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Benchmarking the Performance of OpenStack and CloudStack

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Abstract— **With the rapid increase of growth and development in cloud computing it is clear to see that it is becoming a common trend within the industry leading to the adoption by businesses and Information Technology (IT) users alike. Coupled with this trend comes a vast amount of academic research into the cloud computing industry covering most aspects but still leaving some untouched. There is, however, a gap in the academic research for this specific area with current studies focusing on very specific performance issues without considering a general overview of performance. This paper demonstrates the importance of understanding the need to benchmark cloud platforms in order to gain a performance overview of the platforms which one may be integrating into a production environment. This paper investigates the performance of two open source cloud platforms, OpenStack and CloudStack. The performance testing is strictly focused on the platforms themselves other than the underlying elements. Therefore, the platforms have both been tested on a mutual hypervisor and mutual available resources. The experiment results demonstrate the advantages of performing cloud management platform benchmarking.**

Keywords—Cloud; Benchmark; OpenStack; CloudStack

I. Introduction

Several sources, including trend reports identified within this study show cloud computing has gained an increased interest over the recent years at a rapid rate. It is, therefore, important to have relevant and meaningful academic research into the many areas of cloud computing which led to this study.

The virtualization paradigm has evolved over time to offer more defined levels both in terms of service and deployment.[1] In line with these changes the platforms of which manage these cloud services have also changed, developed and emerged bringing greater elasticity to the way in which cloud platforms are managed at all levels. Whilst the platforms have evolved with new ones also emerging it is clearly important to have an understanding of the performance of these platforms.

This paper aims to analyse current performance research in relation to cloud computing at varying levels and fill a gap in the research around the specific area of benchmarking the performance of two open source cloud platforms, OpenStack and CloudStack, both of which are products of Citrix however written in different programming languages.

Firstly, in this paper an in-depth literature review was conducted not only to review the previous overlapping studies but also to cover the broader issues, such as the cloud offerings, the available software and subsequently the compatibility of such software with the two platforms in question.

Secondly, having identified the previous studies and their findings, this paper fills the void in the current research by defining the ways in which the cloud platforms can be benchmarked. And several key performance metrics are identified to enable cross comparison of the platforms against these criteria.

Then, in order to evaluate the platforms (i.e. OpenStack and CloudStack), the mutually suitable hypervisors for both platforms are evaluated. Whilst both platforms have a large dependency on the hypervisor of which they run on it is not only important for the hypervisor selection to be mutual for both platforms to ensure fair testing but it is just as important to ensure that the selected hypervisor is evaluated in terms of its standard and industry recognition.

After performed the performance evaluation of the platforms by using a mutual hypervisor against the set of identified criteria, we highlighted some interesting results to make recommendations. This is important to ensure the research has been meaningful and served a purpose not only in terms of simply benchmarking the platforms in question but also helping to identify further improvements.

In general, this study also aims to serve as a base point in order for performance benchmarking to be completed on more platforms. This in turn will help to create a bigger picture in relation to the performance benchmarking of a wide variety of platforms which can then be compared against once such research has been conducted.

This paper is structured as follows. In section 2, we present the findings of a comprehensive literature review. We demonstrate the deployment methods of the systems in section 3. In the following section 4, we show the performance evaluation testing results. Section 5 discusses performance trends and suggested improvements. Finally, we conclude in section 6 and highlight aims and objective of the paper outlines the further work.

II. Literature Review

There are many existing lines of research, simulations and performance testing around cloud platforms both in public and private environments.[2, 3] Although this paper specifically evaluates OpenStack and CloudStack, two open source cloud

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computing solutions, there are also many other cloud computing solutions available all of which offer similar solutions with slight varying differences from features and performance all the way to pricing. It is important not to disregard other products and previous research and it is even more important to ensure a firm understanding is in place of previous findings with a critical viewpoint to enable the structure of this research to be the most informative at the time.

A. Platform evaluation studies

In 2011 [4] conducted a study on evaluating open-source cloud computing solutions in which they developed an extensive list of possible criteria for which solutions may be evaluated against. In this study they try and set a standard based on research into the important areas within cloud computing and categorize this list into several main categories which include support, security, network, management, storage and virtualization. Each criterion they have identified fall into one of these categories.

This study is related in some capacity to the one being conducted however it is more of evaluation criteria for the general features of a product versus the performance which this research looks to measure. The criteria were also specifically designed for enterprise deployments, something this project does not have the capacity nor the scope for yet the categories make use for an interesting possible criteria scope in this project.

As with all research there are different avenues which can be taken regarding the analysis of a system. This could be feature analysis all the way through to performance with sub divisions for example performance in a specific scenario vs. overall software performance. A study by [5] investigates a comparison between three open source platforms; Eucalyptus, OpenNebula and Nimbus in which although they test the systems this is purely for the functionality of the features they have to offer. Typically feature sets of software could be pulled from the vendors' literature however they demonstrate the need to testing the flexibility and extent of such features to perform a detailed cross comparison. Features can relate to performance however this still leaves an open gap in research for correlating the features they have identified with the performance of the system. After all, what use is a system with lots of features which performs badly.

