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Comparación del rendimiento entre las plataformas para IAAS Open Source: OpenStack y CloudStack

Comparison of performance between platforms for IAAS Open Source: OpenStack and CloudStack

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Palabras claves: OpenStack, CloudStack, IaaS, rendimiento, Nube Privada, Cloud Computing

Resumen

Introducción: La implementación de una plataforma IaaS en la UNACH representa una gran oportunidad para mejorar la infraestructura tecnológica de la institución, fortalecer las capacidades de estudiantes y docentes, y promover la innovación y la competitividad. **Objetivo:** Comparar las plataformas OpenStack y CloudStack mediante el rendimiento en un entorno virtualizado para la implementación de una nube privada en la Universidad Nacional de Chimborazo. **Metodología:** El establecimiento del escenario contó con la instalación de tres nodos: el nodo controlador, el nodo cómputo y un nodo de almacenamiento desplegados sobre Proxmox VE. **Resultados:** Se realizó el análisis de cada dimensión obtenidos del Modelo de FURPS con una muestra de 35 pruebas, un porcentaje de error del 0.05%, verificando en primera instancia la normalidad de los datos y posteriormente las pruebas de contraste correspondientes, obteniendo de esta manera para la dimensión de Tiempo de procesamiento una diferencia de 5.6% de mejor desempeño a favor de OpenStack así también en los indicadores de Uso de RAM con un 0.89%, Uso de CPU con un 2.67% y Tráfico de Red Saliente con un 2.07%. **Conclusión:** Se calculó un resultado general a través de un análisis multicriterio con el método de NAIADE obteniendo que el desempeño es similar. **Área de estudio general:** Computación. **Área de estudio específica:** Computación en la nube.

Keywords: OpenStack, CloudStack, IaaS, performance, Private Cloud, Cloud Computing

Abstract

Introduction: The implementation of an IaaS platform at UNACH represents a great opportunity to improve the technological infrastructure of the institution, strengthen the capacities of students and teachers, and promote innovation and competitiveness. Objective: To compare OpenStack and CloudStack platforms through performance in a virtualised environment for the implementation of a private cloud at the National University of Chimborazo. Methodology: The establishment of the scenario included the installation of three nodes: the controlling node, the computing node and the storage node deployed on Proxmox VE. Results: The analysis of each of the dimensions of the FURPS model was carried out with a sample of 35 tests, an error rate of 0.05%, the first time the normality of the data and the corresponding contrast tests, obtaining this way for the processing time of a difference of

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5.6% The best use of OpenStack The use of RAM with 0.89%, The use of the CPU with 2.67% and Outgoing Network Traffic with a 2.07%. Conclusion: a general result was calculated through a multicriteria analysis with the NAIADE method, obtaining that the performance is similar.

Introduction

According to Tam Malaga (2015), Cloud computing "is part of the reality of this time, as a concept it is in everyone's mind and implies that we consider, in a totally different way, the limits in storage capacity, processing and bandwidth; different from when only the capabilities of one's own infrastructure (whether of the person or the organization) are available. In other words, many initiatives that would be impossible to consider due to the high investment in infrastructure today are possible thanks to the cloud."

Infrastructure as a Service (IaaS) is one of the types of cloud computing that offers several of the options found on the market. Through these solutions, users can use virtual resources, such as virtual servers, virtual networks, virtual routers under demand(Yamoto, 2018). In the cloud computing paradigm, the IaaS provider can provide basic resources (i.e., CPU, RAM, storage, networking) as virtual instances to users (students, teachers) (Zangara et al., 2015). , eliminating the need for users to own and operate these resources, which can lead to better performance in their activities (Salam et al., 2015).

OpenStack and CloudStack are the most used open source platforms for Cloud today and their use continues to increase (Yamoto et al., 2014). OpenStack is a cloud software that offers the ability to control large achievements of computing, storage and network resources (Sharma, 2015), on the other hand CloudStack is an open source software platform, written in Java, designed for the development and Cloud Infrastructure as a Service (IaaS) management (Sabharwal & Shankar, 2013).

Due to the rise of different offers for the implementation of IaaS services, there are several studies that analyze the different operating parameters, such as that of Yamato et al. (2015) who carried out a development study of the resource management server allowing the production of cloud services based on OpenStack, measuring the performance of the multiple uses of the APIs to demonstrate that this implementation reduces the waiting time on the part of the users.

Badia et al. (2013) presents mechanisms designed for the automated deployment of the main open source IaaS platforms: Nimbus, OpenNebula, CloudStack and OpenStack allowing users to compare each architecture and the performance offered by each of them to make use according to their needs. .

Kim et al. (2017) makes a comparison of the OpenSource platforms: CloudStack and OpenStack, providing their own programming interfaces (API) to manage the cloud resources that each of them offer. Additionally, it shows the implementation details of the integrated API and performance evaluation. Concluding that the overhead imposed on the interface is negligibly small and can be successfully used for multi-cloud access.

Hahm et al. (2014) analyzes the OpenSource platforms: OpenStack, CloudStack and OpenNebula, selecting CloudStack to verify the functionalities and performance that this platform offers through test scenarios.

The National University of Chimborazo (UNACH) has the Center for Educational Technologies (CTE), which houses a technological infrastructure where computer applications for the regular processes of the institution, both academic and administrative, are housed. Within the academic tasks, several of the projects that are developed require technological infrastructure for their implementation, so an iCloud solution is required. It is therefore important to implement an IaaS platform that offers high performance, covering different dimensions such as: response time, processing time and resource consumption, thus it is expected that UNACH students and teachers can create computer solutions. that allow them to catch up on the growing rise of technology.

The objective of this research is to compare the performance between the Open Source IaaS platforms OpenStack and CloudStack for the subsequent implementation of an iCloud IaaS server at the National University of Chimborazo.

For the comparison, a bibliographic review of the tools used for the comparison was carried out in the first instance, then comparison dimensions and indicators obtained from the FURPS model were selected. Subsequently, the implementation of the test scenario was carried out on a Proxmox VE server where the samples were obtained with each platform. Next, statistical algorithms were applied to verify existing differences between the platforms, as well as a multi-criteria analysis for a general result. At the end, the conclusions of the work are detailed, showing a slight advantage of OpenStack over CloudStack in several analyzed indicators.

