EPOKA UNIVERSITY | Computer Engineering Department

PERFORMANCE ANALYSIS OF INFORMATION SYSTEMS INFRASTRUCTURE FOR ENTERPRISES (ALBANIAN POSTAL OFFICE)

A THESIS SUBMITTED TO
THE FACULTY OF ARCHITECTURE AND ENGINEERING
OF
EPOKA UNIVERSITY

BY

ERLI ASABELLA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
COMPUTER ENGINEERING

JUNE, 2022

Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Performance analysis of information systems infrastructure for enterprises. (Albanian Postal Office)"** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

____

Head of Department: Dr. Arban Uka
Date: June 17, 2022

Examining Committee Members:

Assistant. Prof. Dr. Arban Uka (Computer Engineering) _________________

Dr. Maaruf Ali (Computer Engineering) _________________

Dr. (Computer Engineering) _________________

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name Surname: Erli Asabella

Signature: ______________

ABSTRACT

PERFORMANCE ANALYSIS OF INFORMATION SYSTEMS INFRASTRUCTURE FOR ENTERPRISES (ALBANIAN POSTAL OFFICE)

Erli Asabella

M.Sc., Department of Computer Engineering

Supervisor: Dr. Maaruf Ali

VT is one of the most sought-after topics these days. Virtualization allows a single computer to run several OSs at the same time [1] VT enables businesses to run multiple services on a single server, lowering the cost of managing multiple hardware and maximizing resource utilization. Cloud computing is currently a hot topic of research in computer systems, and virtualization is the key to cloud computing.

VT reduces costs in corporate data centers by combining server applications into fewer servers in a more reliable and secure manner. Different loads running on the same platform improve management, security, and cost. Computer hardware is rapidly increasing the performance of its physical resources and as a result tends to have some resources not fully utilized and VT has overcome this problem. Maximum utilization of the computer system is made possible with the help of this technology.

There are several reasons to answer why virtualization is needed as it has several advantages both financial and managerial. There are many challenges that can arise as you develop new applications and computer systems, especially nowadays when modern hardware is available for commercial and enterprise use on a large scale. VT enables abstraction from actual hardware while also removing limits on operating a single OS on a single piece of hardware. We use methods like Iozone, Ram Speed Testing and UnixBench for measuring the performance of the systems.

Keywords: *Benchmark tool, operative system, Hardware, virtualization, CPU, Iozone.*

ABSTRAKT

ANALIZA E PERFORMANCËS SË INFRASTRUKTURËS SË SISTEMIT TË INFORMACIONIT PËR NDËRMARRJET

(POSTA SHQIPTARE)

Erli Asabella

Master Shkencor, Departamenti i Inxhinierisë Kompjuterike

Udhëheqësi: Dr. Maaruf Ali

Teknologjia e virtualizimit është një ndër temat më të kërkuara në ditët e sotme. Virtualizimi lejon një kompjuter të vetëm të ekzekutojë disa sisteme operative në të njëjtën kohë [1]. Teknologjia e virtualizimit ndihmon kompanitë të ekzekutojnë shërbime të ndryshme në një server të vetëm i cili mundëson reduktimin e kostos të menaxhimit të shumë hardware dhe përdorimit të burimeve në një mënyrë më efiçente. Në ditët e sotme cloud computing është një temë që ka interes të madh studimi në sistemet kompjuterike dhe virtualizimi është çelësi në cloud computing.

Në qendrat e të dhënave të kompanive, teknologjia e virtualizimit bën të mundur minimizimin e kostove duke kombinuar aplikacionet e serverave në më pak servera në mënyrë më të besueshme dhe të sigurte. Ngarkesa të ndryshme që ekzekutohen në një platformë të vetme sigurojnë menaxhim, sigurim dhe kosto më të mirë. Hardware-ët e kompjuterave po rrisin shumë shpejt performancën e burimeve fizike të tyre dhe si rrjedhojë janë të prirur të kenë disa burimet jo plotësisht të shfrytëzueshme dhe teknologjia e virtualizimit solli kapërcimin e këtij problemi. Shfrytëzimi maksimal i sistemit të kompjuterave është bërë e mundur me ndihmën e kësaj teknologjie.

Janë disa arsye për tju përgjigjur se përse nevojitet virtualizimi meqë ai ka një numër avantazhesh si financiare dhe menaxheriale. Janë shumë sfida që mund të shfaqen ndërsa zhvilloni aplikacione të reja dhe sisteme kompjuterike, veçanërisht ditët e sotme kur hardware modern janë të disponueshëm për tregti dhe përdorim të kompanive në shkallë të lartë. Abstragimi nga hardware fizikë është mundësuar nga teknologjia e virtualizimit, e cila gjithashtu heq kufizimet e ekzekutimit të vetëm një sistemi operative në një hardware të vetëm.

Fjalët kyçe: Mjete *Benchmark, system operativ, Hardware, virtualizim, CPU, Iozone.*

ACKNOWLEDGEMENTS

I would like to thank my supervisor Dr. Maaruf Ali who made this work possible. His guidance and advice carried me through all the stages of my thesis.

I thank my family for the support and encouragement they gave me to successfully complete this scientific project.

TABLE OF CONTENTS

List of Figures

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

One of the most popular subjects these days is VT. Virtualization allows a single machine to run many OSs concurrently [1]. VT enables businesses to run several services on a single server, lowering the cost of operating various hardware and maximizing resource efficiency. Virtualization is the key to cloud computing, which is now a hot area of research in computer systems [2].

VT reduces expenses in corporate data centers by integrating server applications onto fewer servers in a more dependable and secure manner [3]. Different loads running on a same platform offer improved administration, security, and cost savings. Computer hardware is quickly improving the performance of its physical resources, which causes certain resources to be underutilized, and VT has solved this problem [4]. This technology enables the computer system to be used to its full potential.

There are various reasons why virtualization is required, since it provides a lot of financial and management benefits. Many obstacles might occur while developing new applications and computer systems, especially now that contemporary technology is widely available for commercial and business usage.

IBM was the first to incorporate VT into their high-speed computers System 360 and 370 in the 1960s and 1970s. The invention of personal computer architecture and its fast development in the 1980s nearly put an end to virtualization [5]. The demand for this technology surged once again when individuals realized that their data centers were filling up and the power they required was skyrocketing, which could no longer be financed with additional infrastructural investments [6]. Hardware manufacturers such as Intel and AMD presently support virtualization, having changed their designs to allow virtualization on x86 CPUs. Because of the great convenience that virtualization brings, the VT sector is attracting a lot of interest from many businesses. As a result, virtualization tool providers such as VMware, Xen, and Red Hat are studying virtualization technologies, as are many other system suppliers such as IBM, Sun, and Microsoft.With the excellent characteristics of its products, VMware is regarded the industry leader in VT. According to some sources, VMware controls more than half of the virtualization business, with the remainder held by other manufacturers such as Xen, Microsoft, Red Hat, IBM, and others. Red Hat asserts that after customizing KVM with its product, it provides a more secure and robust virtualization solution. VMM is used by VMware to manage resources between the OS and the hardware.

VMware created x86 system virtualization in 1999 to maximize system resources and turn x86 systems into a shared goal, sharing hardware infrastructure that offers ultimate isolation, mobility, and OS choice for application environments.

1.2 Thesis Objective

In this thesis will be presented a study aiming to analyze and compare the performance of virtualization environments, notably the Hyper-V and VMware platforms, to that of a non-virtualized "bare-metal" environment, using benchmark tools in operative systems.

1.3 Scope of works.

This topic was developed to compare the Hyper-V and VMware ESXi hypervisors' performance. Many virtualization solutions are now available, and it is widely understood that virtualization introduces different delays that result in worse performance when compared to non-virtualized settings. The performance of various virtualization systems differs because they use different types of hypervisors or VMMs. The purpose of this article is to provide answers to the following questions:

• Decreased performance of virtual machines as comparison to actual computers.

• What is the distinction between the virtualization platforms Hyper-V and VMware?

• What variables contribute to virtual system performance degradation?

1.4 Organization of the thesis

This dissertation is divided into five chapters. The following is how the organization is carried out:

The issue statement, thesis aim, and scope of works are all addressed in Chapter 1. The second chapter is a literature review that explains all the words and ideas utilized in this study. Chapter 3 describes the methods used in this study to explain the implementation and testing processes. Theoretically, and in figures and tables of data acquired through testing, the experimental results are explained in Chapter 4. Conclusions and recommendations for further study are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1.1. What exactly is virtualization?

Virtualization employs software to establish a layer of hardware abstraction that enables the hardware pieces of a single computer – processors, memory, storage, and so on – to generate many virtual computers, also known as virtual machines (VMs). Even though it only uses a piece of the core hardware, each virtual machine runs its own OS and operates like an independent computer.

Virtualization provides for increased efficiency in the usage of physical hardware and a higher return on investment in a company's hardware.

Virtualization is becoming a common trend in corporate IT infrastructure. In addition, virtualization is the technology that leads to cloud computing**.** Virtualization enables cloud technology providers to serve customers using their existing physical hardware; it enables cloud users to acquire computer resources only when they are needed, and to expand these resources quickly and cost-effectively as their demand rises.

2.1.2. Advantages of virtualization.

- *Resource efficiency:* Prior to virtualization, each application physical server had its own dedicated physical capabilities – IT workers had to buy and configure a dedicated physical server for each application they needed to execute. In contrast to these traditional methods, server virtualization enables you to execute several programs on a single physical computer, each on its own virtual machine with its own OS. This allows for the most efficient use of the computers' actual hardware capacity.

- *Easier management:* By replacing real computers with virtual machine software, regulations established in software become easier to use and maintain. This allows for the development of automated IT management services. System administrators, for example, can identify virtual machines and apps as services in software models using automated deployment and configuration tools. This implies that system administrators can deploy these services again and constantly without losing time or risking problems due to manual construction. System administrators can use virtualization security rules to configure various security settings based on the virtual machine's function. To conserve storage space and processing power, police can boost resource efficiency by removing them from virtual machine allocation if they are not needed.
- *Minimize downtime:* Breaking down OSs and apps can result in downtime and user productivity loss. When issues arise, system administrators can establish numerous redundant virtual machines adjacent to each other, and these machines can transfer their services to clients to each other. It is more expensive to build and operate some redundant physical servers.
- *Faster service delivery:* Purchasing, installing, and configuring hardware for any application takes a significant amount of time. It is substantially faster to provide hardware and services to virtual machines running applications. You may also use management software to automate them and incorporate them into your existing process.

2.1.3. Virtual Machines.

Virtual machines [7] are software-based virtual environments that imitate the operation of a real computer. They are made up of multiple files that hold the virtual machine configuration, virtual hard drive backup space, and some virtual machine content storage that keeps its state at a given time. Advantages of virtual machines:

- *Resource utilization and ROI improvement*: Because some virtual machines operate on a single physical computer, a client does not need to purchase a new server every time they need to run another OS, and they can make the most of every piece of hardware they have.

- *Scalability*: With cloud computing, it is easy to create numerous clones of the same virtual machine to improve service in case of load.
- *Portability*: Virtual machines can be transferred as required over a network of actual computers. This allows loads to be distributed to servers with backup compute resources. Virtual machines may even travel between on-premises and cloud environments, making them ideal for hybrid cloud situations in which your data center and a cloud service provider share computing resources.
- *Flexibility*: Because you can clone a virtual machine with an already installed OS, creating a virtual machine is faster than installing an OS on a real server. Software developers and testers may quickly establish new environments to address new tasks as they occur.
- *Security*: When compared to OSs that operate directly on hardware, virtual machines improve security in various ways. A virtual machine is a file that an external software may examine for infection. If the virtual machine is infested with malware, you may make a content log of the complete virtual machine at any point in time and then return it to the condition you registered, effectively turning the virtual machine back in time. Because of the ease and speed with which the virtual machine is created, it is also feasible to remove a compromised virtual machine entirely and then immediately reconstruct it, fast recovering the virtual machine from malware infestations.

2.1.4. Cases of using virtual machines.

Virtual machines have a variety of applications [7], both for company IT administrators and its users.

- *Cloud computing:* For the past decade, virtual machines have been the primary unit in the cloud, allowing hundreds of different types of apps to run and scale successfully.
- *Support for DevOps*: Virtual machines are a terrific technique to help developers since they may configure virtual machine models with functionality for their software development and testing. They can establish virtual machines for specialized activities such as static testing software and workflow development automation.

- *Testing new OSs*: A virtual machine allows you to test a new OS without interfering with your primary OS.
- *Malware investigation:* Virtual machines are important for software researchers who frequently require fresh computers to test malware on.
- *Running incompatible software*: Some consumers favor one OS over another, but you want an application that is only accessible on another.
- *Safe Internet surfing:* By using virtual computers for Internet browsing, you can browse the site without fear of infecting the virtual system. After each cruise session, you may capture the contents of the virtual computer and then turn it back in time.

2.2 Hypervisors

The software layer that coordinates virtual machines is known as a hypervisor [8]. It acts as a bridge between virtual machines and critical real hardware, ensuring that each virtual machine has access to the physical resources it requires to operate. It also guarantees that these virtual machines do not interact with each other in terms of memory space and CPU cycles.

There are many types of hypervisors, as well as various brands [8] within each category. Although the industry has stabilized to make hypervisors a comfortable solution for businesses, there are still several aspects that should influence your decision. Some of the variables to consider while selecting a hypervisor are as follows:

- *Performance:* Look for data from benchmark tools that demonstrate how well hypervisors perform in a real-world operating environment. In general, type 1 hypervisors will deliver performance that is near to the real-world speeds supplied by actual hardware resources for OSs that operate on these types of hypervisors.
- *Ecosystem:* To build and administer hypervisors across multiple scalable physical servers, you'll need comprehensive documentation and technical

assistance. Look for a third-party developer community that can give hypervisor support through plugins that enable capabilities such as backup and restoration analytics and redundancy management.

- *Management tools*: When utilizing a hypervisor, we must manage more than only the functioning of virtual machines. Virtual machines should anticipate, manage, audit, and eliminate those that are no longer in use in order to prevent virtual machines from using large amounts of worthless actual hardware resources. Ascertain that manufacturers or the third-party community provide extensive management tools to support the hypervisor architecture.
- *Real-time migration*: This allows you to migrate virtual machines across hypervisors on various physical machines without interrupting their operations, which is helpful for redundancy and load balancing.
- • *Cost:* Take into account the cost and pricing structure associated with licensing hypervisor technology. Consider more than just the price of the hypervisor. Management software that is scalable to serve a corporate context is frequently costly. Finally, look at the license arrangement of the manufacturer, which may differ based on whether you use the hypervisor in the cloud or locally.