Similarly, [6] also perform a comparison of open source cloud platforms but this time the comparison is between Eucalyptus, OpenNebula, Abicloud and Nimbus. Much like [5] this research compares the features of the platforms in generalities such as its intended use, license information, programming language, interoperability, security and the platforms computability to interact with current cloud platform offerings such as Amazon EC2.

It is important to understand that in contrast to other studies such as those mentioned above, the research to be conducted in this project will provide a general overview of performance as oppose to features which will hopefully in turn correlate to future feature/performance related studies. An interesting feature of this study is to consider the base language as a comparison point. If other future studies are conducted on platforms with matching base languages this could serve as a point for correlation to help identify performance trends. Such studies are yet to conclude on a final point and lead into further fields of research.

Interestingly, although for different platforms, both [5] and [6] conclude on their studies outlining the feature differences in platforms they also outline areas for further work from feature improvements through to future studies now they have identified feature differences in the platforms. It is here where we have identified the main gap for a performance related study at a high overview level to bring some academic research into this currently untouched area.

B. Test methodologies

In the above previous test methodologies were identified in the various overlapping studies however when concluding on their effectiveness for this study not only are they unsuited to the way in which this study looks to measure performance but they are also measured against a specific application or application layer as opposed to measuring the performance of a platform. The study by [7] showed the importance of performing the study on the platform you wish to test against as oppose to a similar setup and considering this to be suitable as a scaled solution to the setup you propose your results for. The particular example included a study in which a cluster was tested and considered to be a cloud computing solution.

As with all platforms although there is a reliance on the underlying hardware for performance there also serves a link between the hardware and the software in the way this can affect performance with the kernel code being the interlaying feature between the various layers of software and hardware. Obviously, as with all test methodologies, especially in a comparison situation it is important they are performed on identical hardware with the closest configuration possible.

As well as the configuration of the test bed it is equally as important to consider the way in which to test the platforms to give the general high level performance overview of these two platforms. A study on Virtual Machine Monitors (VMM), a term for a hypervisor, was undertaken by [8] in which they used performance monitoring tools to successfully monitor the behavior of the machines running on the hypervisor. This however gives rise to concern particularly for this study in that the test methodology used primarily analyses the virtual machines performance in relation to the hypervisor as oppose to the platform of which is used to manage the machines. This would not be suitable for this study as it still needs to test the cloud platforms basic tasks such as machine provisioning times, deployment times and deletion times and the effects on the hypervisors performance per se.

The contributions of this paper are not only to fill this gap in the research but also to contribute to providing a benchmarking set of criteria for cloud platforms. This will allow further studies to be conducted on additional platforms helping to further fill this void in the current research area. This coupled with the conclusions drawn from the performance testing of the platforms will give good ground for the importance and understanding of such platforms.

III. Deployments of the Systems

Both OpenStack and CloudStack are deployed and configured as virtual instances using Oracle VM VirtualBox 4.2.10 on a host machine configured with an Intel Core i7-2630QM running with full Virtualization Technology (VT) enabled alongside 8GB DDR3 memory and 700GB of hard drive storage. The choice of VirtualBox to run the platforms was down to both platforms, "Dev" Cloud and Stack, respectively offer system build options for this particular type 2 hosted hypervisor of which our tests will be conducted on.

OpenStack requires a different installation configuration from CloudStack, which is to be expected with them both being different products; however it is required to be installed as a virtual machine (VM) on the XCP hypervisor. To do this the XCP is installed as an instance using Virtual Box and subsequently once this completed the OpenStack could be created as a VM running within it.

To maintain a fair test both system are configured in a single virtual machine in line with the development deployment options for both platforms each will have allocated 4 CPUs and 4GB of RAM with a single file 100GB virtual disk to both virtual machines making the comparison fair. The exact machine specifications will be detailed in the relevant proceeding sections.

The OpenStack deployment has been carried out in keeping with the recommended deployment infrastructure for development and testing purposes. The entire machine resources essentially pool from those of the XCP hypervisor and are distributed according. OpenStack was deployed on top of the XCP hypervisor allowing for this to take place whilst ensuring the mutual hypervisor remained consistent.

Although having a similar architecture the devcloud installation to install the CloudStack development/testing environment follows a more simplified installation process in comparison to OpenStack. The process allows for one partially pre-configured VirtualBox virtual machine file to be downloaded followed by a few subsequent configurations before a fully operational devcloud environment is ready for testing/development purposes.