Bibliographic review

For Celaya & Sakellariou (2014), Cloud computing could be defined as a service model over the Internet where a wide range of ICT resources are shared: network, applications, services, storage, infrastructure, etc. In this way, companies can focus on their business by outsourcing certain services. These services are characterized by being scalable, on-demand, flexible and secure. They allow companies to focus on their competitive advantages and convert investments into a variable expense. For Clavijo & Ledesma & Duque (2018), and Cloud Computing refers to a set of services offered over the Internet, through applications configured through the convergence of hardware and software in data centers around the world.

The basis of Cloud Computing solutions is virtualization. Virtualization is a framework or methodology of dividing a computer's resources into multiple execution environments, applying one or more concepts or technologies such as hardware and software partitioning, time sharing, partial or full machine simulation, emulation, quality of service, and many others. Virtualization software makes it possible to run multiple operating systems and multiple applications on the same server at the same time (Sharma, 2015).

For Portnoy (2012), virtualization is the engine that will drive cloud computing by turning the data center, which used to be a hands-on, people-intensive process, into a "self-managing," highly scalable, highly available, stack. easily consumable resources. Before virtualization, system administrators spent 70 percent or more of their time on routine functions and reacting to problems, which left little time for innovation or growth. Virtualization and, by extension, cloud computing provide greater automation opportunities that reduce administrative costs and increase a company's ability to dynamically deploy solutions.

IAAS stands for Infrastructure as a Service or Infrastructure as a Service. It is a model for distributing computing infrastructure as a service, usually through a virtualization platform. Instead of purchasing servers, data center space, or networking equipment, customers purchase all of these resources from a third-party service provider. In other words, what the provider offers in this case are virtual machines, whether Linux, Windows or other operating systems. The client installs its applications on them, as well as the necessary architecture, etc.

Among the different public IAAS providers on the market, Amazon Web Services (AWS) and IBM SmarthCloud stand out. Options for the implementation of private IAAS include OpenStack and CloudStack.

The components that make up the architecture of the Open Source platforms: OpenStack and CloudStack where it can be seen that OpenStack offers the possibility of dividing into 3 nodes at the time of its implementation (CloudStack.apache.org, 2016; OpenStack.org, sf; European Commission, 2010), as shown in figure 1.

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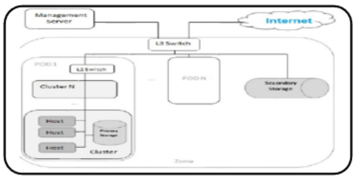
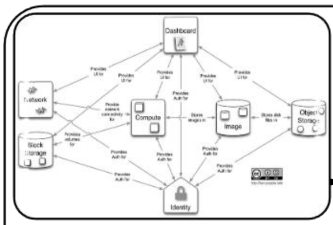
Figure 1

CloudStack and OpenStack architecture



COMPONENTES DE CLOUDSTACK

- Anfitrión
- Cluster
- Pods
- Zona
- Región
- Administración de servidores
- Almacenamiento: almacenamiento primario y almacenamiento secundario
- Redes



COMPONENTES DE OPENSTACK

Calcular (NOVA): Nova - api, Nova - cálculo, Nova - volumen, Nova - red, Nova horario, Queue, Base de Datos.

• Red (Neutron): gestión de red, red de datos, red externa, API de red.

•Almacenamiento (Storage)

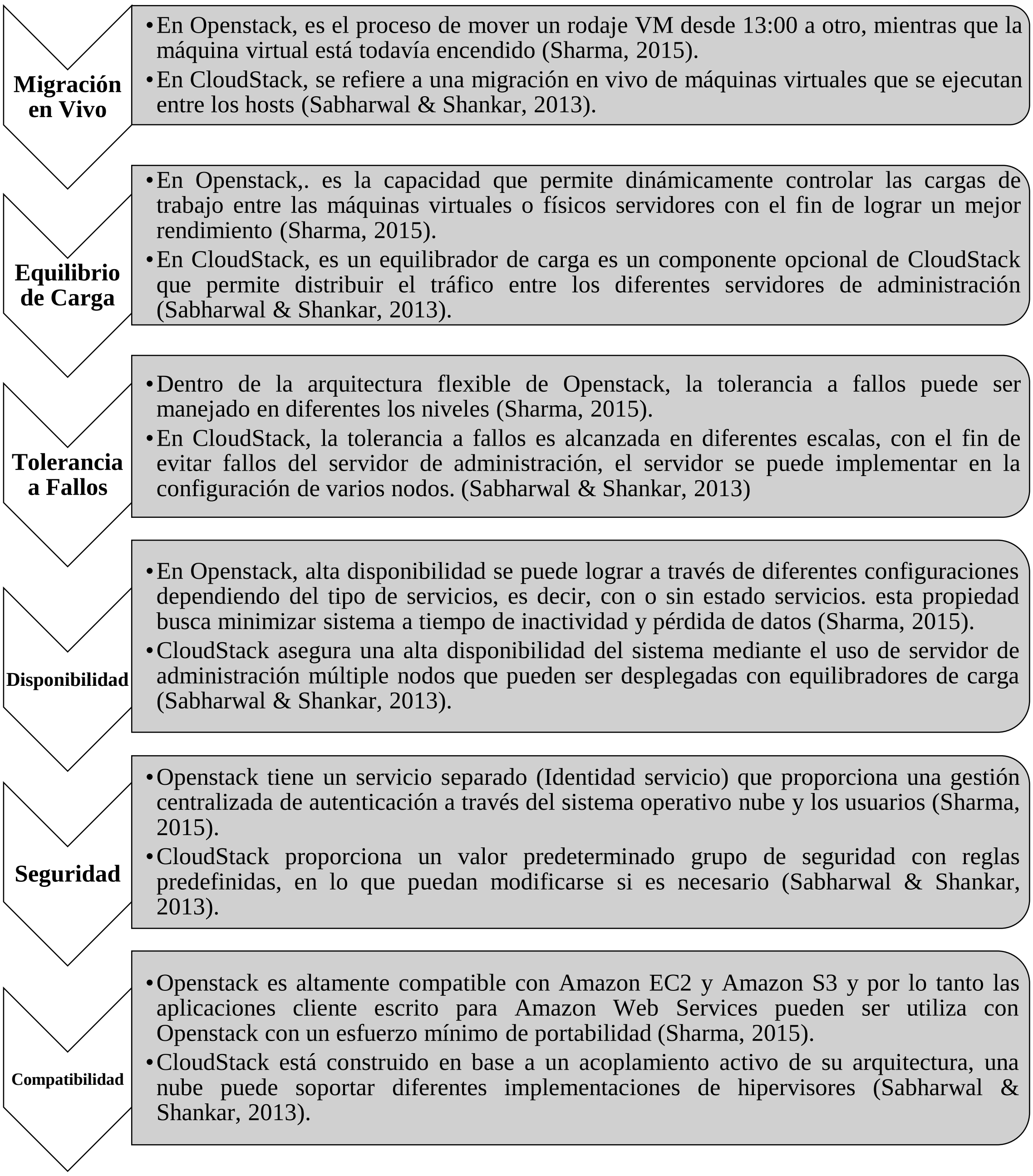
•Interfaz de usuario (Horizon)