2.2.1. Types of Hypervisors, Advantages and Disadvantages.

Virtualization has altered how we supply server infrastructure, construct development environments, and acquire hardware. It enables great efficiency in data centers that, because to the crucial nature of their job, are unable to run on physical servers. Microsoft Hyper-V and VMware vSphere are the two most used hypervisors in corporate data centers today.

Type 1: Type 1 hypervisors run directly on the computer's basic physical hardware, interfacing with the CPU, RAM, and physical storage space. As a result, type 1 hypervisors are often known as "bare-metal" hypervisors. The traditional OS is replaced with a type 1 hypervisor.

Advantages: Because they have direct access to actual hardware, type 1 hypervisors are more efficient. This also strengthens their security because nothing else can be compromised between them and the CPU.

Disadvantages: In most circumstances, a type 1 hypervisor requires a separate administration system to administer many virtual machines and control actual hardware.

Type 2: A type 2 hypervisor [8] does not run on the primary hardware. On a standard OS, they execute as an application. In dedicated server settings, type 2 hypervisors are rarely employed. They are extremely handy for individual machines that must run many OSs. Type 2 hypervisors are used by user engineers, professional malware security analysts, and corporate users that want access to apps that are only available on other platforms.

Type 2 hypervisors sometimes need the installation of extra software tools on traditional OSs. These software solutions shorten the time it takes to switch between the virtual machine and standard OSs.

Advantages: A Type 2 hypervisor provides simple and quick access to virtual machine OSs that are similar to regular OSs. This is really beneficial to end consumers. For example, an end user might utilize it to access their favorite programming tools that are only available on Linux OSs, while another application that is only available on Windows OSs could be used.

Disadvantages: A type 2 hypervisor must use the traditional OS, which has direct access to the machine's physical resources, to access CPU, memory, network, and backup space resources. This generates delays that have an impact on performance. If malware penetrates the conventional OS, it can then control the virtual OS running on the Type 2 hypervisor, posing possible security problems. (Figure 1)

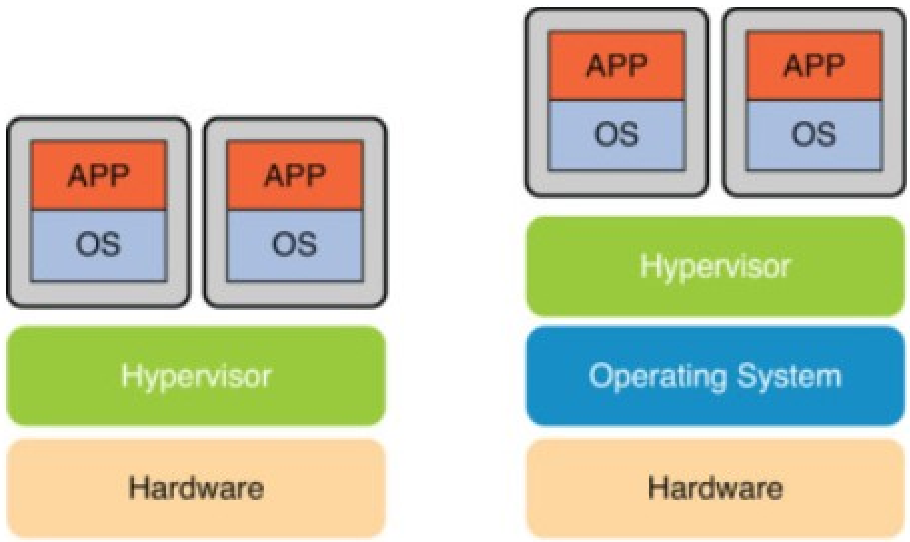

Figure 1: Type 1 and Type 2 Hypervisors ***[9]***

2.2.3. Differences between Hyper-V and VMware.

VMware vSphere is a phrase that refers to essential virtualization technologies that aid in the management, monitoring, and configuration of virtual data centers. The hypervisor is at the heart of vSphere. VMware ESXi is a VMware virtual hypervisor that operates on a real (bare-metal) server. vSphere is a collection of technologies that work together to provide a corporate data center offering. It sits behind the ESXi hypervisor. Among the VMware vSphere products are the following:

The VMware ESXi Hypervisor is a physical-hardware-based type 1 hypervisor.

VMware vSphere vCenter Server - The management server platform that enables corporate data center features such as ESXi clustering and vMotion.

Hyper-V is a type 1 hypervisor that operates on the Windows Server platform as a role. On top of the Windows Failover Cluster, Hyper-V may run as a single server or as part of a cluster with shared storage areas. With each upgrade to the Windows Server platform, Microsoft continues to enhance the Hyper-V platform. The IaaS Azure platform is a customized version of the Hyper-V hypervisor.

2.2.4. Architecture.

Hyper-V: Hyper-V is a hypervisor of type 1. Many people believe Hyper-V is a type 2 hypervisor because it is installed as a role within a Windows Server; however, Microsoft performs some engineering tricks as the Hyper-V role is installed, initially placing Hyper-V directly on the physical hardware and the traditional OS above Hyper-V. Hyper-V virtualizes processors and memory, and employs several partitions to deploy virtual machine I / O services and devices while also facilitating their separation. What are these divisions? *(Figure 2)*

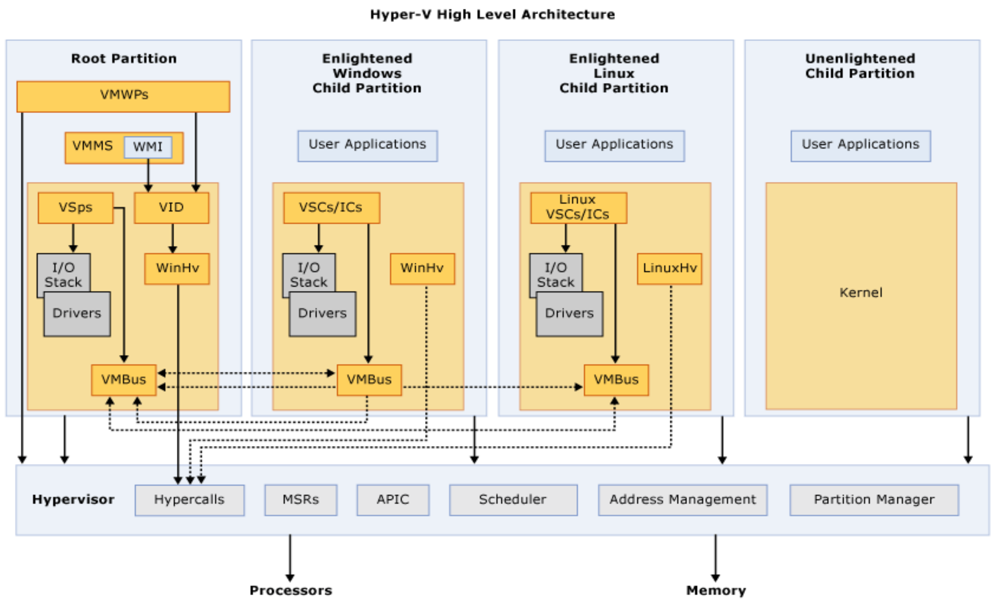

Figure 2: Hyper-V High Level Architecture ***[10]***

These partitions serve as logical isolation units for the OS. Partitions do not have direct access to the real processor, but instead have a virtual representation of it**.** Hyper-V handles CPU outages and redirects them to the partitions that need to be moved.

Root - The partition that contains Microsoft Windows and the initial partition that launches the hypervisor.

Parent - This is where virtualization, memory management for virtual machines, administration APIs, and virtualized I / O devices enter the picture. This partition is likewise handled by simulated devices. This is accomplished through the use of VSP, which interacts through VMBus to handle device requests from multiple child partitions.

Child - Virtual OSs are stored in child partitions.

Although Hyper-V may be hosted on a solo server, for maximum flexibility and availability, it is run on a large number of servers that are part of the Windows Failover Cluster role of Windows Server platforms. Virtual machines in a Hyper-V cluster context are performed as a cluster service, allowing for high availability. Executing Hyper-V servers in a Windows Failover Cluster with shared storage spaces provides features such as Live migration, which transfers processing capabilities and virtual machine memory between Hyper-V hosts in the cluster.

VMware: • VMware ESXi: VMware ESXi is a prototype OS interface that delivers capabilities and functionalities like existing OSs. It is, however, intended to run virtual machines. ESXi is a type 1 hypervisor software that may be deployed on a real server.

ESXI software builds an abstraction layer that virtualizes actual server hardware. This enables virtual machines to leverage the hardware resources of real servers while remaining completely autonomous and segregated from other computers on the system. One of the advantages of VMware ESXi is the tiny amount of space it requires when deployed. Because the ESXi is so little, it may run entirely in memory. All actions are carried out in the system memory file, which contains all of the files that allow the core functionality of ESXi.

VMware ESXi is made up of the following major component groups:

- VMkernel
- DCUI in User World (Direct Console User Interface)
- Virtual Machine Monitor
- Various agents
- CIM-based systems (Common Information Model)

The VMkernel is the core component of ESXi that oversees scheduling all system resources for virtual resource demands. VMkernel provides the layer of abstraction required for virtual machines to consume system resources as they would in a physical machine, while remaining isolated from other virtual machines operating on the real server where the VMware ESXi hypervisor is installed.

The administration agents - hostd and vpxa - are two critically crucial User World APIs. These two management agents oversee transmitting orders from management tools like vSphere Client or vCenter Server to the hypervisor. Virtual Machine Monitors are layer applications that allow each virtual machine to operate and virtualize CPU and memory. In ESXi, the CIM system is an API suite that enables remote applications to handle hardware.

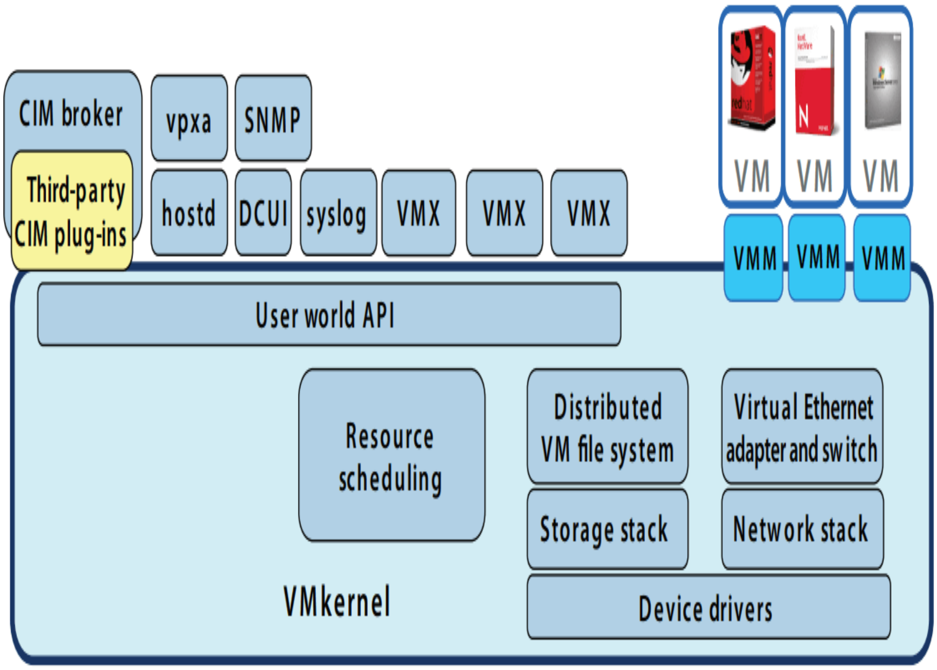

Figure 3: ESXi Hypervisor Architecture ***[11]***

2.2.5. Security.

Nowadays, security is a vital consideration while constructing any form of infrastructure. Both the Hyper-V and VMware systems feature robust security procedures. In this comparison, VMware appears to be ahead, particularly with the latest technologies and advances with AppDefense and NSX.

Hyper-V supports several of the most recent advancements in the deployment of virtual machines. These are some examples:

- Secure Boot
- Virtual Trusted Platform Module
- Encrypted networks
- Protected virtual machines

Secure Boot and the Virtual Trusted Platform Module (vTPM) contribute to the security of Hyper-V hosts and virtual machines. Malware can corrupt boot code, drivers, and other software, leaving gaps in the system that can be exploited to undermine system security. This danger is considerably mitigated by Secure Boot and vTPM technologies. All subnet traffic can be encrypted in encrypted networks. Moving data may be safeguarded efficiently without requiring any further changes to virtual computers or network devices.

While VMware Security includes all of the above-mentioned Hyper-V breakthroughs and capabilities, as well as Virtualization Based Security. To easily isolate and filter out aberrant traffic, VMware NSX relates to the AppDefense technology.

In the Hyper-V world, there is no equivalent solution.

2.2.6. Backup.

Despite the built-in high availability and resilience capabilities of both Hyper-V and VMware, data can still be lost for a variety of causes, including human mistake and security attacks such as ransomware.

Businesses should back up their Hyper-V and VMware setups to protect their data from these and other dangers. Safeguarding your environment with a cutting-edge data protection solution that is equally capable of protecting Hyper-V and VMware will ensure that your data is safeguarded efficiently and effectively regardless of which hypervisor you use.

However, there are certain distinctions between the many critical aspects of Hyper-V and VMware that are directly tied to backup methods. Management, backup space, disk delta change, tracking change, and OS services are the primary considerations when doing backups on either the VMware or Hyper-V systems, or both. The following are the key distinctions between the virtual systems VMware vSphere and Microsoft Hyper-V that we shall examine in depth:

- Management - vCenter vs. System Center Virtual Machine Manager
- Reservation space technologies - VMFS vs. CSV
- Delta Disk Architecture and Implementation - Snapshots vs. Checkpoints
- Increased change tracking - CBT versus RCT
- Integrated Services for OSs - VMware vs. Hyper-V

2.2.7. VMware Tools vs. Hyper-V Integration Services.

It's worth noting that both VMware and Hyper-V employ virtual services, which allow for tighter interaction between the hypervisor and the OSs that run on top of it. When it comes to backup, both VMware and Hyper-V take full use of these virtual services to interact with the virtual machine for the purposes of change in the virtual machine. *(Figure 4)*

Figure 4:Operation of VMware tools inside a VMware machine ***[12]***

Hyper-V Integration Services is a technology that is similar to VMware Tools in that it offers the essential integration of the virtual OS to allow for improved performance.