IV. Performance Evaluation

To perform a fair testing evaluation across the two platforms the tests needed to be run on the same specification virtual machines. OpenStack uses flavors to define machine build specification. The main settings defined within the flavor include the number of CPU's, the amount of RAM and also the hard disk storage space. In CloudStack this is split out slightly differently with the CPU and RAM being allocated under a different flavor to the disk. To make this a fair test the below offerings were created on each platform. The names, tiny, small and medium shown on table 1 and table 2 were maintained in keeping with the default naming of flavors/offerings. All tests were performed twenty times to identify any anomalies when plotting the trends onto graphs.

In the proceeding sections a variety of the flavorings above are used to test both the platforms performance in performing a variety of tasks for different variations of flavors to identify their performance in relation to particular machine specifications and if this has any correlation on the performance of the system.

All deployment and deletion test time tests were times from the moment the cloud platform was instructed to deploy/delete the VM to the moment it was reported in the console as running/deleted. For the CPU performance measurements a command was used to capture the average performance of all cores on the hypervisor. These tests were run following the deployment and deletion tests all of which took no longer than 30 seconds however to ensure a safety net was created the command logged the CPU performance over a period of a minute collecting the data every second and reporting the average.

Table 1 - CPU and memory flavor specifications

CPU and memory flavours			
Name displayed on results	**Cloud Platform Name**	**CPU**	**Memory**
1 CPU, 100MB RAM	tiny	1	100MB
1 CPU, 512MB RAM	small	1	512MB
2 CPU, 1024MB RAM	medium	2	1024MB

Table 2 - hard disk size flavors

Hard disk flavours		
Name displayed on results	**Cloud Platform Name**	**Hard disk**
1GB HDD	tiny	1GB
5GB HDD	small	5GB
20GB HDD	medium	20GB

To ensure fair testing and there being no load on the environments each virtual machine was deleted following the test meaning the no virtual machine were running and the cloud platforms were not managing any instances which would in turn affect the performance.

4.1 Processor/RAM effect on deployment times

With processor and memory specifications varying on machines in any environment, whether that is domestic or commercial in a cloud for example, the specification of the machine will largely depend on its purpose and the requirements of the platform(s) it is required to run. To identify any possible correlation between deployment times and machine specification (processor and memory) this study tested the three machine processor/ram specifications with the same hard disk size.

As shown in Fig. 1 above, although there are some clear differences between the three instances, albeit with a couple of anomalies, it is clear to see that there is a correlation between the processor and memory specifications versus the machine deployment time when a larger number of CPUs are allocated. Although, that being said, the scale is miniscule resulting in the machine deployment time difference only being within a few seconds as the instance specification increases. This shows the possibility of the dependence on available CPUs within the host as to the time taken to deploy the machine as both tests with 1 CPU showed similar correlation although they had varying amounts of memory.

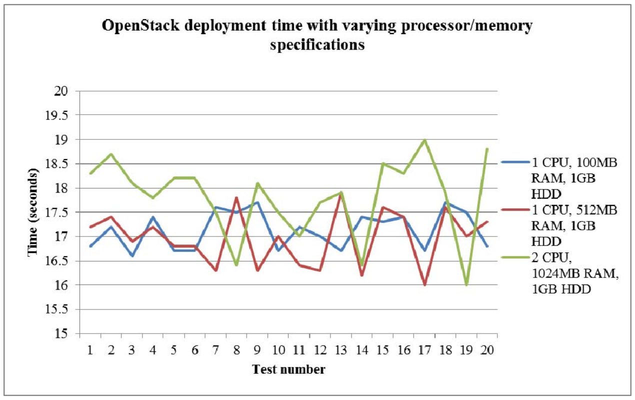

Fig. 1. OpenStack machine deployment times with varying processor and memory specifications

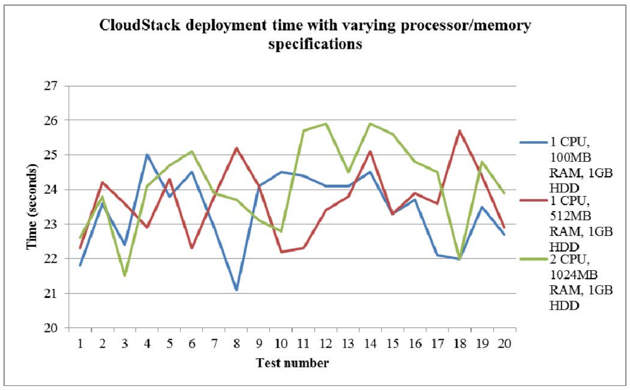

Fig. 2. CloudStack machine deployment times with varying processor and memory specifications

Interestingly, as shown above in Fig. 2 CloudStack shows little to no correlation in processor and memory specifications versus deployment time. It could be said this may be expected with what should only be a quick calculation of required resources versus the available resources therefore explaining the lack of correlation. However, there was some correlation shown on the OpenStack platform.