•Servicios compartidos: servicio de identidad, servicio de imágenes, servicio de telemetría, servicio de orquestación, servicio de base de datos.

A comparative analysis of the properties (Sabharwal & Shankar, 2013; Sharma, 2015) offered by the Open Source platforms: OpenStack and CloudStack at the time of their implementation is proposed, as shown in Figure 2.

Figure 2

Properties of the OpenStack and CloudStack Platforms



Methodology

Research, according to Tamayo (2006), is defined as "an effort undertaken to solve a problem, of course, a problem of knowledge", on the other hand, Ibarra & Onofre (2022),

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define it as "an activity aimed at solving problems. Its objective is to find answers to questions through the use of scientific processes. Table 1 shows the results of the bibliographic search of the topic under investigation.

Table 1

Research Methodology

CRITERION	DETAIL
FOCUSING	The following research project aims to answer the following question: Which of the two platforms: OpenStack and CloudStack offer better performance in the implementation of the private cloud of the National University of Chimborazo?
SEARCH STRATEGY:	AREA: OpenStack and CloudStack, measuring the performance of the Open Source OpenStack and CloudStack platforms in the implementation of a private cloud. PURPOSE OF SEARCH: Analyze the characteristics and functionalities of the Open Source platforms: OpenStack and CloudStack, to select the most appropriate one and implement a private cloud.
INFORMATION SOURCES	Books, Journal, Technical Report, PhD thesis, Handbook.
SEARCH ENGINES	ProQuest, Scopus
SEARCH CRITERIA	"Performance" Openstack AND Cloudstack "OpenStack" AND "CloudStack" "Private Cloud" "Cloud Computing iaas"
SELECTION CRITERIA	Documents that contain information about the characteristics and functionalities of the Open Source platforms: OpenStack and CloudStack that allow us to measure performance in the implementation of a private cloud.
EXCLUSION CRITERIA	✓ Documents that analyze characteristics other than performance such as: portability, security, availability, integrity, reliability are excluded. ✓ Information that is lower than 2013. ✓ All platforms that are not Open Source.
CONTENT EVALUATION CRITERIA	Accuracy, objectivity, coverage, validity, relevance based on the research question. It is investigated in authors who have made contributions to the articles consulted.
INFORMATION ANALYSIS	An overview is provided to measure performance in the implementation of a private cloud, for which two Open Source platforms will be analyzed: OpenStack and CloudStack, determining the optimal one since there is no comparative study between these two platforms about the performance they offer. the same.

QUERY	PROQUEST	SCOPUS	TOTAL
"Performance" Openstack AND Cloudstack	153	14	167
"OpenStack" AND "CloudStack"	343	38	381
"Private Cloud" "Cloud Computing iaas"	7	1	8
TOTAL:	503	53	556

Type of study

According to the object of study, this research is of the application type, which aims to generate knowledge with direct and medium-term application in society or in the productive sector. This type of study presents great added value due to the use of knowledge that comes from basic research.(Lozada, 2014). Depending on the level of measurement and analysis of the information, it is a descriptive research, which consists of the characterization of a fact, phenomenon, individual or group, in order to establish its structure or behavior. The results of this type of research are at an intermediate level in terms of depth of knowledge.

Population and Sample

For the analysis of the indicators, the sample used is 35 tests, for each of the dimensions with its different indicators.

Procedures

When working directly with teams, the procedure adopted is the documentary investigation of the proposed Open Source platforms, which allow the implementation and verification of their code, through their documentation that is hosted on the web pages of the free software communities, using the scientific method which contains the following steps:

- Statement of the problem, which is the main object of study.
- Support of the process prior to the formulation of the hypothesis.
- Gathering of the necessary information.
- Analysis and interpretation of results.
- Hypothesis Testing Process.
- Dissemination of results.

Processing and Analysis

The information related to the research is analyzed and presented in figures, with the Shapiro-Wilk statistical analyzes for normality tests whose application is appropriate in sample sizes less than 50.(Razali & Wah, 2011). On the other hand, for normality tests in groups of samples greater than or equal to 50, as was the case of the processing time with 385 tests, the Kolmogorov-Smirnov statistical analysis was used, appropriate for this type of data set.

Once the normality test has been carried out, two scenarios may result, the first corresponding to data without a normal distribution(Nachar, 2008), and the second to data with a normal distribution, in both cases the significance analysis tests will be carried out, for the first scenario (non-normal data) the Mann-Whitney U formula was used while for the second scenario (normal data) t test was used.

For cases in which there was a significant difference, the percentage variation formula was used to find the difference expressed in percentage between both platforms, the formula is as follows:

$$VP = \frac{Vmayor - Vmenor}{Vmayor} \tag{1}$$

Where:

- VP is the percentage variation expressed in percentage
- VMajor is the largest value among the data to be compared
- VMinor is the smallest value among the data to be compared

Performance evaluation indicators

The evaluation of the performance of computer systems has been addressed in different research works, each of them proposing a number of variables and indicators. For this work, the indicators proposed by both the FURPS model (Constanzo, 2014) and like the one proposed by Comas & Nogueira & Medina(2014), among which the following dimensions and indicators are mentioned:

- Response time: Time in milliseconds that it takes to complete a task, from the moment it is invoked until the response is received. This indicator will be performed through ping tests to the server.
- Processing time: Time in milliseconds it takes to complete a task, this indicator will be carried out with tasks such as: create, delete, lock, suspend, restart and access an instance (virtual machine).
- Resource consumption: Resource consumption is divided into 3 subcriteria such as: CPU Usage expressed in percentage, RAM Memory Usage expressed in MegaBytes, Disk Reading expressed in KiloBytes and Network Traffic both input and output expressed in KiloBytes.
- Efficiency: Number of tasks completed without errors.