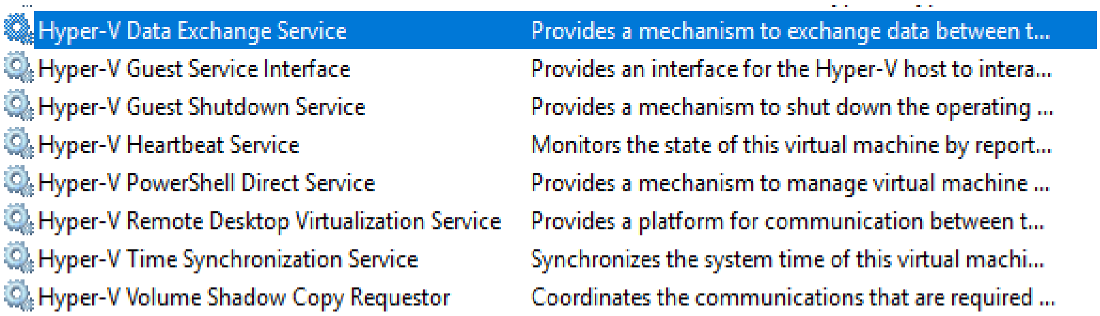

Figure 5: Hyper-V Integration Procceses in Windows 10 Pro ***[13]***

2.2.7. Advantages and Disadvantages.

Hyper-V is a Microsoft hypervisor, which indicates that Microsoft is eager to expand this product with new features and technologies. Microsoft has also created the complete Azure infrastructure as a Cloud architecture as the most advanced Hyper-V version, thus this product is evolving and maturing depending on the extremely complicated load that runs on it daily.

For many years, VMware has been a key participant in corporate data centers. He is a reliable and powerful hypervisor with various features and skills. It has been tried and proven across enterprises for more than a decade, and it continues to innovate and create new and current solutions to take vSphere to the next level. This has several benefits, including a tried-and-true platform, a full-featured administrative interface, and now, full-featured HTML 5.

Advantages of Hyper-V

- Backed by Microsoft, which is dedicated to enhancing the hypervisor.
- Use the Azure public cloud, which can be accessed and tested by anyone at any time.
- The Microsoft ecosystem is widely used in the business world.
- Clients benefit from an enterprise licensing arrangement.

Advantages of VMware

- Time-tested technology.
- Industry pioneer in corporate data center virtualization.
- Continues to be innovative.

Disadvantages of Hyper-V

- Following VMware in some areas.
- Not as mature as VMware.
- VMware has an advantage over Hyper-V in security and networking software solutions.
- S2D must yet be developed as a feature.

Disadvantages of VMware

- Closed manufacturer.
- Public cloud is altering business practices.
- VMware products can be replaced by public cloud.
- VMware is taking a chance with VMware Cloud on AWS.

2.3 Benchmark Tools

Benchmarking is usually associated with assessing performance characteristics of computer hardware, for example, the floating-point operation performance of a CPU, but there are circumstances when the technique is also applicable to software. Software benchmarks are, for example, run against compilers or database management systems.

As for the testing procedure for academic and research purposes, it is hard to secure real systems configuration. In these cases, benchmarks serve the purpose of assuring results in real systems. While implementing a system we must acknowledge the potential performance and the costs of the procedure itself. For a better understanding, benchmark means are separated in the following categories:

1. Performance oriented: These types of benchmarks aim high quality performance, regardless of the costs.
2. Costs oriented: Aiming to ensure low costs regardless of the lack of performance.

For these two types of benchmarks, it is useful to understand the pros and cons of using a low-cost benchmark with lower performance or a higher cost benchmark that can output better performance results.

While testing benchmarks, few elements are key to the process:

1. The systems architecture: 32-bits or 64-bits.
2. The systems measurements: The number of CPU in testing.
3. System configuration: Multti-cluster systems or one single non-cluster system.
4. The database: Varies from 100 GB to many terrabytes.
5. Services: Few benchmarks include the support costs 24x7, while other factors do not support the end results.

2.3.1 Types of Benchmark Tools.

Flexible I/O. - Otherwise referred to as fio,it is a tool that is used to produce a number of threads or procceses in completing a certain action , defined by the user. The benefit is that fio can manage submission rates independently of the device completion rates.

Iozone is a filesystem benchmark tool. The benchmark generates and measures a variety of file operations. Iozone has been ported to many machines and runs under many OSs. Iozone is useful for performing a broad filesystem analysis of a vendor's computer platform [14]. It was written by Norcott and improved by Capps. Iozone offers different testing features, and it is usable in many operative systems. Iozone functions are detailed in the following table:

Table 1: Iozone functions.

Function	
Write	This function creates and edites a file. Whilecreating a file, a meta-data in relation to the location of the file and the data blocks is created, which results in a delay that lowers performance quality. Due to this delay the writting in a already created file is usually faster than creating a new file.
Re-write	Writes in a existing file. Re-writting in a file outputs better performance than creating a new file.
Read	Reads a file in sequency.
Re-read	Repeats the Read feature. Re-reading a file is faster than the first time using Read function because the cache already exists in the operative system.
Record re-write	This function tests writting and re-writting of a file sector. Based on the size of the section to be tested, the charachteristics vary. If the section is small and it already exists in cache, the performance results will improve.
Random read	This test reads files in randmon locations. The cahce size and dick numbers might influence the results on this test.
Random write	Writes a random location for a file.
Backward read	Reads a file backwards. Few OS contain this feature.

Stride read	Used to prove the performance of a RAID organizing , when stride is or is not featured in RAID.
fwrite(3)	This function writes a file using: fwrite(3). fwrite(3) is a standard function in C , creating repetetive write functions.
Re-fwrite(3)	Rewritting in fwrite function. It works as the re-write function.(3).
fread(3)	Reads files while using fread(3). Similar to read function, in this one the fread(3) is used.
Re-fread(3)	Re-reads files using fread(3). AS the file has been recently read, the performance is now higher because the file is already saved in cache.

CHAPTER 3

METHODOLOGY

3.1 Implementation and testing.

In this chapter we describe the methodology used in conducting the testing, the hardware to be tested and the virtual machine's operative system to be used. The details of the testing conducted using benchmark tools are specified in the next chapter.

3.1.1 Hardware System Specifications.

For the purpose of using benchmark tools, we used a Fujitsu Siemens Primergy BX920 S2. This server contains the following technical secifications:

CPU:

Two proccesors: 3.07 GHz Hexa-Core

Intel(R)Xeon(R) CPU X5676

ICore: 6

Threads number: 12

Clock speed: 3.07GHz

L1: 384KB, L2: 1,5MB, L3=12MB

Instruction set: 64-bit

Memory:

72GB; speed: 1333 Mhz.

Hard disk

Two SCSi; 73 GB / each

Software

CentOS 7 x86&x64

Hyper-V Microsoft Windows Server 2016 R2

VMware ESXi 6.5

3.2 Methodology of implementation.

The benchmark tools described in Chapter two were used to test various components of the system, executed in a hardware server type: Fujitsu Simens Primergy BX920 S2.

The scope of this thesis is to test the I/O performance of the operative system CentOS x86_64 in relation to the harddisc, memory and CPU in the following three cases:

1. The virtualisation in Hyper-v Microsoft Windows Server 2016 R2 platform.
2. The virtualisation in Vmware ESXi 6.5 platform.

Following the testing procedure, the results are compared within these cases in a bare metal. Firstly, we implement the operative system CentOS x86_64 in all three environments and in the bare metal environment, which will be used as a comparing environment for the study. Secondly, we install the benchmark Iozone 3.394 [15] to test the I/O performance in the harddisk. We used Ramspeed 3.5.0 [16] for the memory testing and UnixBench 5.1.3 for the CPU testing.

After we have collected the resulting data from the benchmark tools in the bare metal operative system, we execute this operative system on the Hyper-V Microsoft Windows Server 2016 R2 platform and the Vmware ESXi 6.5 platform as well. We execute then, the benchmark tools to collect the data for the CentOS 7x86_64 system executed in both platforms mentioned above.

The Centos 7x86_64 versions and the benchmark tools Iozone, RamSpeed and UnixBench are the same in all three cases taken into consideration. To improve the significance accuracy of the results, the tests are repeated a few times in order to be used as reference for analysis.

3.2.1 Implementing Iozone.

Iozone is used to conduct performance testing of the harddisk in CentOS 7x86_64. For better results it is advised to test differeent sizes of files and for this study we will test it in sizes: 1 MB, 32 MB, 64MB, 128MB, 512MB and 1GB. Each file is generated with a registered size, which is the size of the data registered in a file during a single I/O transaction in size 1KB.

Izone offers different alternatives on the file size change, register group, type of test etc. Further below there is a description of alternatives in disposal for the Iozone benchmarks:

1. s- decides the size of the file under measurement.
2. r- decides the size of the register in KB.
3. i- used to specify the type of the performance, bur if we do not use it, then the benchmark will test all types of performance.
4. R- generates a report in Exel.
5. C- includes close () functions in time calculations.

Iozone examines a few I/O performance characteristics such as write, rewrite, read, reread, random read, random write, backward read, record rewrite, stride read, fwrite, frewrite, fread, freread. In this thesis, the I/O performance is assessed for all parameters, estimated in KB, and the data is translated to MB for a better readability.

An example of an Iozone test execution is as follows:

Iozone: Performance Test of File I/O

Version $Revision: 3.394 $

Compiled for 64 bit mode.

Build: linux

Contributors:William Norcott, Don Capps, Isom Crawford, Kirby Collins

Al Slater, Scott Rhine, Mike Wisner, Ken Goss

Steve Landherr, Brad Smith, Mark Kelly, Dr. Alain CYR,

Randy Dunlap, Mark Montague, Dan Million, Gavin Brebner,

Jean-Marc Zucconi, Jeff Blomberg, Benny Halevy, Dave Boone,

Erik Habbinga, Kris Strecker, Walter Wong, Joshua Root,

Fabrice Bacchella, Zhenghua Xue, Qin Li, Darren Sawyer.

Ben England.

Run began: Sat Apr 11 19:36:42 2020

File size set to 1048576 KB

Record Size 4 KB

Excel chart creation is enabled

Automatic Mode Include close timing in your writing.

The following command line was used:./iozone -s 1024M -r 4k -Rac

The output is in Kbytes/second. 0.000001 second time resolution

The processor cache size has been set to 1024 Kbytes.

The processor cache line size has been adjusted to 32 bytes.

The file stride size is set to 17 * the record size.

random random bkwd record stride

KB reclen write rewrite read reread read write read rewrite read fwrite frewrite fread freread

1048576 4 935275 1068424 1454840 1444865 976989 810261 1061493 1082026 1069148 1029383 1112009 1379126 1406294

iozone test complete.

Excel output is below:

"Writer report"

"4"

"1048576"   935275

"Re-writer report"

"4"

"1048576"   1068424

"Reader report"

"4"

"1048576"   1454840

"Re-Reader report"

"4"

"1048576"   1444865

"Random read report"

"4"

"1048576"   976989

"Random write report"

"4"

"1048576"   810261

"Backward read report"

"4"

"1048576"   1061493

"Record rewrite report"

"4"

"1048576"   1082026

"Stride read report"

"4"

"1048576"   1069148

"Fwrite report"

"4"

"1048576"   1029383

"Re-Fwrite report"

"4"

"1048576"   1112009

"Fread report"

"4"

"1048576" 1379126

"Re-Fread report"

"4"

"1048576" 1406294

This execution provides the detailed output of Iozone testing. In the beggining we see the used commands, file size, the registering size in KB, the second part shows the performance from 13 characteristics during I/O performance in the environment. The amount of data/second is shown in KB and converted in MB.

3.2.3 Ram Speed testing implementation.

RamSpeed provides several options for testing RAM performance. In this example, the system memory is a huge physical memory, but we utilized a portion of 8GB memory for testing, which is also the largest allowable size in Ram Speed benchmark. The –m argument in the Ram Speed benchmark command can be used to specify the maximum size.

In this study, four options were used in testing the memory: Interger Read, Write and Float Point Read and Write. That is why we use number 1 and 2 for testing Interget Read and Write and 3 and 4 for Float Point Read and Write while using the –b alternative of the Ram Speed benchmark command. In this case, we used b1 command aiming to test Interger Write in an 8 GB memory in the given size.

[root@Hyper-V ramsmp-3.5.0]# ./ramsmp -b1 -m 8192

The command above, starts the testing process using Interger Write in a block size of 1 KB to 8 GB while rising exponentially. After each block size, we calculated the speed of the memory performance in MB (last column detailed).

RAMspeed/SMP (Linux) v3.5.0 by Rhett M. Hollander and Paul V. Bolotoff, 2002-09

8Gb per pass mode, 2 processes:

INTEGER & WRITING 1 Kb block: 48703.99 MB/s

INTEGER & WRITING 2 Kb block: 48703.85 MB/s

INTEGER & WRITING 4 Kb block: 48691.29 MB/s

INTEGER & WRITING 8 Kb block: 48698.33 MB/s

INTEGER & WRITING 16 Kb block: 48695.50 MB/s

INTEGER & WRITING 32 Kb block: 48940.06 MB/s

INTEGER & WRITING 64 Kb block: 43250.75 MB/s

INTEGER & WRITING 128 Kb block: 43129.36 MB/s

INTEGER & WRITING 256 Kb block: 36216.68 MB/s

INTEGER & WRITING 512 Kb block: 35662.52 MB/s

INTEGER & WRITING 1024 Kb block: 35722.35 MB/s

INTEGER & WRITING 2048 Kb block: 24856.45 MB/s

INTEGER & WRITING 4096 Kb block: 28637.05 MB/s

INTEGER & WRITING 8192 Kb block: 26950.61 MB/s

INTEGER & WRITING 16384 Kb block: 16945.37 MB/s

INTEGER & WRITING 32768 Kb block: 15278.31 MB/s

INTEGER & WRITING 65536 Kb block: 15310.15 MB/s

INTEGER & WRITING 131072 Kb block: 14815.48 MB/s

INTEGER & WRITING 262144 Kb block: 14407.01 MB/s

INTEGER & WRITING 524288 Kb block: 13359.78 MB/s

INTEGER & WRITING 1048576 Kb block: 12414.27 MB/s

INTEGER & WRITING 2097152 Kb block: 11139.80 MB/s

INTEGER & WRITING 4194304 Kb block: 9410.73 MB/s

INTEGER & WRITING 8388608 Kb block: 7066.72 MB/s

The first column in the results above, shows a Interger Write due to the b1- alternative in terms of Ram Speed benchmark command. In the second column, the size of the block is presented with an exponential rise to a maximum of 8 GB, as we used the –m 8192 alternative in the Ram Speed benchmark command. While in the last column, generated after the test, we see the speed performance of the memory in MB.