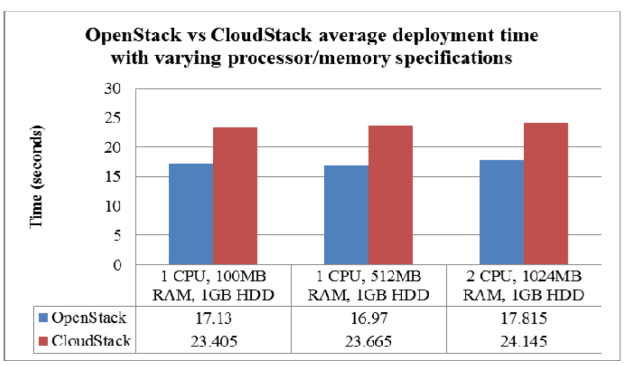

Fig. 3. Average OpenStack and CloudStack machine deployment times with varying processor and memory specifications

Fig. 3 helps to further identify the increasing deployment time in OpenStack as the number of processors increase albeit a difference in milliseconds and taking into account the anomalies there still lies the difference. Across all tests OpenStack shows a more efficient machine deployment time in comparison to CloudStack.

4.2 Processor/RAM effect on deletion times

Having run the above tests in the prior section of this report whilst using the same variable of processor and memory configurations in this section the deletion times can now be tested to see if there is a link between the time taken to delete a virtual instance versus the specification of the instance.

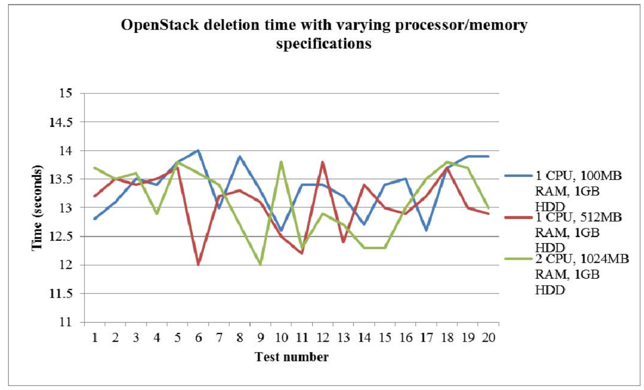

Fig. 4. OpenStack machine deletion times with varying processor and memory specifications

Interestingly, as Fig. 4 shows, there is no correlation between the processor and RAM specification in the time taken to delete the machine on the OpenStack platform. This does not tie inside the correlation demonstrated for deployment times, particularly, with an increased number of processors. The results are all within two seconds of one and other.

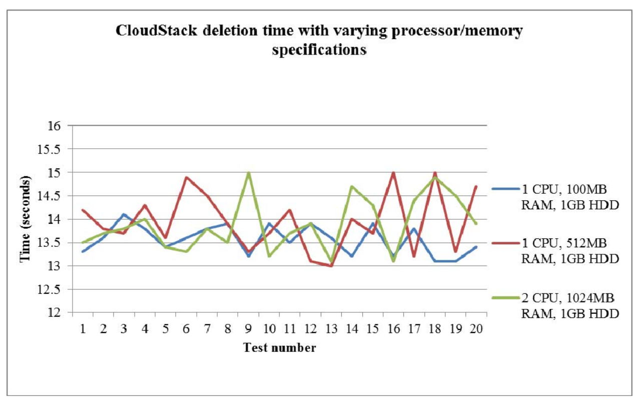

Fig. 5. CloudStack machine deletion times with varying processor and memory specifications

Fig. 5 shows that again CloudStack does not show correlation nor similarity to the performance of the cloud platform in relation to deleting instances of varying specifications. Although all instances are deleted only within a few seconds of one and other, similar to OpenStack, and there are no large outsider anomalies. The fluctuation of the results for all instance sizes demonstrates the lack of correlation between instance specification and deletion time.

In Fig. 6 below, this performance is also evidenced in the averages and it is also clear to see that OpenStack demonstrated faster deletion times across all specification variations in comparison to CloudStack. A similar conclusion to that drawn from the testing in section 4.1.

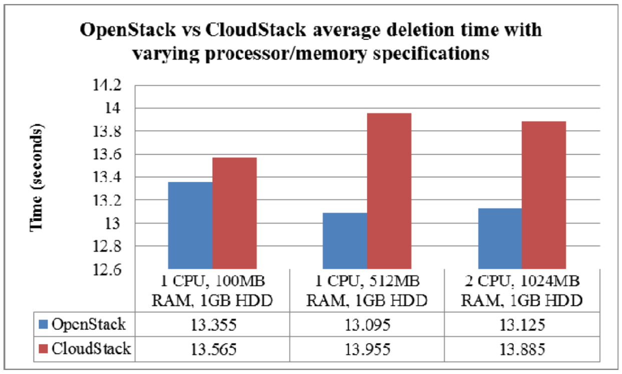

Fig. 6. Average OpenStack and CloudStack machine deletion times with varying processor and memory specifications

4.3 Hard drive size effect on deployment times

Having already discovered some correlation in the previous tests around the effect of processor and memory specifications on certain cloud platform performance tasks, now the effect of hard drive size can be testing in comparison to deployment time.

