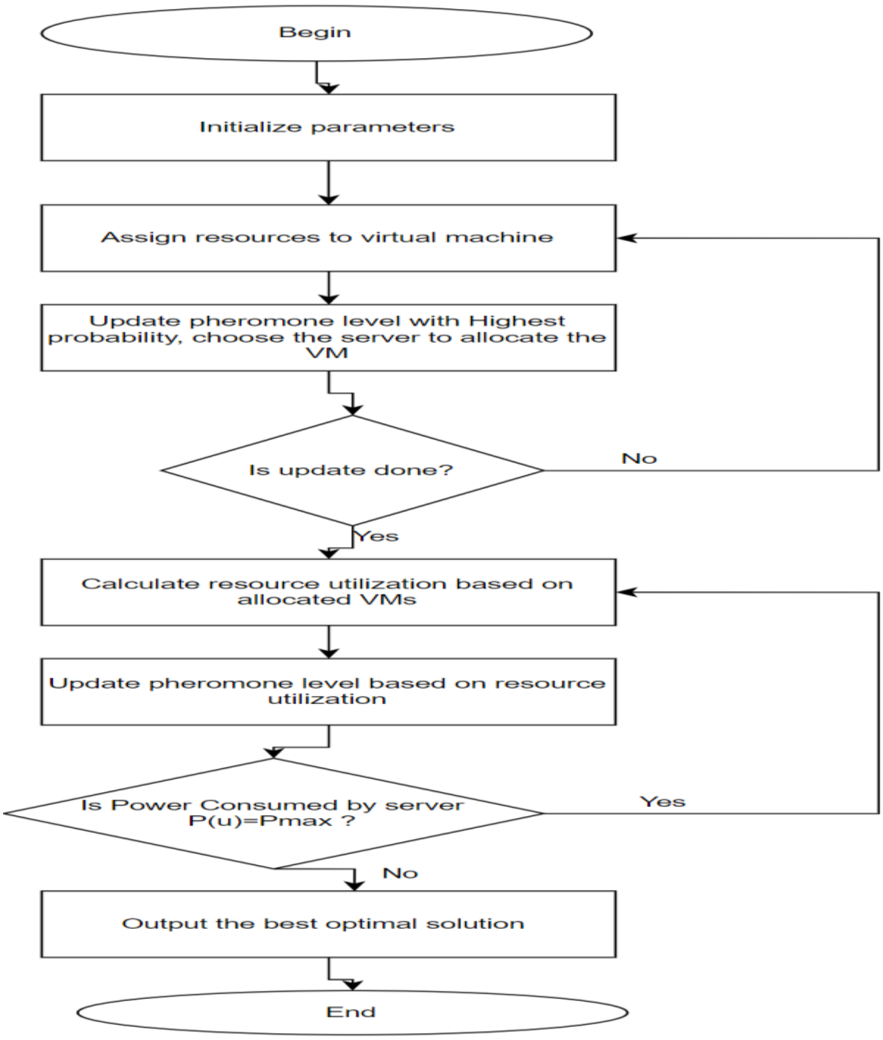


Figure 7: Proposed ER-ACO Algorithm

Table 2: Proposed ER-ACO Algorithm

ALGORITHM1: ER-ACO ALGORITHM	
	Input: Virtual machine required resources **Ri**, Physical Machine resources S, Power utilized by the physical host **P(u)**, the algorithm parameters **α**, **β**, **ϱ**
	Output: The Virtual machine $\mathbf{VM_j}$ mapped to the Physical host **i**
1	**Initialization of Variables:** α, β, ϱ
2	**for** VM_j=1 to N **do** //Deploy all unassigned VMs $\mathbf{VM_j}$ to the cluster host **i**
3	Assign resources **Ri** needed by the VM_j, $\mathbf{R_i} = \sum [\mathbf{r_{(i,j)}} * \mathbf{b_{(i,j)}}]$
4	**for** host **i** = 1 to **j do**
5	Allocate VM_j to Host i
6	Calculate $P_{(u)} = (k * P_{max}) + [(1-k) * P_{max} * u]$
7	**if** $P_{(u)} = P_{max}$ **then** //Compute the resources of the remaining hosts S_i
8	Allocate V_{Mj} to Host i+1
9	**end if**
10	**end for**
11	update the pheromone $\mathbf{T_{(i,j)}} = (1 - \varrho) * \mathbf{T_{(i,j)}} + \varrho * \Delta \mathbf{T_{(i,j)}}$
12	**end for**
13	Return the best optimal solution //Allocate the VM to physical host