As shown in the results, while the block size increases, the data speed decreases. For a 1 KB to 256 MB block size, the writing speed average exeeds 46000 MB/second. This happens because the block size is inside the memonry size L1cache in the hardware in which CentOS 7x86_64 is installed, being also the fastest memory in the system. The range from 512 KB to 1 MB corresponds with the L2 chache memory, in which the writing speed exeeds 35600MB/second, being the second fastest memory after L1. For the range between 2 MB to 8 MB the average writting speed is 26800 MB/second, corresponding with the L3cache memory. And for the range between 16MB to 8GB the average is 11800 MB/second, being part of the RAM memory with a lower speed than the other three memories cosidered. This test was repeated four times in each envoirnment to assure a clear data base for the analysis offered by Ram Speed benchmark.

3.2.4. Implementing UnixBench.

To ensure credibility for the data used for the analysis in this thesis, for the last benchmark aiming to test the CPU performance we conducted four tests using the following command:

```
[root@Bare-Metal UnixBench]# ./Run
```

UnixBench is nessecary to be executed within its directory. It will, then self-generate all the results. One example of the execution of this command is as follows:

Version 5.1.3   Based on the Byte Magazine Unix Benchmark

Multi-CPU version   Version 5 revisions by Ian Smith, Sunnyvale, CA, USA

January 13, 2011   johantheghost at yahoo period com

Use directories for:

* File I/O tests (named fs***) = /root/byte-unixbench-master/UnixBench/tmp

* Results   = /root/byte-unixbench-master/UnixBench/results

----

1 x Dhrystone 2 using register variables 1 2 3 4 5 6 7 8 9 10

1 x Double-Precision Whetstone 1 2 3 4 5 6 7 8 9 10

1 x Execl Throughput 1 2 3

1 x File Copy 1024 bufsize 2000 maxblocks 1 2 3

1 x File Copy 256 bufsize 500 maxblocks 1 2 3

1 x File Copy 4096 bufsize 8000 maxblocks 1 2 3

1 x Pipe Throughput 1 2 3 4 5 6 7 8 9 10

1 x Pipe-based Context Switching 1 2 3 4 5 6 7 8 9 10

1 x Process Creation 1 2 3

1 x System Call Overhead 1 2 3 4 5 6 7 8 9 10

1 x Shell Scripts (1 concurrent) 1 2 3

1 x Shell Scripts (8 concurrent) 1 2 3

24 x Dhrystone 2 using register variables 1 2 3 4 5 6 7 8 9 10

24 x Double-Precision Whetstone 1 2 3 4 5 6 7 8 9 10

24 x Execl Throughput 1 2 3

24 x File Copy 1024 bufsize 2000 maxblocks 1 2 3

24 x File Copy 256 bufsize 500 maxblocks 1 2 3

24 x File Copy 4096 bufsize 8000 maxblocks 1 2 3

24 x Pipe Throughput 1 2 3 4 5 6 7 8 9 10

24 x Pipe-based Context Switching 1 2 3 4 5 6 7 8 9 10

24 x Process Creation 1 2 3

24 x System Call Overhead 1 2 3 4 5 6 7 8 9 10

24 x Shell Scripts (1 concurrent) 1 2 3

24 x Shell Scripts (8 concurrent) 1 2 3

==
======

BYTE UNIX Benchmarks (Version 5.1.3)

System: Bare-Metal: GNU/Linux

OS: GNU/Linux -- 3.10.0-1062.el7.x86_64 -- #1 SMP Wed Aug 7 18:08:02 UTC 2019

Machine: x86_64 (x86_64)

Language: en_US.utf8 (charmap="UTF-8", collate="UTF-8")

Benchmark Run: Tue Mar 10 2020 11:35:43 - 12:03:38

24 CPUs in system; running 1 parallel copy of tests

Dhrystone 2 using register variables	34115018.3 lps	(10.0 s, 7 samples)
Double-Precision Whetstone	4518.3 MWIPS	(8.9 s, 7 samples)
Execl Throughput	1482.8 lps	(30.0 s, 2 samples)
File Copy 1024 bufsize 2000 maxblocks	577402.3 KBps	(30.0 s, 2 samples)
File Copy 256 bufsize 500 maxblocks	155219.3 KBps	(30.0 s, 2 samples)
File Copy 4096 bufsize 8000 maxblocks	1603140.8 KBps	(30.0 s, 2 samples)
Pipe Throughput	786312.2 lps	(10.0 s, 7 samples)
Pipe-based Context Switching	95641.7 lps	(10.0 s, 7 samples)
Process Creation	5193.5 lps	(30.0 s, 2 samples)

Shell Scripts (1 concurrent) 3463.8 lpm (60.0 s, 2 samples)

Shell Scripts (8 concurrent) 1744.2 lpm (60.0 s, 2 samples)

System Call Overhead 713881.5 lps (10.0 s, 7 samples)

System Benchmarks Index Values	BASELINE	RESULT	INDEX
Dhrystone 2 using register variables	116700.0	34115018.3	2923.3
Double-Precision Whetstone	55.0	4518.3	821.5
Execl Throughput	43.0	1482.8	344.8
File Copy 1024 bufsize 2000 maxblocks	3960.0	577402.3	1458.1
File Copy 256 bufsize 500 maxblocks	1655.0	155219.3	937.9
File Copy 4096 bufsize 8000 maxblocks	5800.0	1603140.8	2764.0
Pipe Throughput	12440.0	786312.2	632.1
Pipe-based Context Switching	4000.0	95641.7	239.1
Process Creation	126.0	5193.5	412.2
Shell Scripts (1 concurrent)	42.4	3463.8	816.9
Shell Scripts (8 concurrent)	6.0	1744.2	2907.0
System Call Overhead	15000.0	713881.5	475.9

========

System Benchmarks Index Score 881.6

Benchmark Run: Tue Mar 10 2020 12:03:38 - 12:31:44

24 CPUs in system; running 24 parallel copies of tests

Dhrystone 2 using register variables 447376184.3 lps (10.0 s, 7 samples)

Double-Precision Whetstone 86865.4 MWIPS (9.4 s, 7 samples)

Execl Throughput 40366.3 lps (30.0 s, 2 samples)

File Copy 1024 bufsize 2000 maxblocks 730056.0 KBps (30.0 s, 2 samples)

File Copy 256 bufsize 500 maxblocks 198878.0 KBps (30.0 s, 2 samples)

File Copy 4096 bufsize 8000 maxblocks 2208705.5 KBps (30.0 s, 2 samples)

Pipe Throughput 12426963.4 lps (10.0 s, 7 samples)

Pipe-based Context Switching 2634020.9 lps (10.0 s, 7 samples)

Process Creation 100435.9 lps (30.0 s, 2 samples)

Shell Scripts (1 concurrent) 67360.4 lpm (60.0 s, 2 samples)

Shell Scripts (8 concurrent) 8882.0 lpm (60.0 s, 2 samples)

System Call Overhead 6564320.7 lps (10.0 s, 7 samples)

System Benchmarks Index Values	BASELINE	RESULT	INDEX
Dhrystone 2 using register variables	116700.0	447376184.3	38335.6
Double-Precision Whetstone	55.0	86865.4	15793.7
Execl Throughput	43.0	40366.3	9387.5
File Copy 1024 bufsize 2000 maxblocks	3960.0	730056.0	1843.6
File Copy 256 bufsize 500 maxblocks	1655.0	198878.0	1201.7
File Copy 4096 bufsize 8000 maxblocks	5800.0	2208705.5	3808.1
Pipe Throughput	12440.0	12426963.4	9989.5
Pipe-based Context Switching	4000.0	2634020.9	6585.1
Process Creation	126.0	100435.9	7971.1
Shell Scripts (1 concurrent)	42.4	67360.4	15886.9
Shell Scripts (8 concurrent)	6.0	8882.0	14803.3
System Call Overhead	15000.0	6564320.7	4376.2

========

System Benchmarks Index Score 7374.7

UnixBench developers pretend that the results of the test vary from the user's requests. The aim of this test using UnixBench is to measure the performance of the compilation quality.

All three benchmark tools are implemented in the same method in the bare-metal envoirnment, in the Hyper-V and the Vmware. After we collected all the data using the benchmark tools, we analyse the results in tables using the average measurments.

CHAPTER 4

RESULTS AND DISCUSSIONS

In this chapter we conduct the analysis of the data collected after four sequent tests on each of our three benchmark tools, in all three evoirnments.

4.1. Iozone testing results.

This section discusses the average values of the data produced after four runs of the Iozone benchmark tool for measuring the I / O performance of the reservation space. Mean values were used to generate graphic combinations of different file sizes for different operating scenarios of the CentOS 7 x86 64 OS in a non-virtualized "bare-metal" environment, a virtual environment of the Hyper-V platform, and a virtual environment of the vSphere platform for greater test reliability.

Iozone is used to assess I/O performance in the scenarios described above. To calculate performance under varied loads, different file sizes of 1 MB, 32 MB, 64 MB, 128 MB, 256 MB, 512 MB, and 1 GB were used. The graphs below depict the average test results for the I / O performance of the backup area for the CentOS x86 64 OS in non-virtualized contexts as well as in virtualized environments for Hyper-V and VMware platforms.

Figure 6: *Iozone write function average results.*

***Figure 7:** Iozone re-write function average results*

The performance of the Iozone benchmark tool for its write and re-write functions is illustrated in Graphs 2 and 3. The performance of these functions in the non-virtualized "bare-metal" environment is higher compared to the environments of the Hyper-V and VMware virtualization platforms. The graph of the write function indicates an increase in performance for both the non-virtualized and virtualized environments when the file size is increased from 1 MB to 1 GB. Where for file sizes from 1MB to 32MB the performance of the VMware platform virtualized environment is almost the same as the non-virtualized environment. Whereas in the graph of the re-write function we also notice an increase in performance with the increase of the file size from 1 MB to 1 GB for the non-virtualized environment and for the virtualized environment of the Hyper-V platform, while the performance of the virtualized environment of VMware stays almost constant with increasing file size. As shown in Table 4.1 of the Iozone benchmark features, the re-write function is usually faster than the write function. This is also ascertained from the two graphs above where the re-write function is seen to have better performance than the write function.

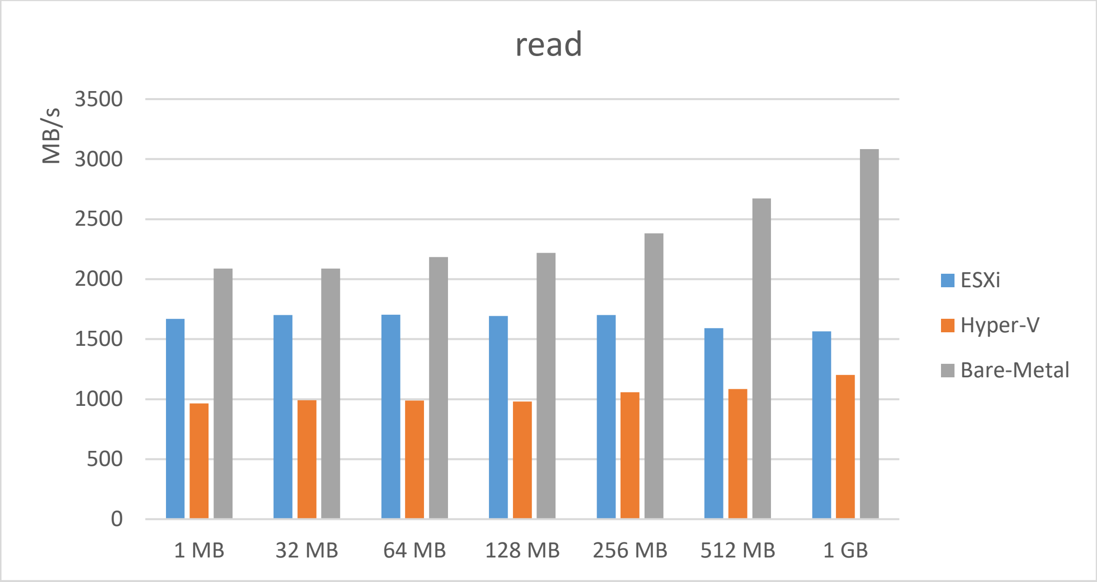

Figure 8:*Iozone read function average results*

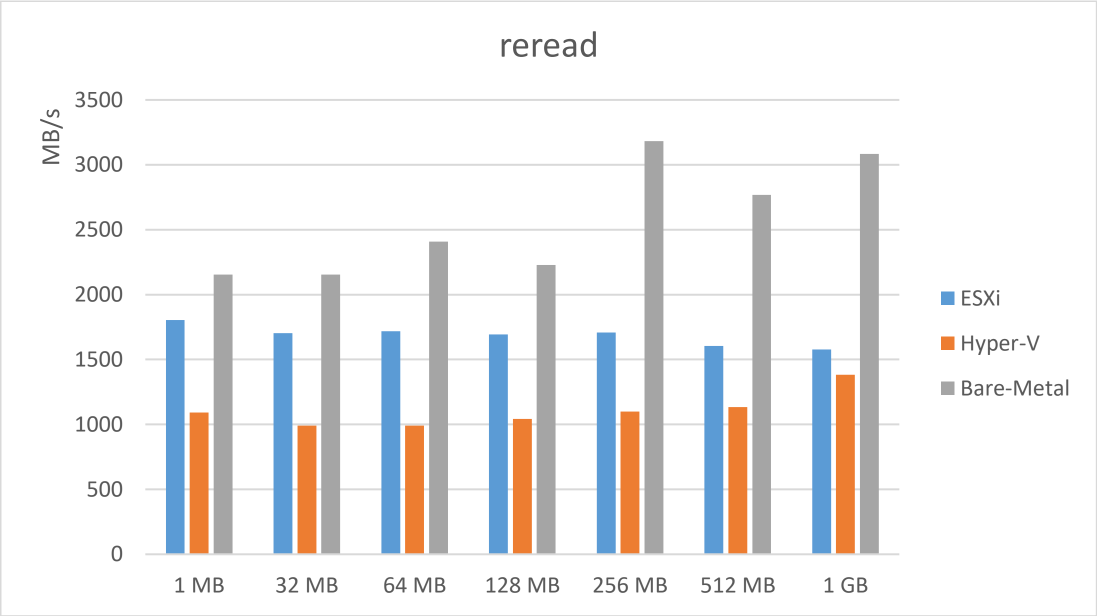

Figure 9: *Iozone re-read function average results*

Because the file is saved in the cache system, the re-read function is quicker than the read function in table 5 of the characteristics of the Iozone benchmark program. We can see in Graphs 3 and 4 that this characteristic is reflected in both the non-virtualized and virtualized environments of the Hyper-V platform, however the VMware virtualized environment does not represent this since the performance of this platform is nearly same. for both purposes. The non-virtualized "bare-metal" environment shows an increase in performance for the read function compared to the file size from 1 MB to 1 GB. While in the case of the re-read function this environment has the largest increase in performance in the file size of 256 MB. The Hyper-V platform virtualized environment shows approximately a constant performance from 1 MB to 512 MB file size and with an increase of this performance to 1 GB sizes for both read and re-read functions. VMware's virtualized environment shows a consistent performance from 1 MB to 256 MB file sizes with a slight decrease in performance from 512 MB to 1 GB for both of these features of the Iozone benchmark tool.