It is important to note that, for this research, with the exception of the effectiveness indicator, in all the others the objective is to minimize time and resource consumption.

Analysis tools

The tool for data analysis is the IBM SPSS Statistics software package, which is a complete set of predictive and data analysis tools, focused on business users, analysts and statistical programmers (IBM SPSS Statistics Family, 2015). There are commercial

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versions, as well as student versions for learning. The Excel spreadsheet program was used to generate the statistical graphs.

The dimensions proposed for the analysis of performance measure different aspects that affect the final result, however, they contain different measurement units, to consolidate the data obtained from the tests, in this case the statistical means of each dimension, were used the method known as NAIADE (Munda, 2006). NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) is a discrete multi-criteria method, whose impact (or evaluation) matrix can include clear, stochastic or indefinite measures of the performance of an alternative with respect to the evaluation criterion, therefore this method is very flexible for real world applications. NAIADE has been created and developed in several versions by Professor Giuseppe Munda (Falconí & Burbano, 2004).

For the implementation of the tests, the Proxmox VE hypervisor was used, which is a complete open source platform for enterprise virtualization. With the integrated web interface, you can easily manage virtual machines and containers, software-defined storage and connectivity, high-availability clustering, and multiple out-of-the-box tools in a single solution (Proxmox Server Solutions GmbH, 2004-2017), plus you can get data on the performance, percentage of RAM used, CPU, processing speed, network traffic of the instances, which allowed obtaining indicators for the investigation.

Scenery

To carry out the solution, the following scenario is proposed, applied in the installation of the OpenStack and CloudStack platforms (see table 2).

Table 2

Server Hardware

Virtualization platform	Proxmox VE 4.2-2
RAM	78..63GB
CPU	12 x Intel(R) Xeon(E) CPU E5-2620 2GHz (1 Socket)
HDD	300GB

For the implementation of the test scenario, it was carried out on a Proxmox VE server in which the OpenStack and CloudStack platforms were installed in a nested way, as well as the server for monitoring the use of resources, whose arrangement is seen in the figure. 3.

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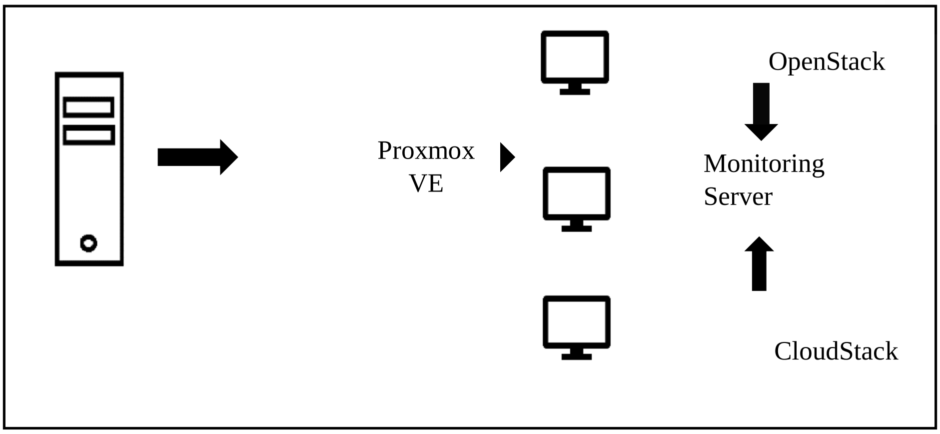
Figure 3

Test deployment scenario



The hardware of the virtual machines for each platform, as well as the server used for monitoring, are detailed in tables 3 and 4.

Table 3

Virtualized hardware for Openstack and Cloudstack

OS	Ubuntu 15.04
RAM	15GB
CPU	8 CPUs
HDD	150GB

Board4

Virtualized monitoring server hardware

Tool	Nagios3, Cacti
OS	Ubuntu 15.04
RAM	2GB
CPU	4 CPUs
HDD	15GB

The implementation architecture for each platform was used the so-called "All in One", which can be seen in figures 4 and 5.

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Figure 4

Cloudstack All-in-One Architecture

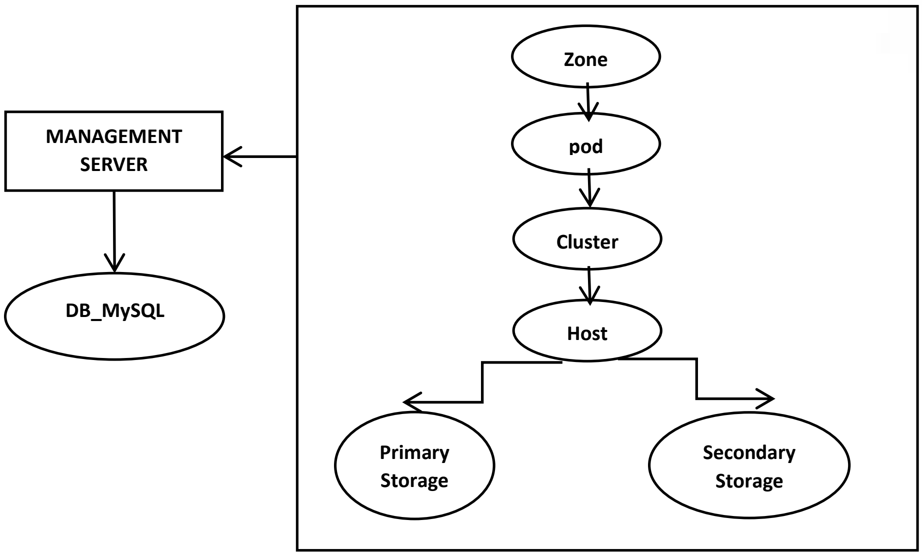
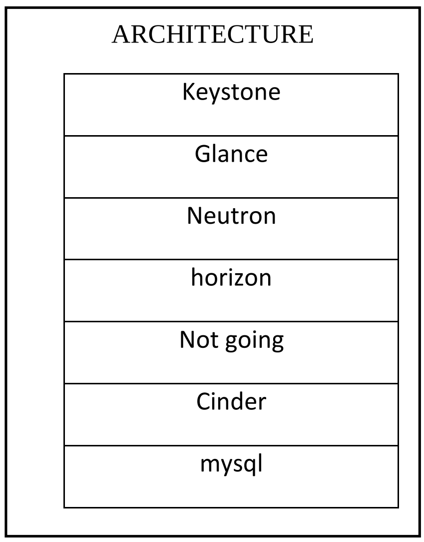


Figure 5

Opencloud "All in One" Architecture



Results

Relevant results are highlighted without incurring repetitions of information.