4.7.2 Results of the experiments

To be able to verify the effectiveness of our proposed algorithm, we conducted the simulation experiments based on the Cloudsim platform named Workflowsim-1.0. The experiments have been coded using Java language using Apache NetBeans IDE 13 software to simulate the Ant Colony Optimization Algorithm for Virtual machine resource management. The hardware configuration of the experiment environment is based on the data collected: 25 physical hosts with 4 TB RAM and 1TB of storage, and 12 physical hosts with 4 TB RAM and 1TB storage. The system Architecture is x64, the Operating System is Windows, the Virtualization platform is Hyper-V. The computing capacity of physical servers is 1000 MIPS. The computing resources of the virtual machine is 1000 MIPS, RAM = 512 MB, CPUs =4. Different parameters in the simulation will have different results. By simulating with the current deployed infrastructure with 30 VMs, the output from the Cloud Report shows the following results:

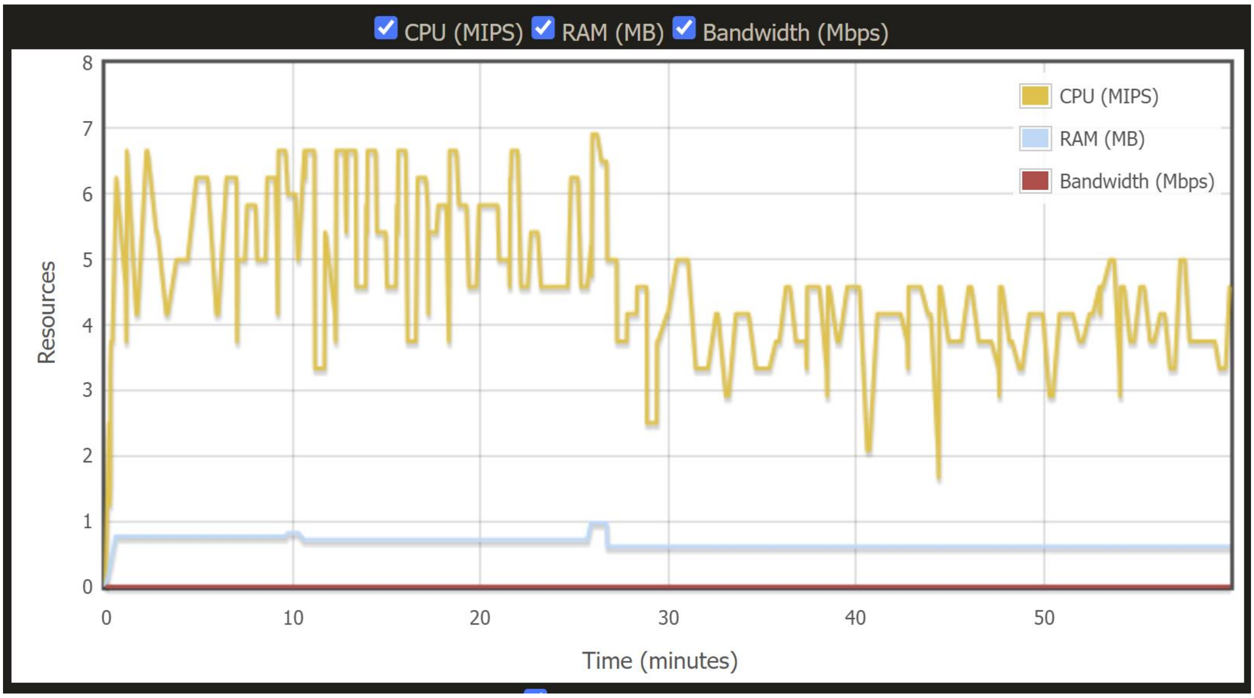


Figure 8: Overall resource utilization in Datacenter

4.7.3 Analysis of the 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. Based on the data collected from the System using SCVMM and from staff on how they understand the resources needed, 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 the two popular Virtualization technologies.

4.7.4 Ranking of Criteria