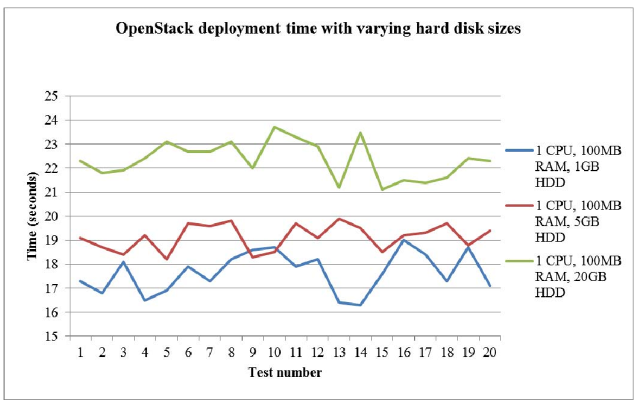

Fig. 7. OpenStack machine deployment times with varying hard disk sizes

Fig. 7 shows OpenStack provides a very strong correlation between the disk size when taking into account the time taken to create the virtual machine instance. There is particularly a noticeable difference as the hard drive size increases from 5GB to 20GB showing the definite increase of deployment time in relation to the hard disk size.

Whilst there is still a correlation with the CloudStack tests as shown above in Fig. 8, it does not demonstrate the relative correlation shown in the same test for OpenStack, particularly the difference in deployment times for the varying hard drive sizes. OpenStack showed a slight increase in deployment time between a 1GB hard disk and a 5GB hard disk whilst showing a greater difference between a 5GB and 15GB hard disk, in relation to the size increase. CloudStack however shows the differences the opposite way round. It is unlikely that all twenty results for the 5GB hard disk are anomalies. That being said the correlation still shows that hard disk size increases deployment time, just not in the relative relation as demonstrated by OpenStack.

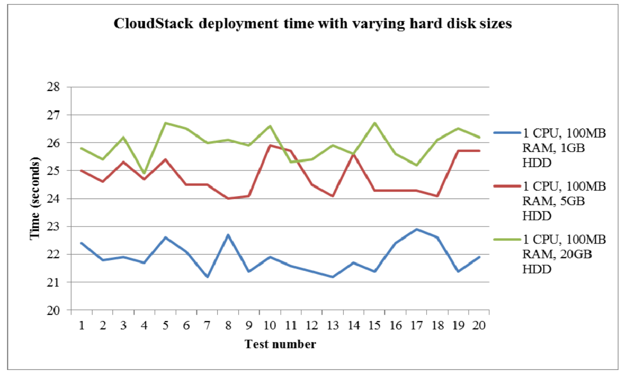

Fig. 8. CloudStack machine deployment times with varying hard disk sizes

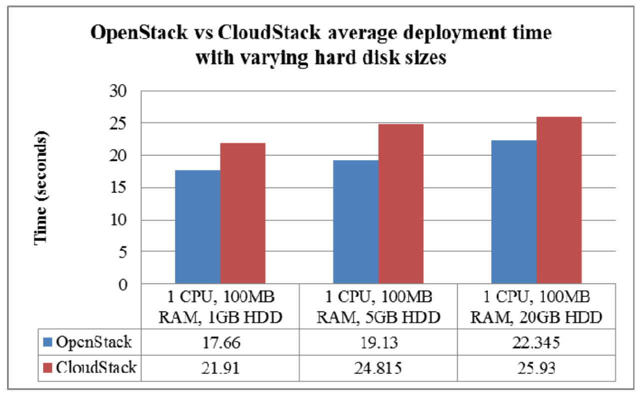

Fig. 9. Average OpenStack and CloudStack machine deployment times with varying hard drive sizes

Fig. 9 shows a clear average performance variation between the two platforms, again with OpenStack performing the better of the two. The first test shows a difference of over 4 seconds between the two platforms which then increases at a similar rate as the hard drive size increases. The two platforms both demonstrate a relation between deployment time and hard drive size unlike the deployment time with varying processor and memory specifications.

4.4 Hard drive size effect on deletion times

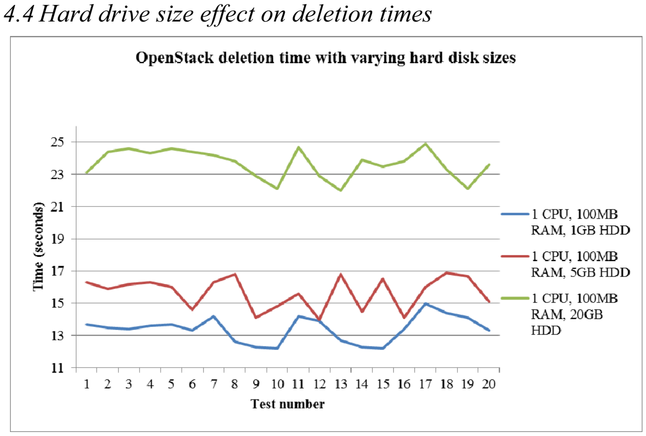

Fig. 10. OpenStack machine deletion times with varying hard disk sizes

Similarly to the processor and memory tests performance tests are run to identify deletion times with varying hard disk sizes. It was clear from the previous set of tests that the hard drive size affected the deployment times.