Figure 10: *Iozone random read function average results.*

As demonstrated in the graph for the random read function of Iozone, we boosted performance for the Hyper-V platform virtualized environment by increasing the file size from 1 MB to 1 GB, where at 1 GB this environment outperformed the VMware platform virtualized environment. We have an increase for the non-virtualized environment by increasing the file size from 1 MB to 256 MB, then for the sizes 512 MB and 1 GB we have a slight decrease in performance. The opposite happens for the virtualized VMware platform environment as with increasing the file size we have a decrease in performance. So the VMware platform virtualized environment also performs better for this feature for smaller file sizes.

Figure 11: *Iozone random write function average results.*

In addition, we can observe in the graph above that the non-virtualized and virtualized environments of the Hyper-V platform have improved speed by increasing file size from 1 MB to 1 GB. The virtualized VMware platform has a performance reduction with increasing file size from 1 MB to 1 GB, where for a 1 GB file size the performance of this platform is almost equal to the performance of the Hyper-V platform.

Figure 12: *Iozone backward read function average results*

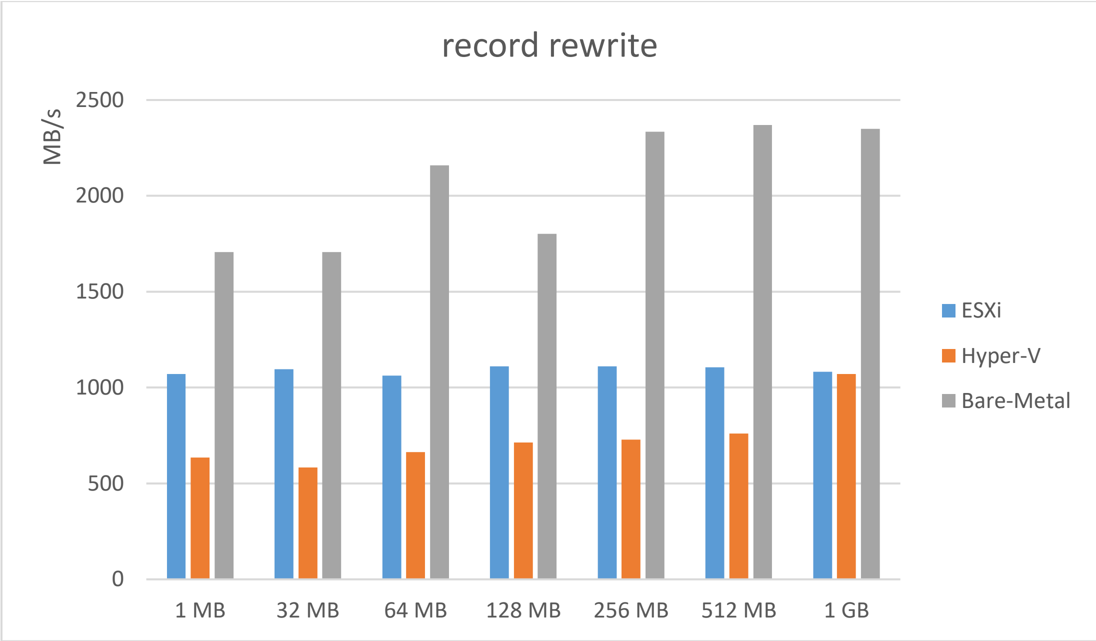

Figure 13: *Iozone Backward re-write function average results*

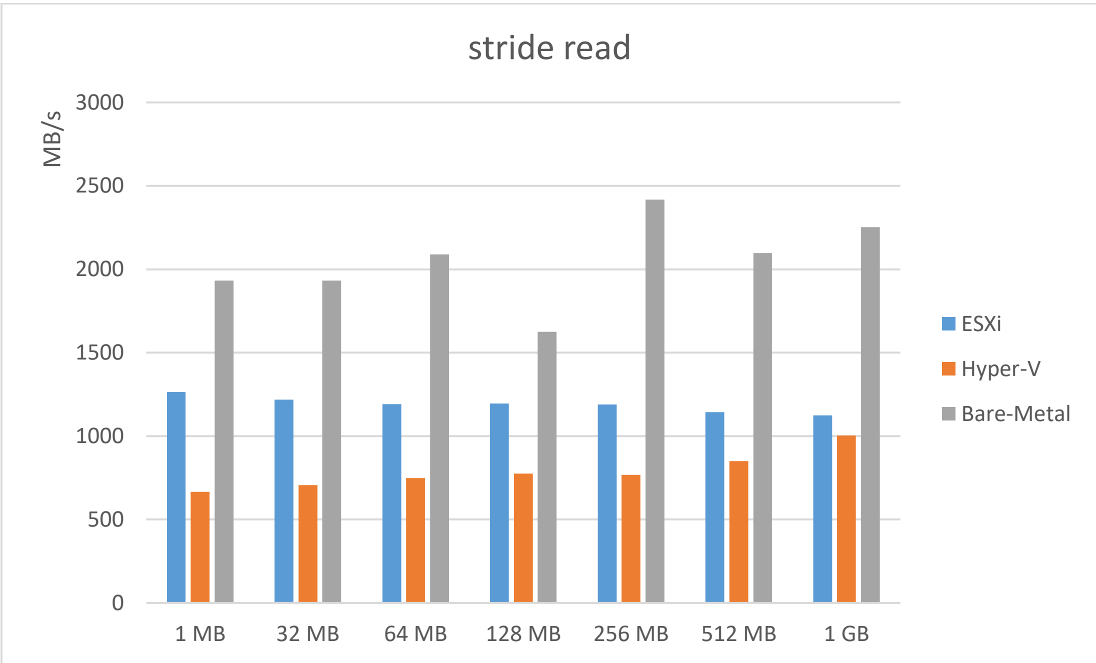

Figure 14: *Iozone stride read function average results*

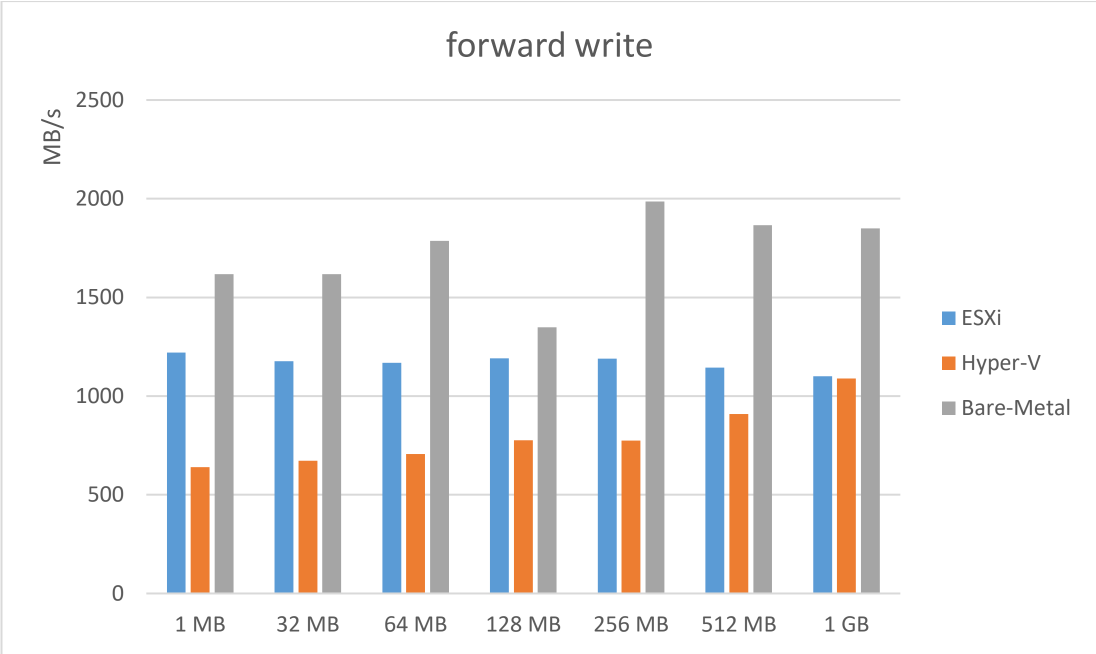

Figure 15: *Iozone forward write function average results*

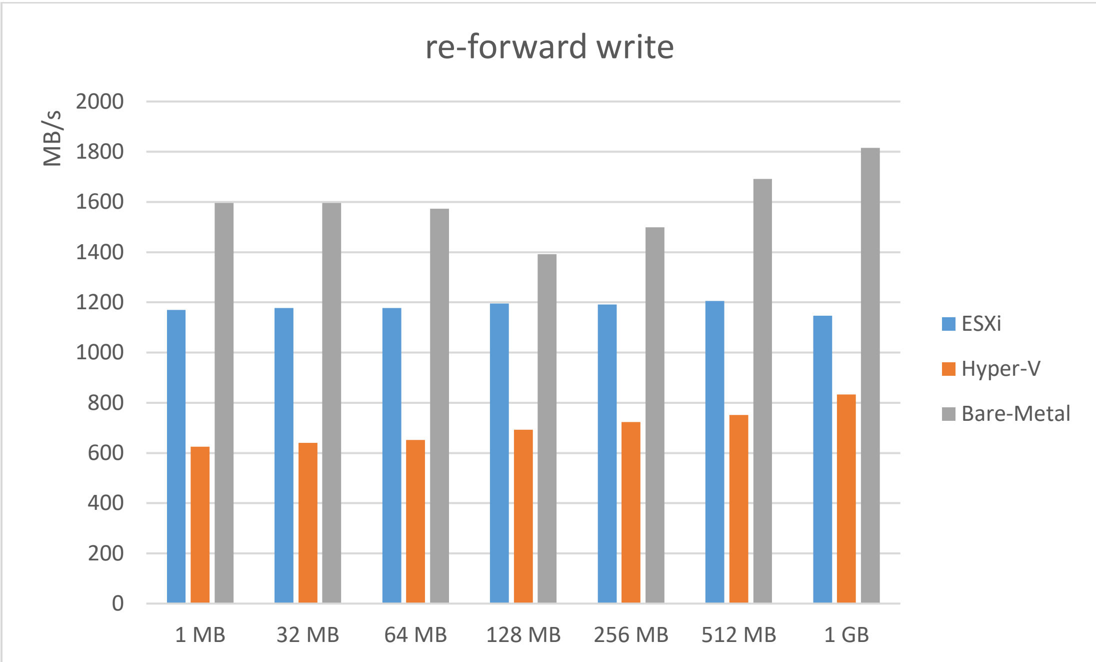

Figure 16: *Iozone re-forward write function average results*

Figure 17: *Iozone forward read function average results*

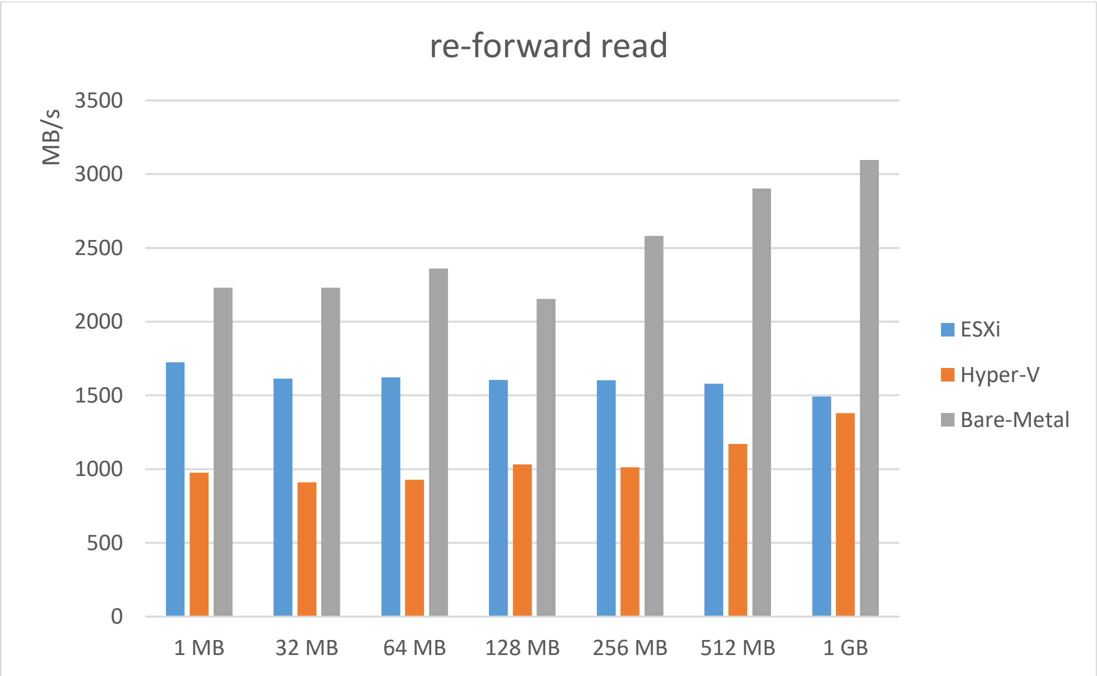

Figure 18: *Iozone re-forward read function average results*

Iozone measures the I / O performance of CentOS 7 x86_64 OS backup space in non-virtualized environment and virtualized environment of Hyper-V and VMware platforms using 13 different types of tests. Results from the non-virtualized environment show better performance compared to the virtualized environment of Hyper-V and VMware platforms. We know that virtualization adds a lag for this reason the performance of the virtualized CentOS 7 x86_64 OS on Hyper-V and VMware platforms remains low compared to the non-virtualized "bare-metal" environment. Through these tests it is seen that there is still room for improvement for virtualization technologies to reduce this delay to achieve better performance, especially for sizes from 64 MB to 1 GB.