We have used the SpiceLogic Analytic Hierarchy Process 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 by IT Staff to be able to play a role in effective managing resources and has less impact on service availability Power is relatively important than cost, and CPU is more important than Power and Cost and RAM is strong importance.

Table 3: 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 .216 and RAM has 0.89

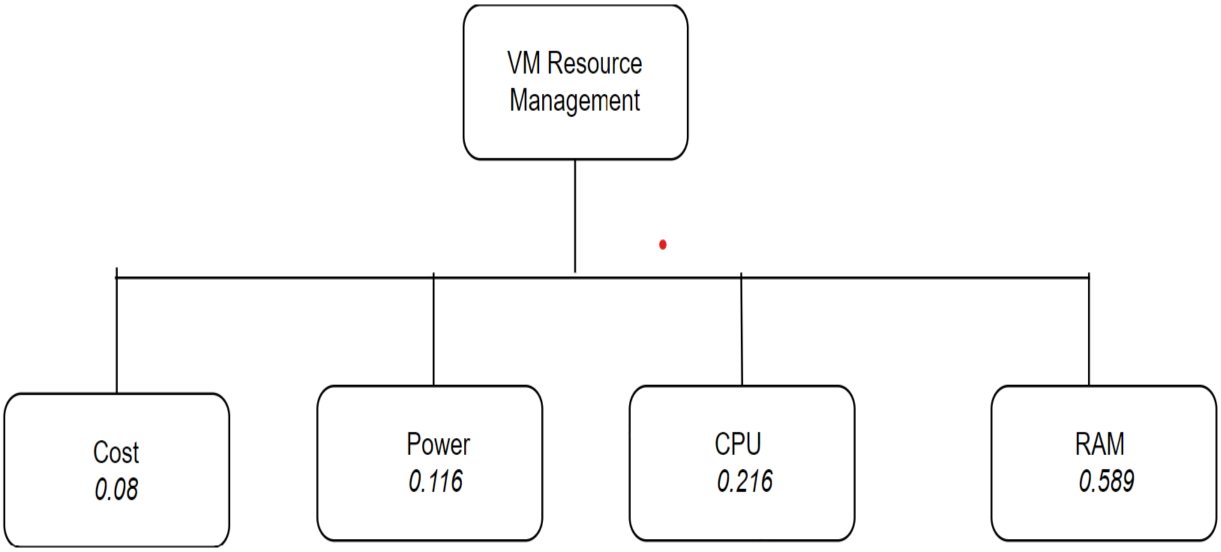


Figure 9: criteria weight

4.7.5 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:

4.7.5.1 Ranking Alternatives:

Cost from all Options:

Table 4: Pairwise Comparison of Options for criteria: Cost

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

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Even though the cost has low weight (least reliability) on Hyper-V is somewhat more important than the cost on VMware (Table 12). Therefore, the Cost of Hyper-V is higher than VMware.

Power from all Options:

Table 5: 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 13 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).

CPU from all Options:

Table 6: 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 14. This indicates that CPU management is easier on VMware than on Hyper-V.

RAM from all Options:

Table 7: 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 15 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 VMW are and Hyper-V. The result demonstrates that VMware is prioritized over Hyper-V.