Fig. 10 below shows the same correlation in deletion time between the disk sizes as it did in deployment time in section 4.3. This not only shows the relative relationship between disk size and deletion times but also that there's a relationship between deployment and deletion with varying hard disk sizes with increased times when a larger hard disk is provisioned. CloudStack deletion times in relation to hard disk size show a stronger and more relative correlation to that of the deployment times identified in the experiment in section 4.3. The results shown in Fig. 11 identify a clear effect on the systems performance as the same processing power for machine deletion takes an extended amount of time which increases as the hard disk size increases.

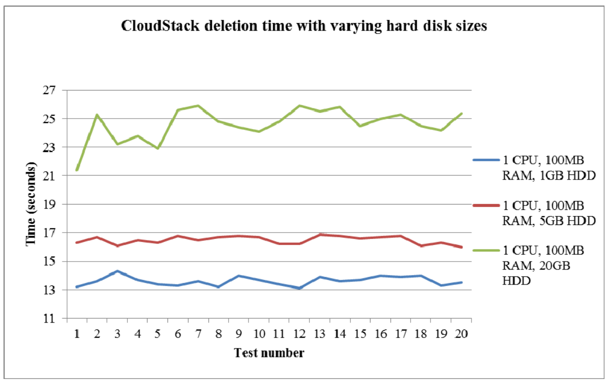

Fig. 11. CloudStack machine deletion times with varying hard disk sizes

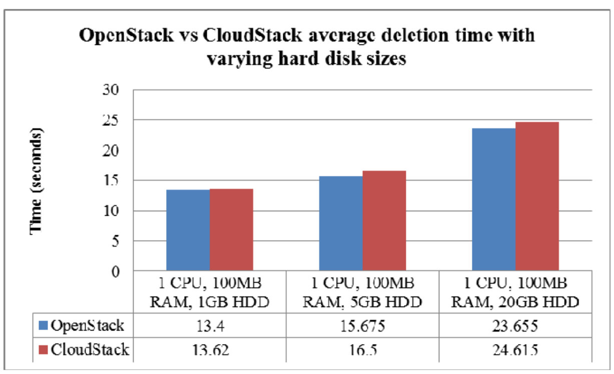

Fig. 12. Average OpenStack and CloudStack machine deletion times with varying hard drive sizes

Again, following the trend that has been identified in the sub section summaries throughout these tests, Fig. 12 demonstrates OpenStack's better performing averages in comparison to CloudStack. This time however, the difference is miniscule and although there is a difference it could also be argued that the platforms perform at similar levels in this particular benchmark test.

4.5 Hard drive size deployment effect on host CPU utilisation

In sections 4.1 through to 4.4 tests were conducted to evaluate the platforms performance in deploying and deleting instances with varying processor/RAM and hard disk configurations. It was clearly evidenced from the results that hard disk configurations are the only variable of the two that demonstrated any performance correlation. Taking this into account in this section and section 4.6 tests are conducted on hard drive size and the effect it places on the average host CPU utilisation. The average was used over a set period of time as it is possible that the deployment process utilises several processes combined for successful deployment and therefore this aggregates the statistics for all processes running on the host which at that particular moment in time will only be all machine deployment processes.

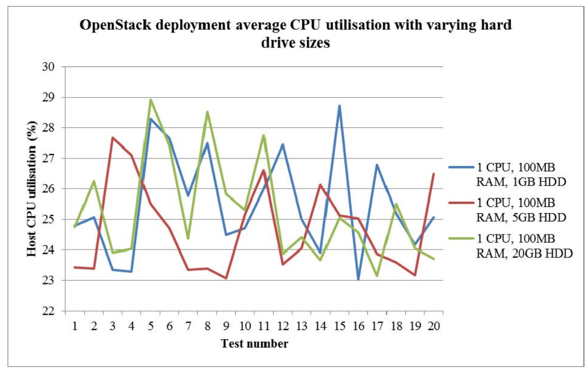

Fig. 13. OpenStack machine deployment average CPU utilisation with varying hard drive sizes

As shown in Fig. 13, there are some clear fluctuations demonstrated on the host performance usage when machines are deployed, none of which are in a relative relation to the machine hard disk size. It is therefore not possible to define any correlation between the hard drive size and host CPU utilisation during deployment for OpenStack. All fluctuations however do fall between 23% and 29% with none going above this which could demonstrate a host CPU limit for machine deployments.