This section shows the results of evaluating the performance of each platform in each of its dimensions such as response time, processing time and resource consumption.

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Dimension Response time

With the Shapiro-Wilk normality tests, it is observed that with a significance level of 0.00 for both OpenStack and CloudStack, the data are not normal, as seen in Table 5.

Table 5

Response time data normality test

	Shapiro-Wilk		
	Statistical	gl	Next.
OpenStack	.848	35	,000
CloudStac k	.847	35	,000

Performing the contrast test, a Mann-Whitney U value of 570 and an asymptotic (bilateral) significance of 0.618 greater than 0.5 is observed, therefore, it is evident that there is NO significant difference in response time between both. platforms (see table 6).

Table 6

Response time contrast test

	Response Time (ms)
Mann-Whitney U	570,000
Wilcoxon W	1200,000
Z	-.499
Asymptotic sig. (bilateral)	.618

Dimension Processing time

For the dimension of processing time, the following tasks have been carried out: creating, deleting, shutting down, turning on, restarting, suspending, resuming, blocking, unlocking, snapshot and entering the console of an instance, for each task the The normality of the data was analyzed using the Shapiro-Wilk test, where as a result it was obtained that the data are not normal in all test cases as seen in table 7.

Table 7

Processing time normality tests

	Guy	Shapiro-Wilk Statistical	gl	Next.
Proc. Time Creation (ms)	OpenStack	0.931	35	0.03
	CloudStack	0.927	35	0.022
Proc. Time Elimination (ms)	OpenStack	0.811	35	0
	CloudStack	0.694	35	0
Proc. Time Snapshot (ms)	OpenStack	0.495	35	0
	CloudStack	0.696	35	0
Proc. Time Start (ms)	OpenStack	0.639	35	0
	CloudStack	0.582	35	0
Proc. Time Shut down (ms)	OpenStack	0.627	35	0
	CloudStack	0.854	35	0
Proc. Time Restart (ms)	OpenStack	0.74	35	0
	CloudStack	0.673	35	0
Proc. Time Suspend (ms)	OpenStack	0.855	35	0
	CloudStack	0.87	35	0.001
Proc. Time Resume (ms)	OpenStack	0.855	35	0
	CloudStack	0.698	35	0
Proc. Time Block (ms)	OpenStack	0.326	35	0
	CloudStack	0.635	35	0
Proc. Time Unlock (ms)	OpenStack	0.937	35	0.046
	CloudStack	0.634	35	0
Proc. Time Income (ms)	OpenStack	0.625	35	0
	CloudStack	0.705	35	0

Next, we proceed with the analysis of the data by applying the Mann-Whitney U test, where it is observed in Table 8 that the level of asymptotic significance is less than 0.05 in all cases, therefore the null hypothesis is accepted. , which establishes that there is a significant difference between the platforms in each of the tasks carried out.

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Table 8

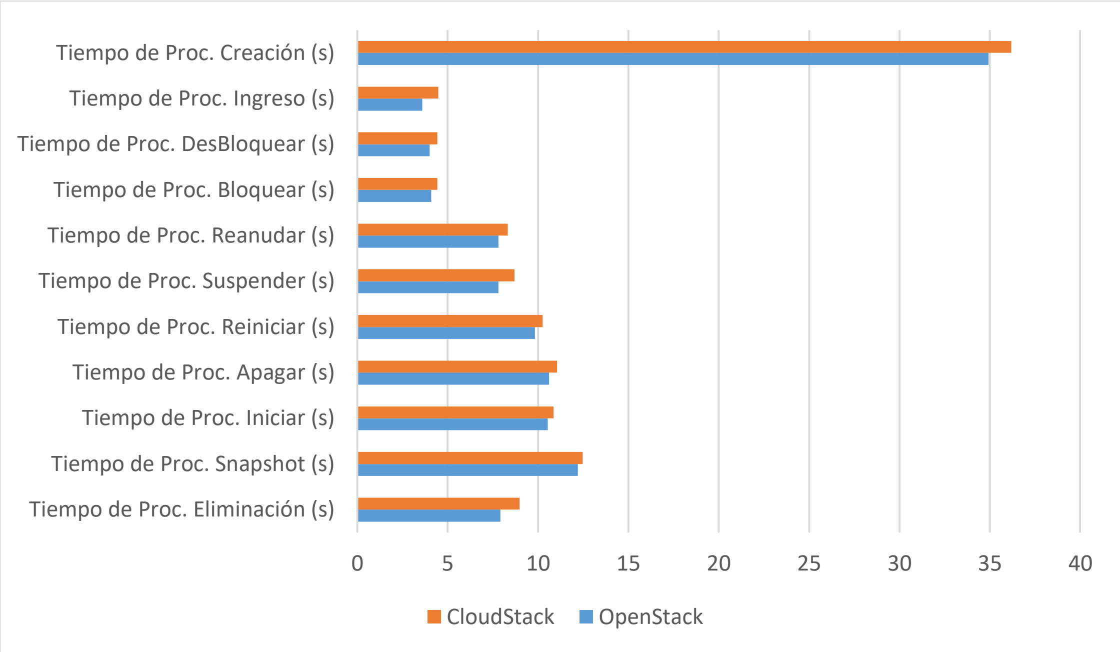
Processing time contrast test

	Mann-Whitney U	Wilcoxon W	Z	Asymptotic sig. (bilateral)
Proc. Time Creation (ms)	440	1070	-2,027	0.043
Proc. Time Elimination (ms)	83.5	713.5	-6,225	0
Proc. Time Snapshot (ms)	436.5	1066.5	-2,081	0.037
Proc. Time Start (ms)	355.5	985.5	-3,028	0.002
Proc. Time Shut down (ms)	407	1037	-2,426	0.015
Proc. Time Restart (ms)	394.5	1024.5	-2,571	0.01
Proc. Time Suspend (ms)	265.5	895.5	-4,085	0
Proc. Time Resume (ms)	372.5	1002.5	-2,827	0.005
Proc. Time Block (ms)	414	1044	-2.34	0.019
Proc. Time Unlock (ms)	357.5	987.5	-3,013	0.003
Proc. Time Income (ms)	121.5	751.5	-5,835	0

Figure 6 shows the comparison of the statistical means of each task of the Processing Time dimension, in which it is observed that OpenStack obtains better performance since it requires less time in seconds to execute the tasks.