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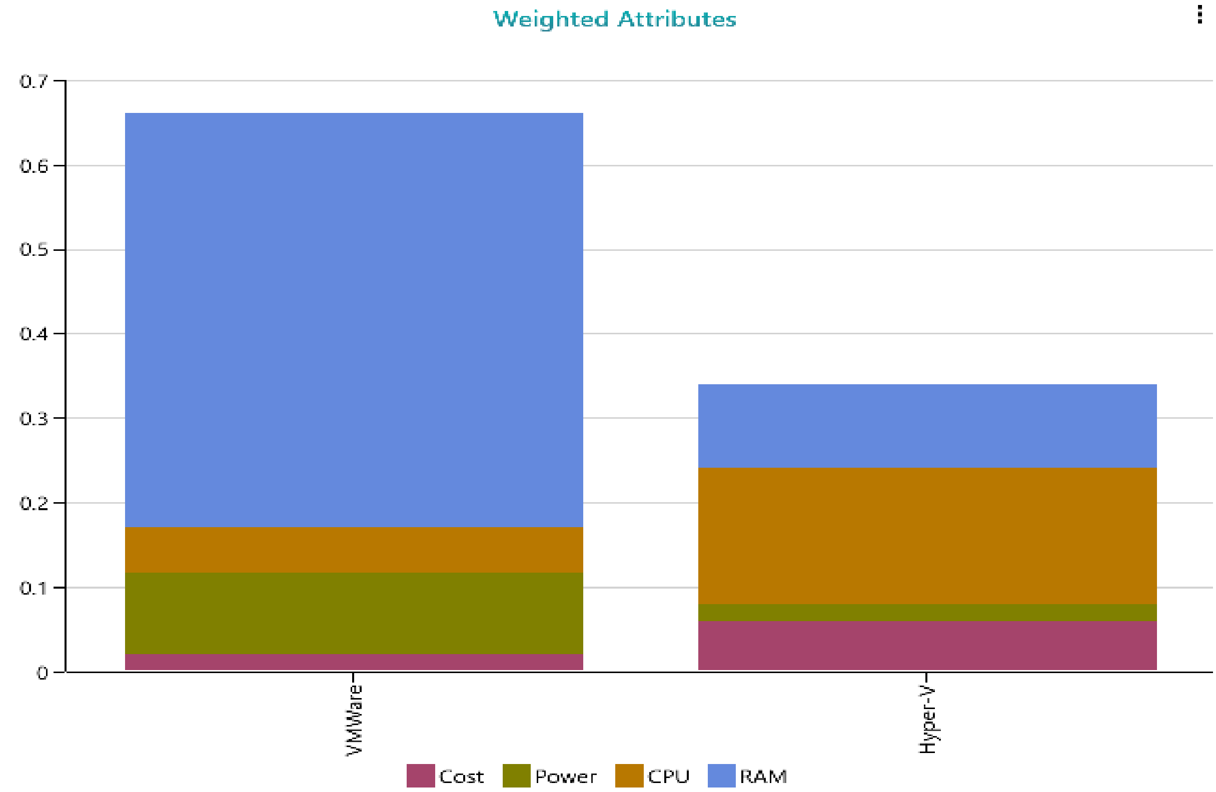

Figure 10: Weighted Attributes for VMware and Hyper-V

The result from SpiceLogic shows that the recommended Virtualization Technology to adopt is VMWare as shown in the Figure 14 above. Having an adequate Virtualization technology implemented will result in proper resource Management such as CPU and RAM. This will have an impact on reducing the maintenance cost of Hardware due to the consolidation, which will, in turn, reduce the amount of Energy consumed by the Physical hots because it will reduce dramatically.