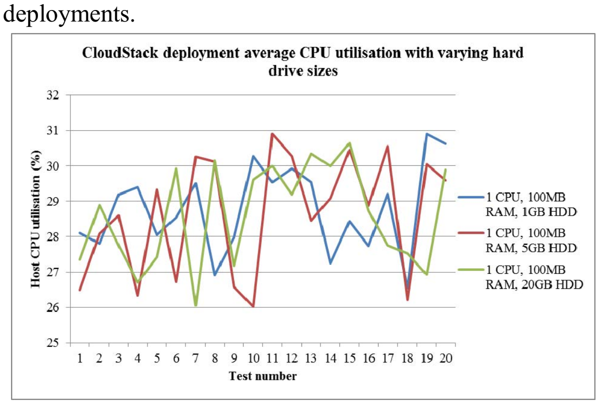

Fig. 14. CloudStack machine deployment average CPU utilisation with varying hard drive sizes

Similarly to OpenStack as shown in Fig. 14, CloudStack also demonstrates no correlation between machines hard disk size and the host CPU utilisation. Results peak and through for all hard disk sizes throughout the tests but with a higher lower and upper boundary of 26% and 31%.

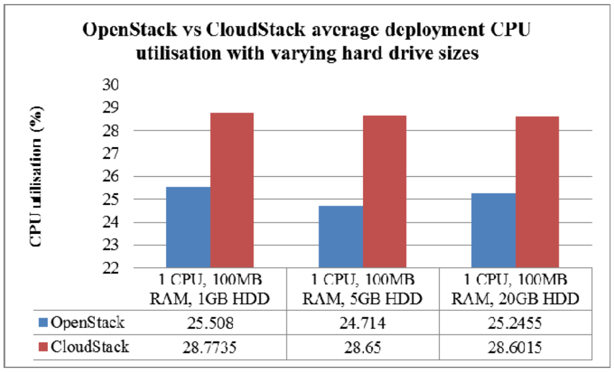

Fig. 15. Average OpenStack and CloudStack machine deployment CPU utilisation with varying hard drive sizes

As the findings in the two previous sections demonstrated, there is no correlation between the hard drive size and the host CPU utilisation during deployment. This is further evidenced by the averages for both platforms as shown in Fig. 15. The averages are all within 1 second of one and other on either platform. Although, the averages here do demonstrate OpenStack's less resource demanding way of deploying machines as also demonstrated it its deployment time tests for both hard drive size and processor and memory configurations in the previous sections.

4.6 Hard drive size deletion effect on host CPU utilisation

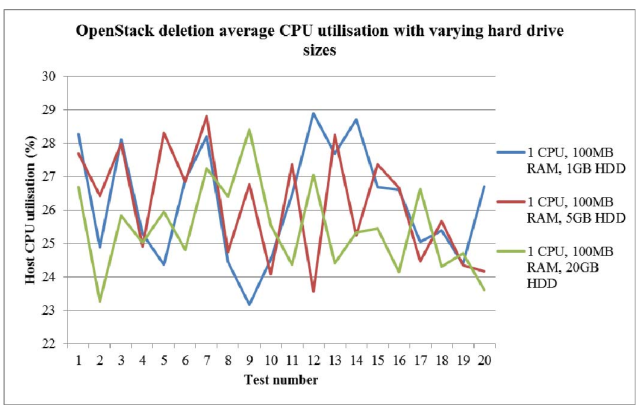

Fig. 16. OpenStack machine deletion average CPU utilisation with varying hard drive sizes

The results for the deletion average CPU utilisation for OpenStack shown in Fig. 16 also show no correlation, similar to that of the deployment tests in the previous section. These results tie in with the previous identified possibility that CPU utilisation may be limited for deployment and also deletion although this is not documented in the platforms online documentation.

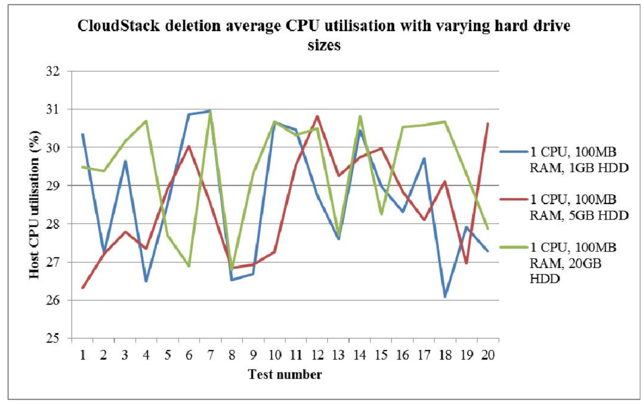

Fig. 17. CloudStack machine deletion average CPU utilisation with varying hard drive sizes