In almost all cases illustrated by Iozone graphics, the VMware platform's virtual environment performs better than Hyper-V. Even in some cases, specifically for write and re-write features for file sizes from 1 MB to 32 MB the VMware platform is very close to the performance of the non-virtualized environment. In the case of the 1 GB file size for random read functions the performance of the Hyper-V platform is slightly better than VMware. While the random write, record rewrite and forward rewrite functions for the 1 GB file size, the performance of the Hyper-V platform is almost equal to the performance of the VMware platform. As a result of this data it would be interesting to see the performance of the Hyper-V platform with file sizes larger than 1 GB.

The low performance of the Hyper-V platform has been observed in cases of small file sizes. In the case of size from 1 MB to 1 GB in almost all cases the performance of Hyper-V was twice lower than the performance of the VMware platform. The performance of the Hyper-V platform is increasing in the case of larger file sizes, where in some Iozone functions it equals the performance of the VMware platform for 1 GB file sizes, but the VMware platform is closer to the performance of the free environment. virtualized especially for write and rewrite functions in file sizes from 1 MB to 32 MB.

All Iozone benchmark tests are either write or read. Write tests include write, re-write, random write, record rewrite, forward write, and re-forward write; read tests include read, re-read, random read, backward read, stride read, forward read, and re-forward read. All write and read test results are pooled regarding various file sizes ranging from 1 MB to 1 GB.

The Iozone benchmark write functions' performance has been integrated, and the percentages of Hyper-V and VMware virtual platforms have been computed by comparing them to the non-virtualized "bare-metal" environment. The results of all Iozone benchmark write function tests have been compiled and their percentages determined. The percentages of write functions for Hyper-V and VMware virtualization systems are calculated with the non-virtualized "bare-metal" environment as the foundation of these results. The percentages for the outcomes in Table 2 are as follows:

Table 2: *Consolidation of Iozone functions*

File size	Hyper-V	Vmware
1 MB	44.4	78.7
32 MB	43.7	78.1
64 MB	40	68.5
128 MB	48.1	77.5
256 MB	41.3	64.5
512 MB	43	61.1
1 GB	49.3	57.6

Graph 15 presents the consolidation of test data for Iozone benchmark write functions in terms of percentage compared to the non-virtualized bare-metal environment.

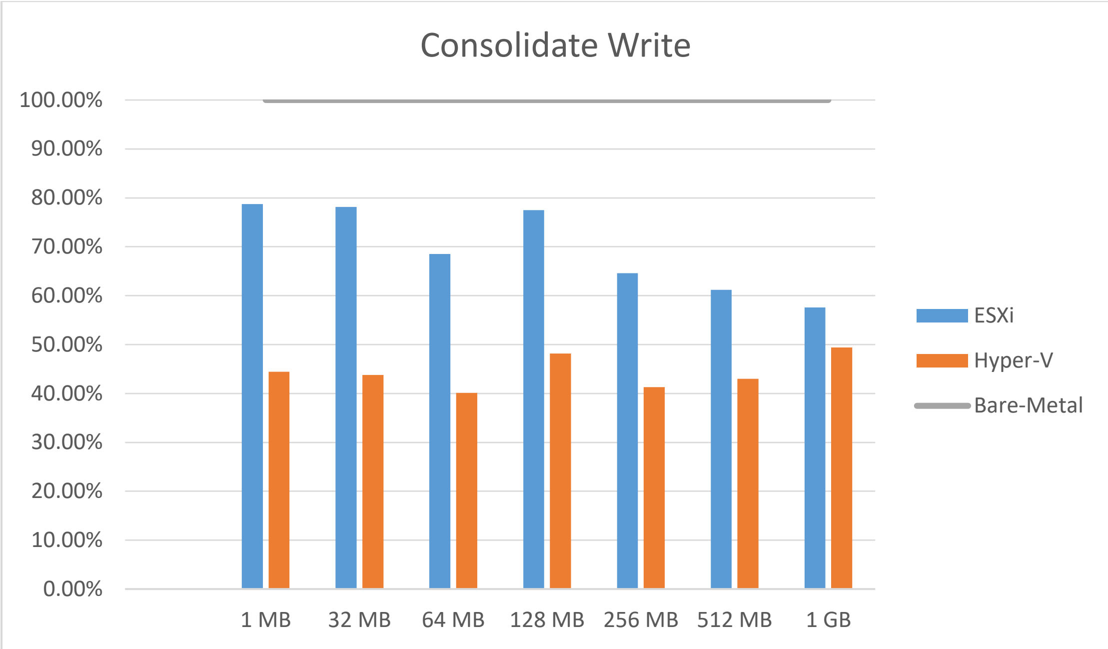

Figure 19: *Combined performance of Iozone benchmark write functions*

The consolidated performance of the write functions in Graph 15 for Iozone benchmark tests shows the comparison of Hyper-V and VMware virtualization platforms with the non-virtualized "bare-metal" environment. The performance of the non-virtualized environment "bare-metal" is shown with the gray line which is always 100% as this environment is the measuring basis of these comparisons. The VMware platform shows better performance across file sizes compared to the Hyper-V platform. In the case of small file sizes, the VMware platform shows almost twice as good performance compared to the Hyper-V platform. As the file size increases the performance of the platform decreases and the performance of the Hyper-V platform increases but never exceeds the performance of the VMware platform.

The Iozone benchmark read functions' aggregated performance for Hyper-V and VMware virtual environments is compared to the non-virtualized "bare-metal" environment. The results of all read function tests were compiled and a percentage was computed. The non-virtualized "bars-metal" environment is based on a percentage computation for Hyper-V and VMware systems.

All data in Table 3 are expressed in percentile.

File size	Hyper-V	VMware
1 MB	43.1	75
32 MB	41.4	73
64 MB	39.5	67.3
128 MB	45.5	73.4
256 MB	38.1	60
512 MB	39.9	56.3
1 GB	42.7	49.5

Table 3: *Consolidated performance of read functions of Iozone.*

Graph 17 is a graphical depiction of the total of the Iozone benchmark read tests. The graph above indicates that the VMware platform outperforms the Hyper-V platform for all file sizes based on the aggregated performance of the Iozone benchmark read function. The performance of the VMware platform is nearly double that of the Hyper-V platform for file sizes ranging from 1 MB to 64 MB. However, as file size increases, so does the performance of the VMware platform.

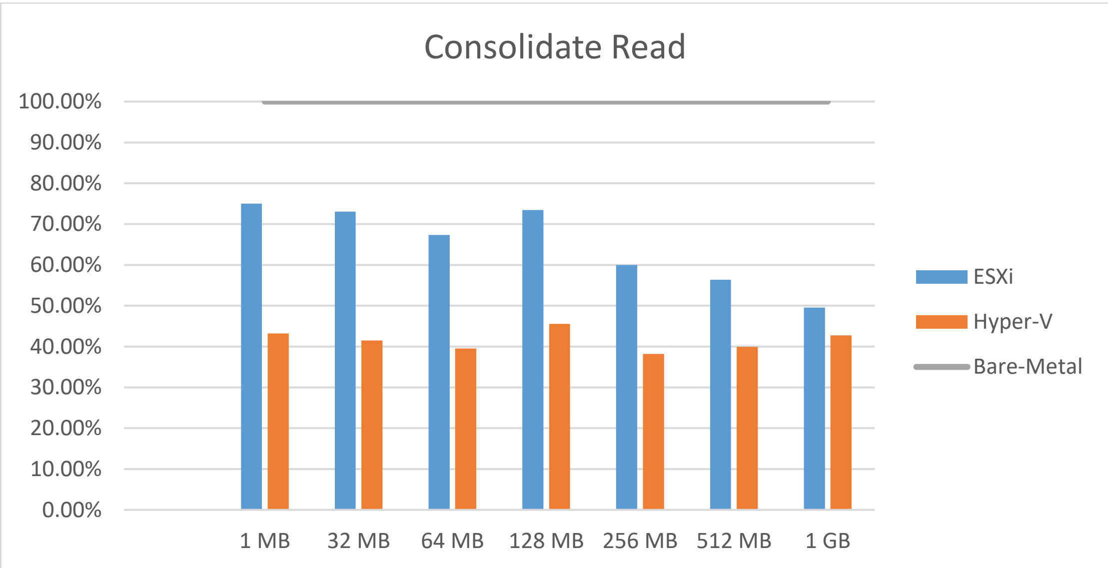

Figure 20.1: *Consolidated performance of read functions of Iozone*

4.2. RamSpeed testing results.

This section presents the graphs of the benchmark Ram Speed tool. For reliability of the results the tests were repeated 4 times. Ram Speed has been tested with exponential blocks from 1 KB with a maximum of up to 8 GB. The average of all test results is calculated and presented in the following graphs.