4.8 Analysis of the Effectiveness of Virtual Machine Technologies in Enhancing Datacenter Resources for Cloud Distributed Systems at the Bank

Based on the study's findings, it was evident that a substantial number of respondents recognize the positive impact that virtual machine technologies can have on system performance within the context of cloud distributed systems. This underscores their appreciation for the value of virtual machines and their potential to support the bank's cloud-based operations. Consequently, it suggests that the implementation of virtual machine techniques, which facilitate the sharing of a limited physical infrastructure by multiple virtual machines, can significantly enhance the utilization of Datacenter resources in the context of cloud distributed systems. This enhancement can lead to cost savings, improved resource management, scalability, and the flexibility to add or remove resources as required, all of which are essential for optimizing Datacenter performance and efficiency in cloud computing environments at the Bank.

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4.8.1 Analysis on Proposed ER-ACO Algorithm to improve resource utilization in Bank Datacenter

Many Algorithms have been developed to improve resource utilization in cloud Datacenters. There is a need to implement those Algorithms in on-premises Datacenters to increase their efficiencies. Therefore, adopting and implementing the ER-ACO Algorithm could significantly improve in optimizing the Datacenter resources not only in Bank Datacenters but also in other On-Premises Datacenters because it would enhance the overall performance of Datacenter infrastructures.

4.8.2 Proposed Virtualization Deployment model based on MCDM-AHP-VMRM

The current Deployed Virtualization Technology (Hyper-V) has shown its limitation in terms of Resource allocation and effective management. This has resulted in poor performance of the organization Critical Systems such as Internet Banking, Mobile Banking and its core Banking System as a researcher gathered the information from responders and from systems using SCVMM and Open Manage tools. The new Deployment model would base on the current infrastructure hardware, current acquired virtualization licences and future deployment new plans for expansion. The figure 15 below shows the new proposed VM deployment model after research study.

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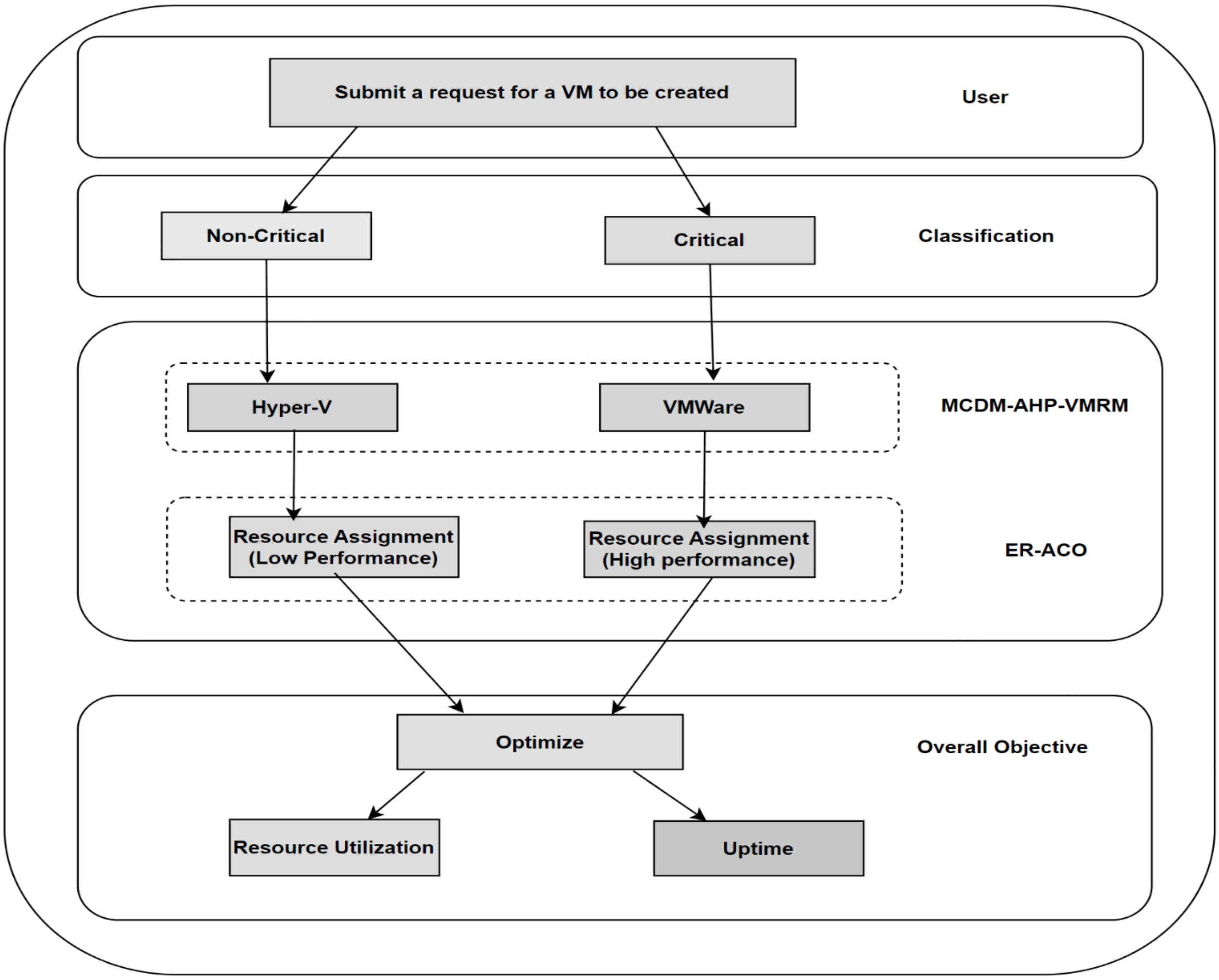