Figure 6

Comparison of means of processing time per task



Consolidating the processing time data, an analysis of all the tasks is carried out, proceeding to the normality test, as in this case the amount of data exceeds 50 tests, so the Kolmogorov-Smirnov formula is used, where evidence with a significance level of 0, that the data does NOT have a normal distribution as seen in table 9.

Table 9

Processing Time Normality Test

		Kolmogorov-Smirnova		
Platform Type		Statistical	gl	Next.
Processing Time (ms.)	OpenStack	.310	385	,000
	CloudStack	,317	385	,000

Performing the contrast test, it is observed that the asymptotic significance value is less than 0.05, therefore it is evident that there IS a significant difference in terms of processing time between the two platforms for the study, which corroborates the previous analysis with each task of the processing time dimension (see table 10).

Table 10

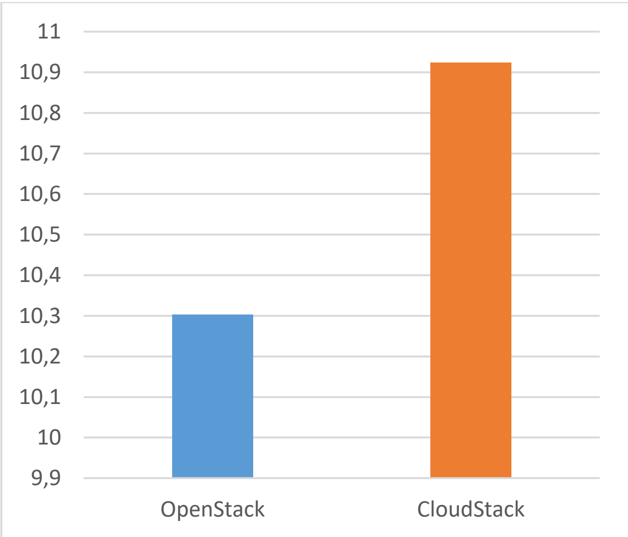
Processing time consolidation contrast test

		Processing Time (ms.)
Maximum extreme differences	Absolute	,117
	Positive	,117
	Negative	0.000
Kolmogorov-Smirnov Z		1,622
Asymptotic sig. (bilateral)		.010

Figure 7 shows the comparison of the processing time between the two platforms, where OpeStack obtains better performance by requiring an average of 10.3 seconds, compared to CloudStack's 10.9 seconds to complete the tasks.

Figure 7

Processing time comparison



Resource Consumption Dimension

For the resource consumption dimension, it has been divided into 4 indicators:

- RAM memory usage, expressed in Giga Bytes of use.
- CPU usage, expressed as a percentage of utilization.
- Disk Reading, expressed Kilo Bytes of use and,

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- Incoming and outgoing network traffic expressed in Kilo Bytes.

To collect the data for each indicator, the Proxmox performance console was used as seen in Figure 8, 9, 10 and 11.

Table 8

Performance Console (RAM Usage)

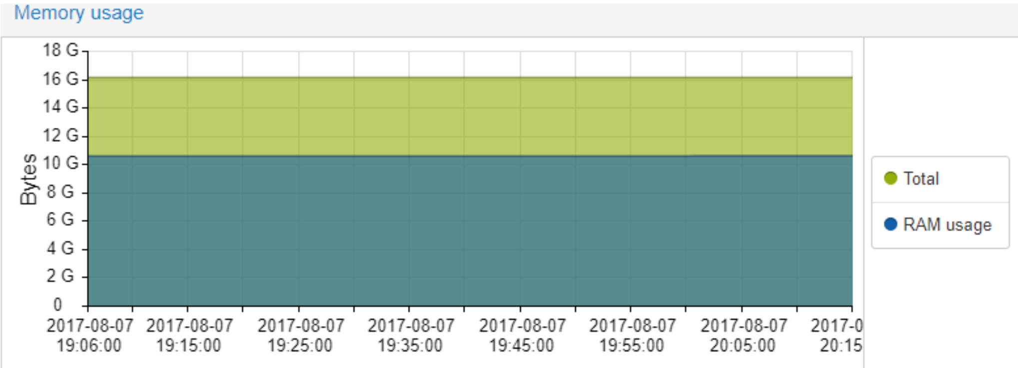

Figure 9

Performance Console (CPU Usage)

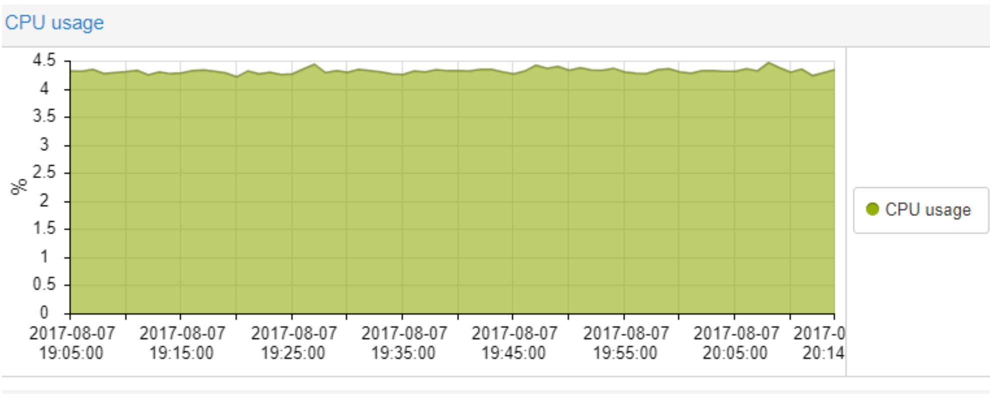

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Figure 10

Performance Console (Disk Read)