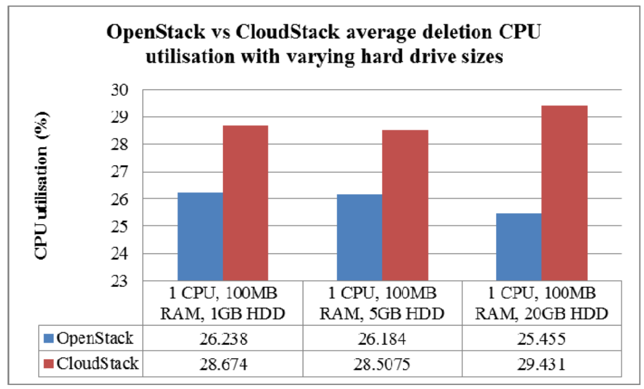

Fig. 18. Average OpenStack and CloudStack machine deletion CPU utilisation with varying hard drive sizes

Again, Fig. 17 shows as expected having previously conducted three other tests of a similar nature, CloudStack has no correlation between the host average CPU utilisation and the hard disk size when completing the management task of deleting a virtual machine instance. All results fluctuate but in a limit of 26% to 31% with no anomalies outside of this range.

Having already summarised throughout these two tests the findings for both platforms are further evidenced in Figure 18. This figure further supports the findings in that there is no distinct variation in average CPU utilisation when deleting virtual machines with varying hard disk sizes.

4.7 Experiement discussions

Having outlined the performance trends in relation to the given scenarios in section 4 and its subsections any identified performance trends and rooms for improvement in the platforms can be outlined, particularly in relation to one and other with no previous similar benchmarking being available for such cloud platforms.

When reviewing the results and identifying the performance of the systems it is crucial to keep in mind the scale of difference between results. Across both platforms and all tests with results having differences between 0.1 and 11.2 seconds the scale on which performance can be measured needs to be reduced. The identified performance against the benchmarks needs to be relative to the variation in the test results.

Generally as an overall consensus it is clear to see that OpenStack offers the best performance out of both the cloud platforms with reduced times taken in the basic tasks one would be undertaking from within the console on a cloud computing management platform. Whilst undertaking the studies it was clear to see that OpenStack had the more basic and less glamorous user interface console of the two platforms however it is unclear if this serves any relation to the enhanced performance it offers in completing tasks. OpenStack also demonstrates a fairly consistent performance even at its increased performance level over CloudStack. With both platforms being developed by Citrix and released under the Apache license it would normally be assumed that there's a fair chance the platforms were developed similarly using the same programming language. However, this is not the case. OpenStack is written in Python whilst CloudStack is written in Java which could help to demonstrate a potential reasoning behind the performance variations.

With the performance testing having identified some areas of improvements for CloudStack it is important that these are fed back for investigation and improvement. With CloudStack being a community driven platform for maintenance and refinements the proposed plan to have these further investigated and possibly implemented in new revisions will be to submit a summary of the findings to the CloudStack community. The CloudStack dedicated Apache web page has a published maintainers guide for different areas and given the areas for which the performance needs to be investigated and software possibly revised it is possible for the results of this study to be submitted to the following: Chiradeep Vittal (Storage/Volumes), Nitin Mehta (Templates) and Rohit Yadav (DevCloud) [9].

The main identified trends outlined in each of the summary subsections in section 4 show that although CPU and memory configurations may increase as machines are deployed these have little to no effect on the deployment and deletion times on both platforms. Hard drive size however is where both platforms performance show a clear relationship in terms of the time taken to complete the task in relation to the size of the hard disk. As the hard disk size increases, so does the time taken to complete the task.

OpenStack demonstrated a more relative correlation to the size of the increase leading to a relative increase in time taken also. CloudStack on the other hand, although time taken increased with the increased size of hard disk it did not always increase at a relative rate to the hard drive size increase. In addition to this the project has now opened up further avenues of research particular around ways for improving the CloudStack platforms performance in the areas identified and also in benchmarking performance of other cloud platforms.

V. Conclusion and Further Work

This paper has examined the performance variations between the two cloud platforms, OpenStack and CloudStack. Through the study it can be clearly identified that the performance of OpenStack supersedes that of CloudStack when measured against the benchmark criteria. This is evidenced and summarised throughout the tests performed in the paper where not only did OpenStack perform tasks in less time than that of CloudStack on all tasks it also showed more relative correlation in its results, particularly relating to hard disk sizes. By doing this, the study has successfully fulfilled the original aim in benchmarking the two open source cloud platforms.

There are many future studies which can now follow from this study. These studies however are not limited to strictly testing more platforms against the same criteria. Having identified the limitations of the testing environment this could also lead to repeating this study in a real world data centre environment to identify any possible differences in results creating correlation links between the development and production platforms. Future work could also help contribute to an increased range of benchmarking criteria and a definitive selection for all future studies creating a solid set of testing criteria allowing for relative comparisons between a range of cloud management platforms.

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