Figure 11: Proposed VM Deployment framework

4.8.3 Proposed Deployment framework Explanations

The figure 15 above shows the phases that can be followed during the VM deployment, where the first phase is the submission of the VM to be created, then classification phase happens. The Non-Critical System should be created on Hyper-V Clusters and critical Systems to be on VMWare Clusters and the resources can be assigned to VMs (using MCDM-AHP-VMRM and ER-ACO) This will allow the proper VM allocation and we will be able to optimize the resources such as CPU and RAM which in turn will reduce the overall maintenance cost and reduce the energy utilized by physical servers and increase the uptime of critical services as the virtualization techniques will provide the possibility to add or remove resources as needed.

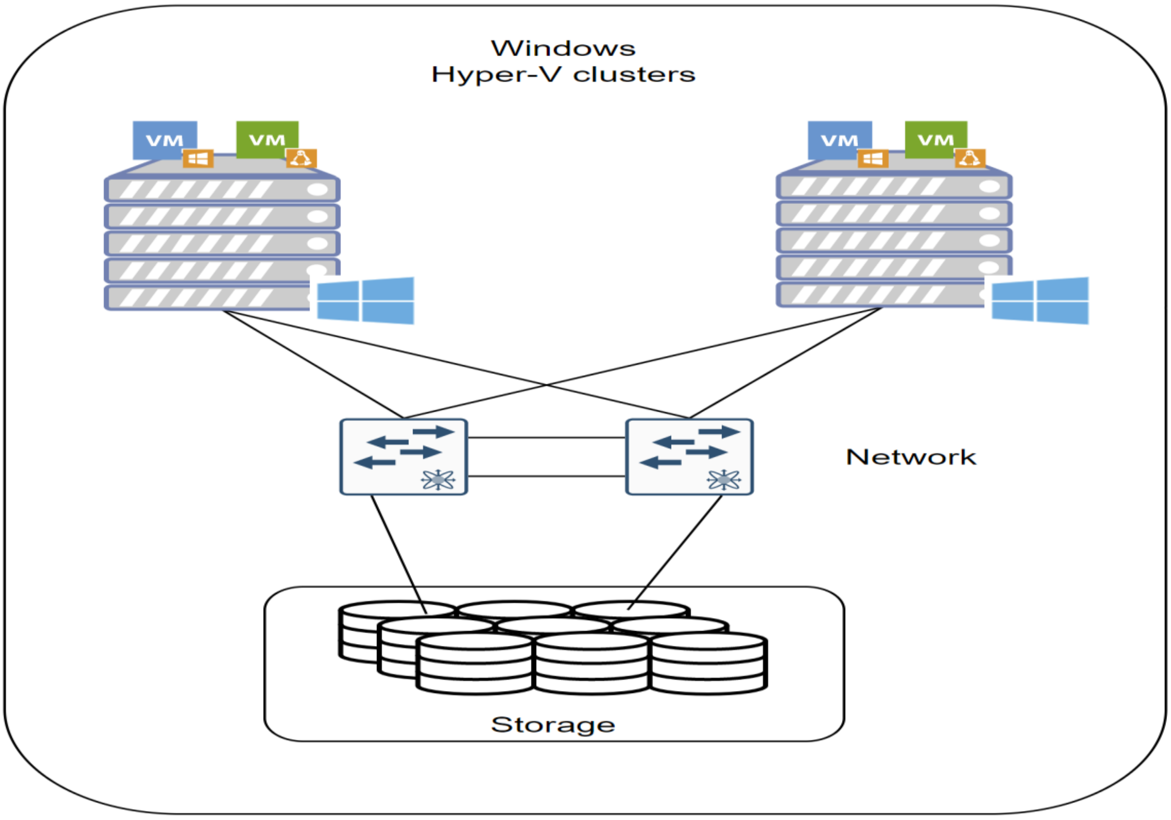

Figure 12: Deployment of tests and development Systems

The figure 16 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 shut down any time and put back online when needed. This can reduce the dramatically the resources being utilized. The Figure 16 below describes the Deployment model proposed by the researcher for production systems.

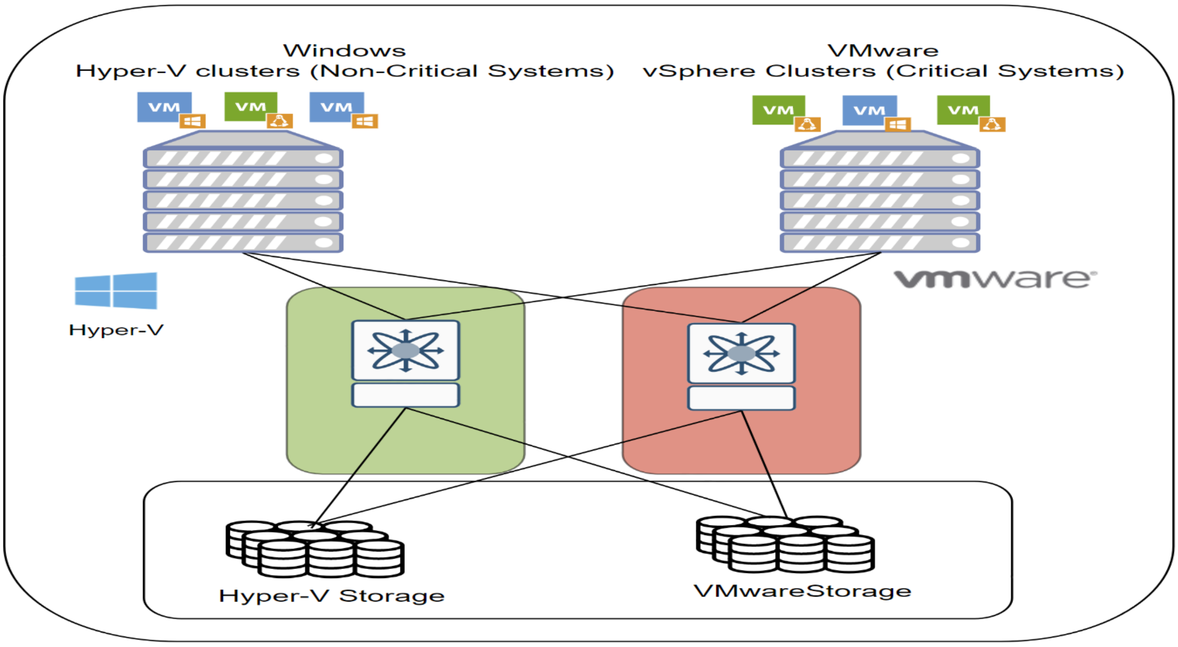

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Figure 13: Deployment of tests and development Systems