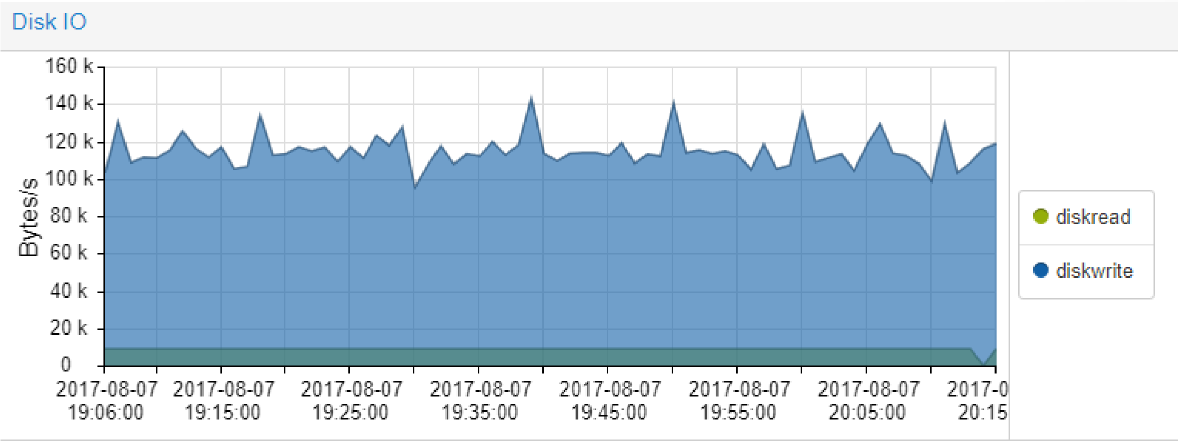


Figure 11

Performance Console (Network Traffic)

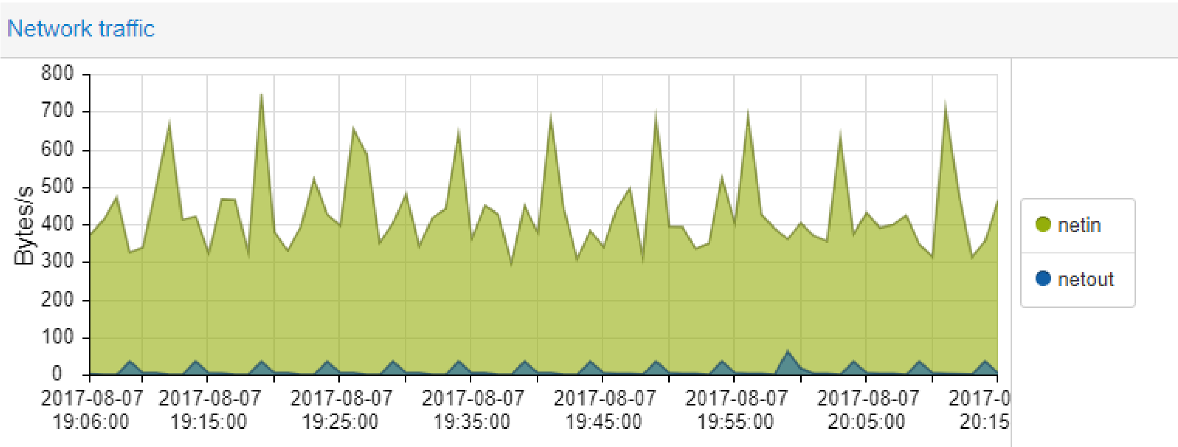


Table 11 shows the results of the normality tests for each indicator, where it is evident that only the data from the "Disk Reading" indicator (on both platforms) and "Incoming Network Traffic" of Cloud Stack show normal behavior. , therefore for the contrast analysis of the RAM, CPU and Network Traffic indicators the Man-Whitney U test was used while for Disk Reading the t test was used.

Table 11

Resource consumption data normality test

Guy		Shapiro-Wilk Statistical	gl	Next.
RAM	OpenStack	.780	35	,000
	CloudStack	.928	35	.024
CPU	OpenStack	.205	35	,000
	CloudStack	.305	35	,000
DISK	OpenStack	.964	35	.293
	CloudStack	.965	35	,314
Incoming Network Traffic	OpenStack	.915	35	.010
	CloudStack	.948	35	.098
Outbound Network Traffic	OpenStack	.511	35	,000
	CloudStack	.580	35	,000

Table 12 shows the results of the contrast tests for the non-normal data corresponding to the use of RAM, CPU and Network Traffic (Incoming and Outgoing), where it is evident that the level of significance for both RAM, CPU and Outgoing Traffic is less than 0.05, therefore, there IS a significant difference, while for Incoming Traffic the value is 0.391 greater than 0.05, therefore there is NO significant difference between the platforms.

Table 11

Contrast tests of the RAM Memory Usage, CPU Usage and Network Traffic subdimensions

	RAM	CPU	Incoming Network Traffic	Outbound Network Traffic
Mann-Whitney U	389,500	306,500	539,500	310,500
Wilcoxon W	1019,500	936,500	1169,500	940,500
Z	-2,627	-3,600	-.858	-3,567
Asymptotic sig. (bilateral)	.009	,000	,391	,000

Figure 11 shows the comparisons of the statistical means of the indicators where if there is a significant difference, such as the cases of RAM Usage, CPU and Outgoing Traffic, it is observed that in the same way OpenStack has a slight advantage by requiring less amount of resources to carry out the work.