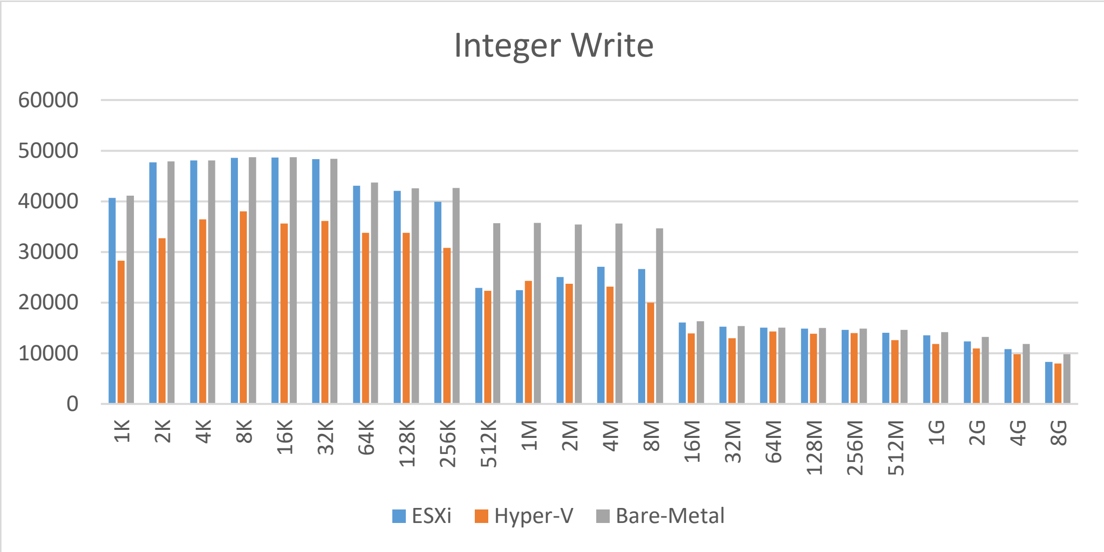

Figure 20: *Mean values of the Ram Speed benchmark Integer Write function*

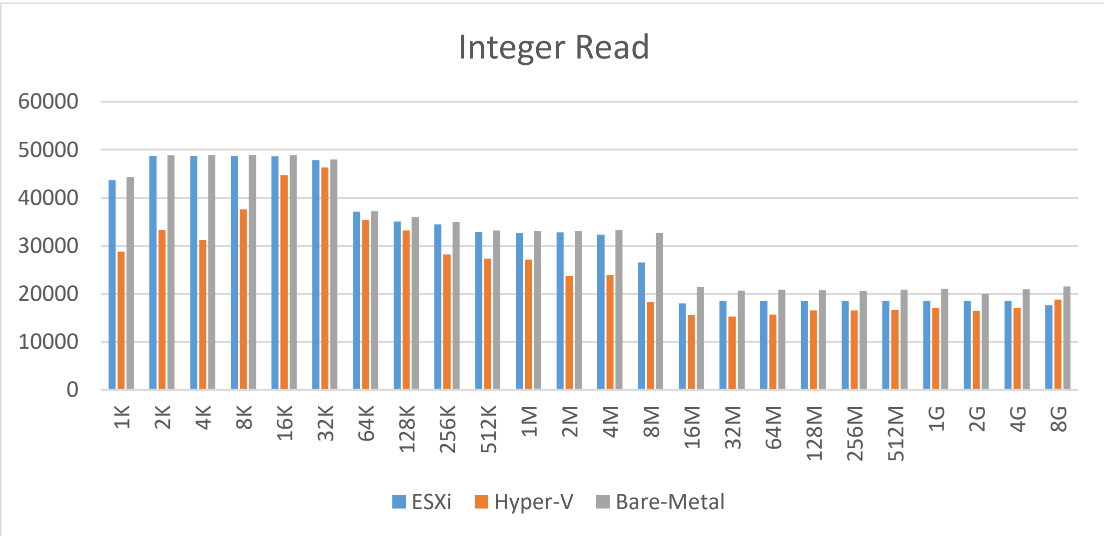

Figure 21: *Mean values of the Ram Speed benchmark Integer Read function*

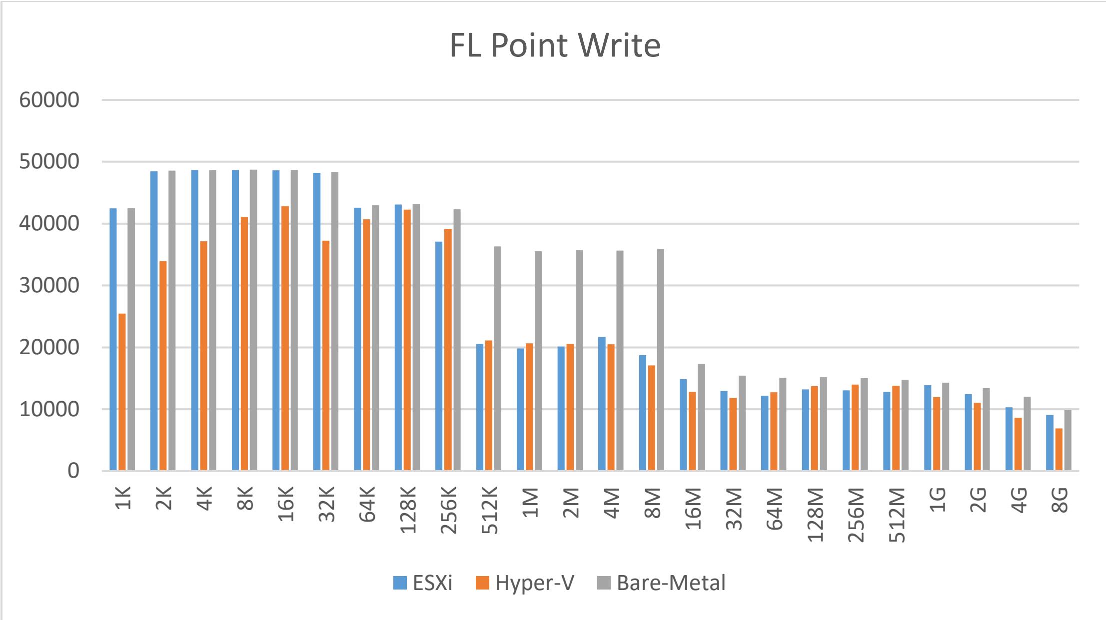

Figure 22: *Mean values of the Ram Speed benchmark Float Read function*

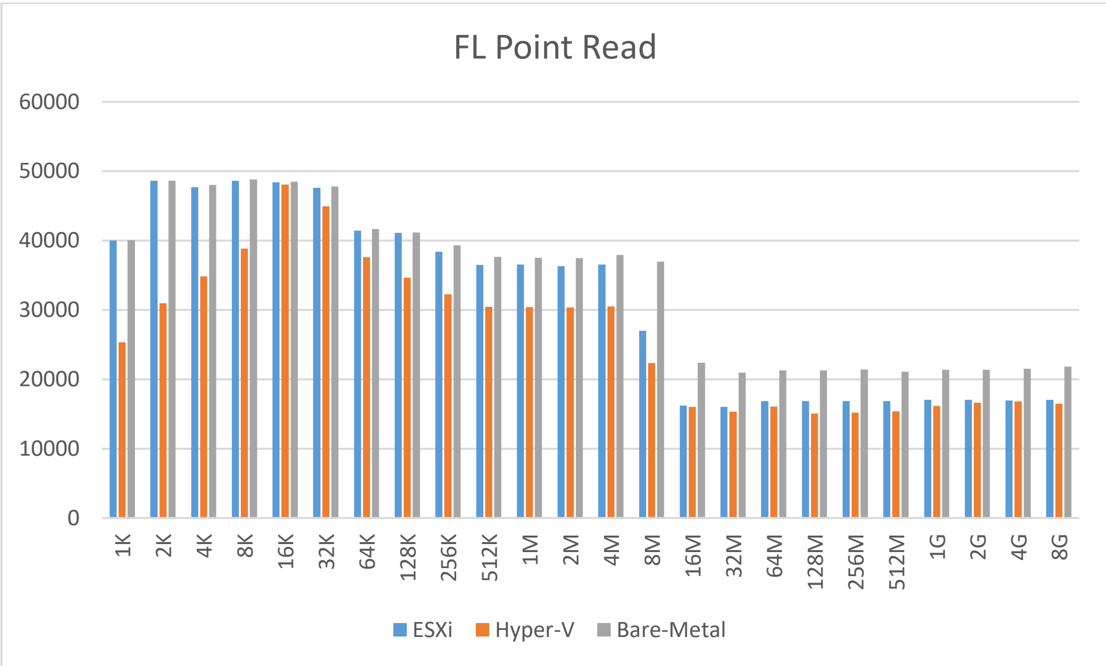

Figure 23: *Mean values of the Ram Speed benchmark Float Point Read function*

Memory performance is measured by Ram Speed utilizing four distinct types of testing which include Interger Read and Write as well as Float Read and Write. The Ram Speed benchmark tool uses blocks to measure performance. In all cases of Ram Speed benchmark tests, the non-virtualized "bare-metal" environment shows better results compared to the Hyper-V and VMware virtualization platforms. The abstraction layer used by the VT brings this performance reduction in Hyper-V and VMware virtualization environments compared to the non-virtualized "bare-metal" environment.

While when we make the comparison between two virtualization platforms, which is also the purpose of the study topic, the performance of VMware platform is better than the performance of Hyper-V platform. In the Integer Read and Float Read function the performance of the VMware platform for block sizes from 1 KB to 4 MB is almost the same as the performance of the non-virtualized environment, while for the Integer Write and Float Write function this performance is almost the same for the sizes of the block from 1 KB to 128 KB.

The Integer and Float Read and Interger and Float Write routines are used in all four Ram Speed benchmark tests. After that, the aggregated percentage for the Hyper-V and VMware virtualization systems is computed. The read and write functions are calculated independently of one another. The non-virtualized "bars-metal" environment is used to calculate the percentages of Hyper-V and VMware platform virtualized environments.

Table 4 shows the performance of Hyper-V and VMware platform virtualization environments for the write function compared to the non-virtualized "bare-metal" environment

Table 4: *Consolidated results on Interger and Float Write*

File size	Hyper-V	VMware
1 KB	64.2	99.3
2 KB	69	99.6
4 KB	76	99.9
8 KB	81.1	99.8
16 KB	80.5	99.8
32 KB	75.8	99.8
64 KB	85.8	98.8

128 KB	88.6	99.3
256 KB	82.4	90.6
512 KB	60.3	60.3
1 MB	63.1	59.2
2 MB	62.2	63.4
4 MB	61.2	68.4
8 MB	52.5	64.3
16 MB	79.1	91.8
32 MB	80.4	91.5
64 MB	89.8	90.3
128 MB	91.4	93
256 MB	93.5	92.6
512 MB	89.6	91.2
1 GB	83.6	96.3
2 GB	82.5	93.1
4 GB	77.1	88.7
8 GB	75.8	88.3

The non-virtualized "bars-metal" environment shows the optimal performance with gray at the top of the graph 23.

The write performance of VMware virtualization environment in small blocks from 1 KB to 256 KB is better than Hyper-V virtualization platform, even for block sizes from 1 KB to 128 KB the performance of this platform is almost the same with the performance of the non-virtualized environment. The performance of both virtual platforms drops significantly compared to the performance of the non-virtualized environment for block sizes from 512 KB to 8 MB. In almost the entire block size range the VMware platform performs better than the Hyper-V platform. Hyper-V platform performance exceeds VMware platform performance only in 1 MB and 256 MB block size.

Table 24 displays the performance of consolidated memory using the read function. The performance of Hyper-V and VMware platform virtualization environments is measured as a percentage of the performance of a non-virtualized "bare-metal" system.

Table 5: *Consolidated performance of Interger and Float Read functions*

Madhësia e skedarit	Hyper-V	VMware
1 KB	64.1	99.1
2 KB	65.9	99.8
4 KB	68.1	99.4
8 KB	78.1	99.5
16 KB	95.3	99.6
32 KB	95.2	99.6
64 KB	92.4	99.6
128 KB	87.9	98.7
256 KB	81.4	98
512 KB	81.6	98
1 MB	81.3	97.9
2 MB	76.6	97.9
4 MB	76.3	96.7
8 MB	58.3	76.8
16 MB	72.1	78.1
32 MB	73.5	83
64 MB	75.2	83.8
128 MB	75.1	84
256 MB	75.6	84.1
512 MB	76.4	84.3
1 GB	78.3	83.7
2 GB	80	86
4 GB	79.6	83.5
8 GB	81.3	79.9

The performance of the non-virtualized environment is the gray line that is the maximum for the virtualized environments of the Hyper-V and VMware virtual platforms as shown in Table 25.

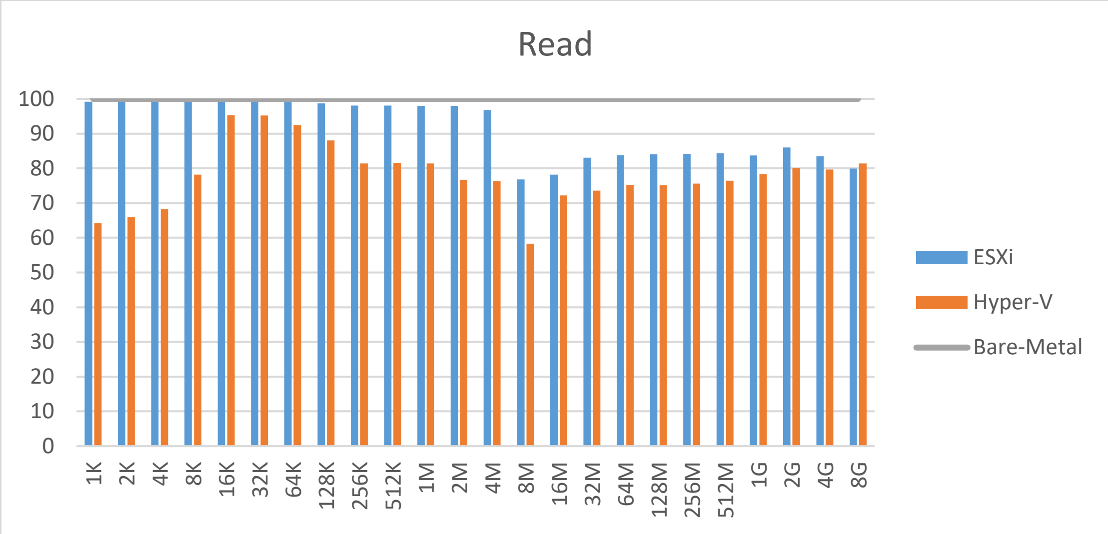

Figure 24: *Consolidated results of Integer & Float Read functions*

In the case of Ram Speed benchmark read functions, the performance consolidated in Figure 6.21 of the VMware platform virtualization environment is almost equal to the performance of the non-virtualized environment for block sizes from 1 KB to 4 MB. Across the block-size range tested, VMware's virtual environment performance is almost better than Hyper-V's virtual environment performance. Only at the 8 GB block size the performance of the Hyper-V platform is better than the performance of the VMware platform.

4.3. UnixBench testing results.

UnixBench tests system CPU performance through various types of tests as shown in Table 26. CPU throughput, process communication throughput, and system file throughput are all grouped for performance calculation. Dhrystone 2, Whetstone and Excel throughput tests are to the left of the throughtput performance of the UnixBench benchmark CPU. Pipe throughput tests, process creation, Shell script (8 concurrent), System call overhead is the left-over performance of interprocess communication. The system file performance is still being tested with the File copy 256, File copy 1024, and File copy 4096 tests. Graphs are used to compare CPU throughput performance, process communication, and file system communication.

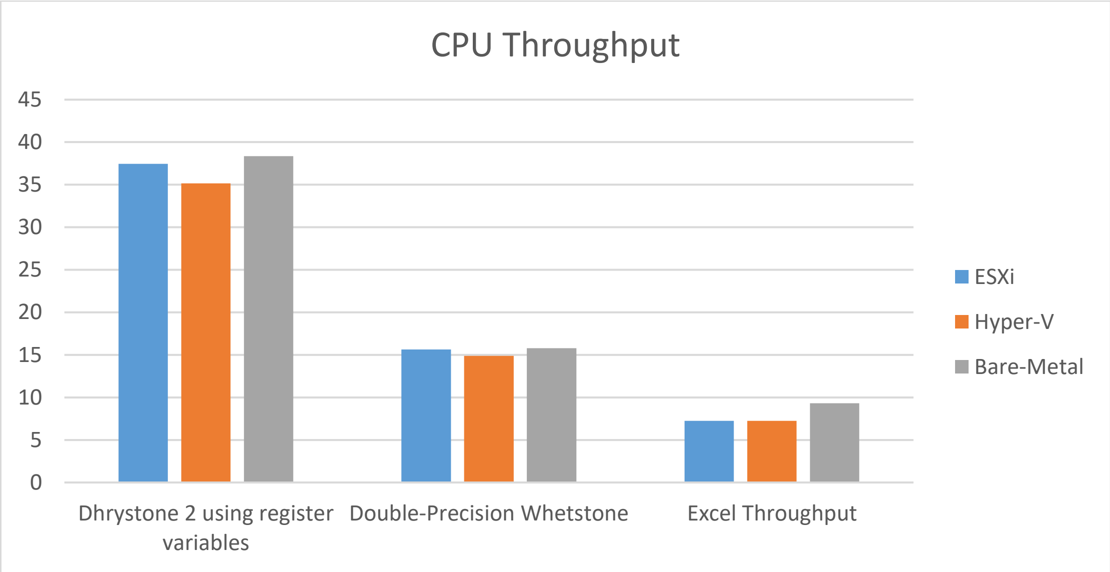

Figure 25: *The result of the throughput functions of the UnixBench CPU*

Table 26 shows the CPU throughtput performance. The performance of the non-virtualized environment "bars-metal" has the best performance followed by the virtualized environment of the VMware platform that is very close to the non-virtualized environment. While the performance of the virtualized environment of the Hyper-V platform has a slightly lower performance compared to the non-virtualized environment "bars-metal" and the virtualized environment of the VMware platform.

- The Dhrystone 2 test examines array manipulation, character strings, indirect addressing, and other non-float point instructions that are commonly used. The non-virtualized "bare-metal" environment outperforms the basic UnmarkBench benchmark comparison system by slightly more than 38 times, the Hyper-V platform virtualized environment by 35 times, and the VMware virtualized platform environment by 37 times. Whetstone double-precision is an arithmetic test that evaluates addition, subtraction, and multiplication calculations. The non-virtualized "bare-metal" environment and the virtualized VMware platform environment have a performance of a little more than 15 times better, while the Hyper-V virtualized environment has a slightly lower performance than 15 times better compared to UnixBench benchmark benchmarking system.

- Excel Throughput testing include replacing existing processes with new ones. The non-virtualized "bare-metal" environment performs slightly better than 9 times in this test, while the virtualized environments of the VMware platform and the virtualized environment of the Hyper-V platform perform slightly better than 7 times when compared to the UnixBench benchmark benchmarking system.