The Figure 17 above describes the virtualization deployment strategy proposed by the researcher for production systems, it will include the critical systems such as customer-facing applications like Internet Banking, Mobile Banking systems and its Core Banking system and non-mission -critical applications such as support-to-business applications. The critical systems will be deployed on VMWare platform such as like Microsoft Azure, as it is suitable for providing high availability for critical workloads and other capabilities such as expand or reduce resources as they 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.

4.9 Microsoft Azure Virtual Machines

Microsoft Azure Virtual Machines (VMs) play a significant role in the optimization of virtual machines within cloud-based distributed systems to achieve enhanced performance and cost efficiency. Azure VMs are a core component of Microsoft's cloud computing platform, Azure, and offer a wide range of features and capabilities tailored to meet the demands of modern cloud-based applications. In the context of optimizing virtual machines for enhanced performance and cost efficiency. Azure provides several services and tools for workload balancing, ensuring that resources are distributed efficiently and evenly across the available infrastructure like Azure Load Balancer: Azure Load Balancer is a high-performance, Layer 4 load-balancing service that distributes incoming network traffic across multiple virtual machines (VMs) to ensure application availability and scalability. It can balance traffic across availability sets and virtual machine scale sets. Azure Application Gateway: This is a Layer 7 load-balancing service that provides application-level routing and load balancing. It can route traffic based on URL path, host headers, and more, making it suitable for web applications. Traffic Manager: Azure Traffic Manager is a DNS-based global load balancer that routes traffic to the nearest available data center or Azure region based on various routing methods. It helps improve application performance and availability for global users. Dynamic provisioning is crucial for scaling resources up or down based on demand. Azure offers various services and features to achieve this flexibility: Azure Virtual Machine Scale Sets: This service allows you to automatically scale the number of VMs in a set based on metrics or schedules. It ensures that your application can handle varying workloads without manual intervention. Azure Kubernetes Service (AKS): AKS is a managed Kubernetes container orchestration service that automatically scales your containerized applications. It can adjust the number of pods in your deployment based on CPU usage, memory, or other metrics.

Azure Functions: Azure Functions is a serverless computing service that automatically provisions resources to execute code in response to events. It dynamically scales to handle incoming requests and automatically adjusts resources as needed.

5.1 Conclusion

In conclusion, the general objective of this thesis is to Optimize Virtual Machines in cloud-based distributed systems to enhance performance and cost efficiency. The research aims to develop strategies that ensure optimal utilization of computing resources while considering workload balancing, dynamic provisioning, and fault tolerance requirements in Bank of Kigali and based on the purpose of this study, researchers collected data using questionnaires from Staff working in IT division of Bank of Kigali who are managing critical systems especially Data Center team who always dealing with servers and resources are being consumed by the services. The sample size was 92. The data gathered was presented in tables and graphs, the data from the infrastructure was collected using SCVMM, iDRAC and Open manage to be able to collect the infrastructure resources and virtual machines technology deployed. Based on the objectives of the research study, the findings showed that Virtual machine technologies can improve Datacenter resources utilization in Bank of Kigali and based on the findings, the proposed deployment strategy will align with the Banks business objectives.

5.2 Recommendations

This research offers valuable insights applicable not only to Banks but to banks globally, particularly in Africa, aiding in the effective implementation of Virtual Machine technologies. The recommendations emphasize meticulous planning and execution of virtualization deployment to enhance efficiency, achieve cost savings, reduce energy consumption, and improve scalability and system flexibility for optimal outcomes.

5.3 Acknowledgement

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