Figure 11

Comparison of the statistical means of the dimensions with a significant difference

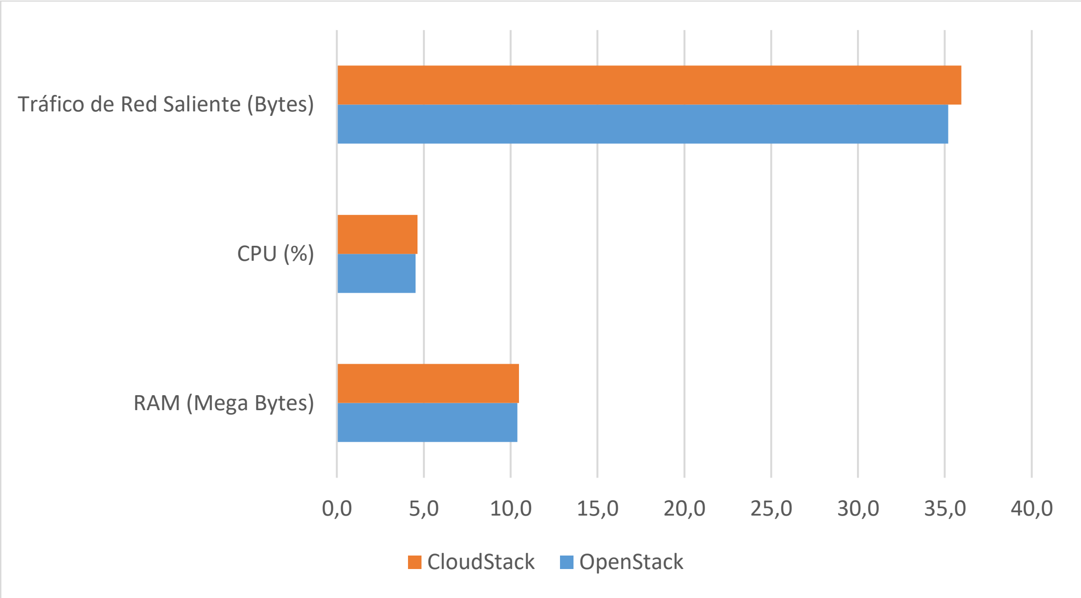


Table 13 shows the results of the contrast test of the normal data corresponding to the Disk Reading, using the t test a significance level of 0.186 is obtained, whose value is greater than 0.05, which shows that there is no a significant difference between the platforms in this dimension.

Table 12

Contrast test of the Disk Reading subdimension

	Sum of squares	gl	mean square	F	Next.
Between groups	107,409	1	107,409	1,788	.186
Within groups	4084,206	68	60,062		
Total	4191,615	69			

Effectiveness Dimension

For the effectiveness dimension, tasks carried out without errors were taken into account, which were completed satisfactorily on both platforms.

Consolidated data

Once the results of the analysis of all dimensions have been obtained, the table of statistical means for each dimension is obtained as seen in table 14.

Table 13

Impact Matrix of Multicriteria Analysis with NAIADE

Dimensions and Variables	Unit of measurement	Guy	Aim	OpenStack	CloudStack
Response time	Milliseconds	Quantitative	Minimize	467.74	473
Processing Time	Milliseconds	Quantitative	Minimize	10303.1	10923.8
RAM Usage	MegaBytes	Quantitative	Minimize	10.3817	10.4751
%CPU Usage	Percentage	Quantitative	Minimize	4.5206	4.6449
Disk Reading	Kilobytes	Quantitative	Minimize	123,639	126,117
Incoming Network Traffic	Kilobytes	Quantitative	Minimize	2.5657	2,606
Outgoing Network Traffic	Kilobytes	Quantitative	Minimize	35.2003	35.9477

Applying the percentage variation formula (Formula 1) specified in section 3.4 (Processing and Analysis), table 15 is obtained with the consolidated data where the percentage difference is shown in the cases where there was a significant difference, such as: the processing, and resource consumption (RAM memory utilization, CPU utilization and Output Traffic).

Table 15

Consolidated data from the analysis of the dimensions.

Dimension	Significant difference	Best Platform	Percentage difference
Response time	NO	-	-
Processing time	YEAH	OpenStack	5.68%
Resource Consumption: RAM	YEAH	OpenStack	0.89%
Resource Consumption: CPU	YEAH	OpenStack	2.67%
Resource Consumption: Disk Reading	NO	-	-
Resource Consumption: Inbound Network Traffic	NO	-	-
Resource Consumption: Outbound Network Traffic	YEAH	OpenStack	2.07%

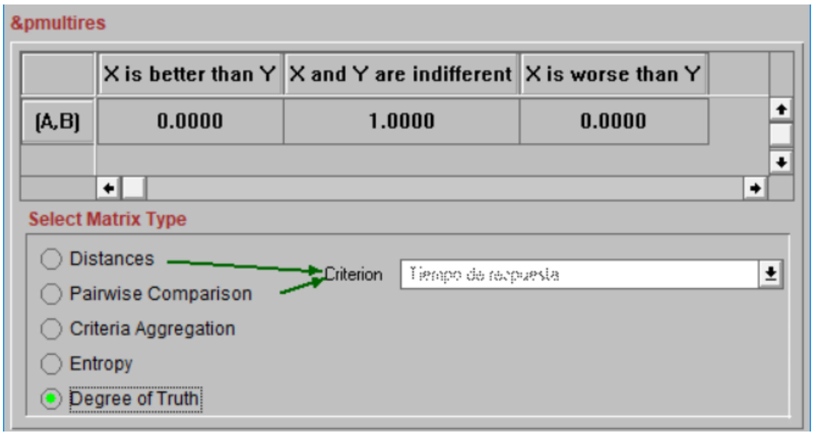
Multicriteria analysis

Additionally, to obtain a general result, multicriteria analysis was used with the NAIADE method proposed by Munda (2006). Table 12 shows the impact matrix with the statistical means obtained for each dimension and indicator which was entered into the program. IT.

As a result of the truth test, it is obtained that, taking into account the different criteria, it is NOT evident that there is a difference between both platforms, as seen in figure 13.

Figure 12

Truth test of Multicriteria analysis with NAIADE



Conclusions

- The OpenStack and CloudStack platforms are currently widely used alternatives for the implementation of iCloud solutions, allowing savings in licensing costs for organizations that require these services.
- Through NAIADE's multi-criteria analysis, it was found that there is no marked difference between the OpenStack and CloudStack platforms in the different criteria, while performing a more detailed and individual statistical analysis for each dimension, it was evident that there is a significant difference in favor of OpenStack. in the dimension of processing time with a 5.68% improvement as well as in the indicators of RAM usage 0.89%, CPU usage 2.67% and Outgoing Network Traffic 2.07%.
- Using nested virtualization allowed us to simulate real scenarios for testing both Openstack and Cloudstack. In the implementation of the Openstack platform using the Separate Node architecture, a better result was obtained in terms of performance compared to the All-in-One architecture.

Conflict of interests

The authors declare that they have no conflict of interest in relation to the article presented.

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