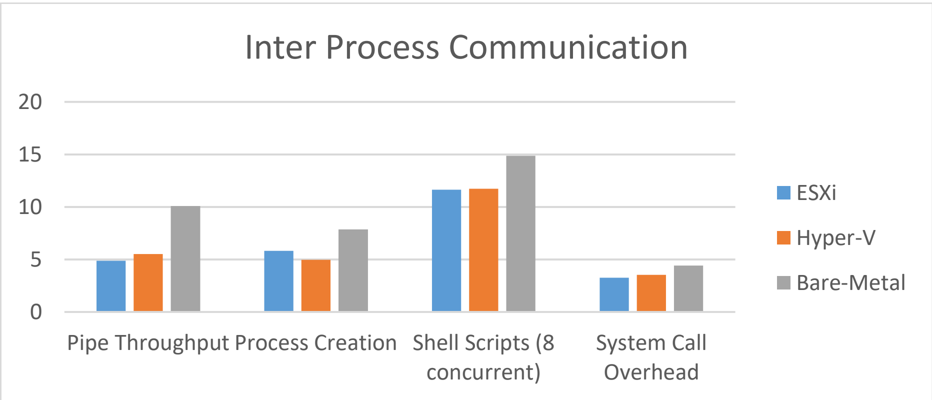

Figure **26**: Results of the Inter Proccess Communications

In the communication between the processes in graph 6.31 both virtualized environments present the following results compared to the non-virtualized "bars-metal" environment:

• Pipe Throughtput examines a single procedure that opens a funnel itself and communicates the data in the loop. The non-virtualized "bars-metal" environment shows a performance of 10 times better while the virtualized Hyper-V environment has a performance of 5.5 times better. While VMware virtualized environment shows a performance of slightly less than 5 times better compared to the base system.

• Success Creation evaluates the repetition of the creation of a child process which ceases to function immediately after its fork () function. The non-virtualized environment "bars-metal" has a performance of 7.8 times better, while the virtualized environment of the Hyper-V platform has a performance of 5 times better and the virtualized environment of the VMware platform has a performance of 5.8 times better compared to the basic system.

• Shell Scripts examines shell scripts that are run by 1, 2, 4, and 8 concurrent processes. This test performed 14.8 times better in the non-virtualized "bare-metal" environment and about 11.6 times better in the virtualized environments of VMware and Hyper-V platforms.

• System Call Overhead estimates the time it takes to repeat dup (), close (), getpid (), getuid () and umask () calls. The performance of this test was 4.4 times better for the non-virtualized "bare-metal" environment, and 3.2 times better for the virtualized environment of the VMware platform and 3.5 times better for the virtualized environment of the Hyper-V platform.

In the instance of the System Call Overhead result, the performance of the Hyper-V virtualized environments was greater than the performance of the VMware virtualized environment. In addition, the Hyper-V platform virtualized environment outperformed the VMware platform virtualized environment in the Pipe Throughput test. For the Process Creation test scenario, the VMware platform virtualization environment outperformed the Hyper-V platform virtualization environment. In the instance of the Shell Scripts test, both virtualized systems performed nearly identically. The delay provided by VT has a highly significant influence on the performance of virtualization platforms, and as a result, both virtual platform implementations have space for improvement.

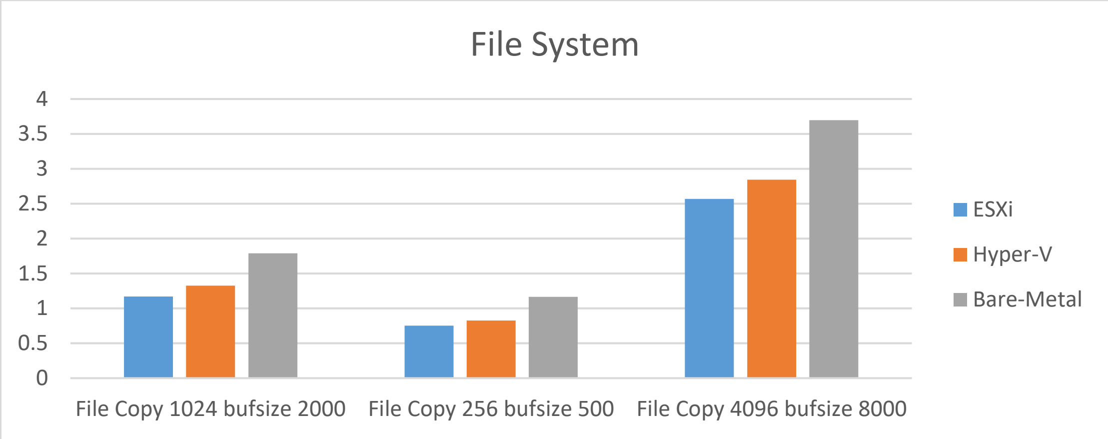

Figure 27: *The result of the system file throughput functions for UnixBench*

The file system graph 28 findings show the amount of characters that can be transferred in 10 seconds based on buffer sizes of 256 bytes, 1 KB, and 4 KB. As seen in the following findings, the non-virtualized "bare-metal" environment outperformed the virtualized environments of the Hyper-V platform and the VMware platform.

• 256-byte file copy the performance result for a non-virtualized "bare-metal" environment was 1.1. While it was 0.7 in VMware's virtualized environment and 0.8 in Hyper-virtualized V's environment.

• Duplicate file 1 KB repetition per second was 1.7, 1.3, and 1.1 for the non-virtualized "bare-metal" environment, the Hyper-V platform's virtualized environment, and the VMware platform's virtualized environment, respectively.

• 4 KB File copy the bare-metal “virtualized” environment has shown higher performance than 3.6 followed by the Hyper-V platform virtualization environment with 2.8 repetitions per second. While the virtualized VMware platform environment showed a performance of 2.5 repetitions per second.

In these tests, the Hyper-V platform virtualized environment performed better than the VMware platform virtualized environment. But from the results we see that for both the virtualized environments of the Hyper-V platform and VMware there is still room for improvement compared to the non-virtualized environment.

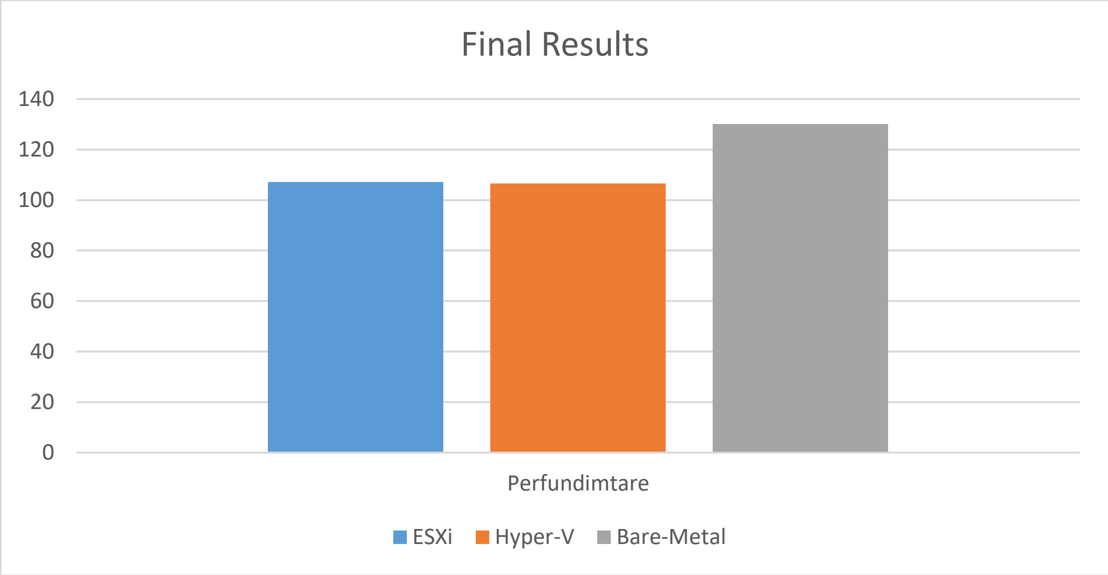

Figure 28: *The final result of UnixBench's throughput functions*

The final CPU throughput performance shown in Figure 29 shows that the non-virtualized "bare-metal" environment has a higher performance of 130 times better. While both virtualization environments have an almost identical performance concretely of 107 times better for the VMware platform and 106 times better for the Hyper-V platform compared to the basic UnixBench system.

UnixBench benchmark tests concentrate on a range of system resources such as CPUs, filesystems, and processes. These processes interact with system kernel services and cause kernel-level memory events. Changes in architecture result in changes in performance. In terms of ultimate performance, the two virtualized environments of the VMware and Hyper-V platforms are identical and virtually identical to the performance of the non-virtualized "bare-metal" environment.

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

The primary goal of this study was to compare the virtual platforms Hyper-V with VMWare. The main benefit of this work is to select the right technology for organizing the company's computer infrastructure for better and faster performance results. The performance of the identical operating system running in a non-virtualized environment would be used in this comparison. The layer of abstraction between the physical resources of the hardware and the OS in a virtualized environment definitely impacts the performance of the OS operating on Hyper-V and VMware platforms. Hyper-V and VMWare are distinct virtualization systems with distinct designs. VMWare places the virtualization layer on the hardware platform, whereas Hyper-V enables partition isolation. This distinct approach to virtualization may have resulted in a performance difference. [17]

When comparing the non-virtualized and virtualized environments, it was found that the non-virtualized environment outperforms the Hyper-V and VMWare virtualization platforms in all tests. Some intriguing outcomes were noticed while comparing Hyper-V vs VMWare. In the instance of the Iozone benchmark program, they observed that the performance of the VMware platform fell for file sizes ranging from 256 MB to 1 GB, while the performance of the Hyper-V platform grew but virtually never surpassed the performance of the VMware platform. While for file sizes ranging from 1 MB to 128 MB, the VMware platform demonstrated storage I / O performance that was nearly identical to that of the non-virtualized environment.

While testing memory performance for consolidated Read functions we note that for almost all block sizes the VMware platform virtualized environment performs better than the Hyper-V platform virtualized environment, except for the 8 GB block size in which the Hyper platform -V performs a little better. For block sizes from 1 KB to 4 MB the performance of the VMware platform is almost the same as that of the non-virtualized environment. Even for consolidated Write functions, the VMware platform performs better than the Hyper-V platform for all tested block sizes with minor exceptions, namely the 1MB and 256 MB block sizes where the Hyper-V platform performs better. For block sizes from 1 KB to 128 KB, the VMware platform performs at almost the same level as the non-virtualized bare-metal environment.

CPU performance for both virtual platforms addressed in this study topic was tested using the UnixBench benchmark tool. The performance of the VMWare platform and the Hyper-V platform was equal, even close to the performance of the non-virtualized "bare-metal" environment. In this regard, these virtual platforms have made a very good optimization of their architecture, but still here there is little room for improvement.

Overall, the VMWare platform performs better than the Hyper-V platform especially for the I / O performance of the backup space and for the performance of the memory. As for CPU performance both virtual environments of Hyper-V and VMware platforms perform the same.

5.2 Recommendations for future research

The Iozone benchmark tool has a maximum file size of 1 GB for testing. As a result, it will be of interest to test the I/O performance of the storage space for file sizes larger than 1 GB. The same consideration for the benchmark Ram Speed, which has a maximum memory block size of 8 GB for testing. Using block sizes larger than 8 GB some interesting facts can be elaborated. The performance comparison for the Hyper-V platform virtualization environment and the VMware platform virtualization environment was performed using Iozone benchmark tools for I/O performance of storage spaces, Ram Speed for memory and UnixBench for CPU. It would also be of interest to compare the performance of these virtual environments with some other available benchmark tools. This study topic was conducted using CentOS 7 x86_64 as the operating system on virtual environments.

It will also be of interest to compare the performance of virtual environments of Hyper-V and VMware platforms using other operating systems. Interesting facts can also be elaborated by measuring the hypervisor performance of Hyper-V and VMware platforms by executing several virtual machines at once. This helps measure the scalability of these hypervisors.

References

[1] "Steven J. Vaughan-Nichols, "New Approach to Virtualization" IEEE," *IEEE,* pp. 12-14, 2006.

[2] S. A. Herrod, "Herrod, S. A., "Systems Research and Development at VMware" ACM SIGOPS Operating Systems Review archive, Vol. 44(4), ACM New York, NY, USA, December," *ACM SIGOPS,* 2010.

[3] S. a. B. D. Crosby, "The Virtualization Reality. ACM QUEUE Jr., pp.34-41,," *ACM QUEUE ,* pp. 34-41, 2006-2007.

[4] G. G, "Virtualization: Old Technology Offers Huge New Potential," *IEEE Computer Society,* p. vol.8(2), 2007.

[5] Hirt.T, "The kernel-based virtual machine," *KVM,* 2010.

[6] I. C. Education, "Virtualization," *IBM,* 2019.

[7] I. C. Education, "Virtual Machines," *IBM,* 2019.

[8] I. C. Education, "Hypervisors," *IBM,* 2019.

[9] R. Maurya, "H2S Media," 7 February 2021. [Online]. Available: https://www.how2shout.com/tools/8-free-best-open-source-bare-metal-hypervisors-foss.html.

[10] Microsoft, "Microsoft Documents," 26 April 2022. [Online]. Available: https://docs.microsoft.com/en-us/virtualization/hyper-v-on-windows/reference/hyper-v-architecture.

[11] VMware, "The Architecture of VMware ESXi," VMware Documentation, 2021. [Online]. Available: https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/techpaper/ESXi_architecture.pdf.

[12] SkyTap, "SkyTap," Installing and upgrading VMware Tools on Windows VMs, [Online]. Available: https://help.skytap.com/installing-and-upgrading-vmware-tools-on-windows-vms.html.

[13] Microsoft, "Microsoft Documentation," Microsoft, 18 January 2022. [Online]. Available: https://docs.microsoft.com/en-us/windows-server/virtualization/hyper-v/manage/manage-hyper-v-integration-services.

[14] H. J. X. X. W. C. P. Y. Guan T, "Measuring and Alanyzing CPU Overhead of Virtualization System," *APSCC, 2011 IEEE,* pp. 243-250, 2011.

[15] B. Lee, "Difference between VMware and Hyper-V: A Complete Guide," *IEEE,* 2019.

[16] R. M. a. B. P. V. Hollander, "RAMspeed, a cache and memory benchmarking tool," *IEEE,* 2012.

[17] D. Capps, "A nine year study of file system and storage benchmarking," *IEEE,* p. 28, 2012.