Virtual Machine Performance Comparison of Public IaaS Providers in China

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Abstract — **We compare the virtual machine (VM) performance of two public IaaS providers in China (GrandCloud and Aliyun). UnixBench and Hadoop wordcount are utilized to provide benchmark data for the comparison. It is found that VM specifications such as the number of CPU cores and the amount of memory can no longer be used as reference for VM performance. In both UnixBench and Hadoop wordcount tests, as the VM gets bigger, the performance / price ratio gets lower. In Hadoop wordcount tests, a cluster with several smaller VM's provides much better performance as performance / price ratio as compared to a bigger VM. It is recommended to practice horizontal scaling when an application needs more computing resource.**

Public IaaS, Aliyun, GrandCloud, performance comparison, UnixBench, Hadoop wordcount, vertical scaling, horizontal scaling

I. INTRODUCTION

IaaS, as defined by NIST [1], refers to the capability provided to the consumer to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. In the United States, Amazon EC2 and Amazon S3 are widely recognized as examples of public IaaS. In China, public IaaS is a relatively new business. Aliyun unveil it public IaaS service in October 2011. GrandCloud started invitation-based beta in July 2011, and went into public service in March 2012. All three major telecommunication carriers - China Telecom, China Mobile, and China Unicom – have announced plans to provide public IaaS services, but have not make much progress except for the announcements. Several others, including traditional IDC and CDN service providers, and cloud computing startups, are entering the public IaaS business. However, most of these new comers are still in an early phase to be included in this study.

End users of public IaaS services are often concerned about the performance of their VM's. With a specific benchmark method, the performance of a physical server can be estimated to a certain accuracy given the server specifications such as the model and number of CPU, the type and amount of memory, and the type of hard disks. Similar estimations are no longer valid for VM's acquired from public IaaS providers. This is because (1) information such as CPU model and memory type is often shadowed by the underlying hypervisor, (2) VM's in the same cluster compete for computing resources, which results in different VM performance under different cluster work load scenarios, and (3) public IaaS providers often use over-commit technologies (over-commit refers to the practice of committing more virtual resources to customers than the actual resources available on the underlying physical cluster) to increase VM density, which means higher profit for investors.

When an IaaS service provider practices over-commit, the over-commit parameters are usually unknown to the end user. When an end user creates a VM with 1 vCPU (virtual CPU), the CPU usage limit set for that particular VM might be 1, 0.5 or even 0.1 of the physical processor core. Similarly, a host server with 16 GB physical memory may be committing 24 GB or even 32 GB virtual memory to VM's. In a private IaaS environment, system administrators can categorize VM's according to their resource consumption pattern. When the resource consumption pattern is known to the system administrator, over-commit parameters can be carefully designed to achieve a balance between VM density and performance. The same practice can not be applied in a public IaaS environment, because the service provider has only very limited (if any) knowledge regarding the applications running on the VM's. Therefore, it is reasonable for public IaaS end users to be concerned about their VM performance.

To understand the VM performance of Aliyun and GrandCloud, this paper carries out a set of benchmark tests using UnixBench and Hadoop wordcount. Based on the test data, we calculate the price/performance ratios of the VM's, which can be used as references for end users in selecting the appropriate VM product for their own applications.

II. EXPERIMENT DESCRIPTION

A. Virtual Machines

Both Aliyun and GrandCloud allow end users to purchase VM instances through their websites with a registered account. Similar to Amazon EC2, VM's are offered in the form of standardized products with predefined configurations such as the number of CPU cores and the amount of memory. TABLE I provides a list of the VM products available through Aliyun and GrandCloud, along with their specifications and monthly prices. It should be noted that a specific VM product might be available from only one vendor. When a product is not available from a specific vendor, its monthly price is left as blank in the table. Furthermore, the original product names (in

Chinese) are replaced with alphabetic labels in this paper. For the convenience of this discussion, we call VM's with lower configurations (less CPU and memory) smaller VM's, while VM's with higher configurations (more CPU and memory) bigger VM's.

TABLE I. VIRTUAL MACHINE SPECIFICATIONS

Model	Virtual Machine Specifications			
	CPU Cores	*Memory (GB)*	*Aliyun Price (RMB)*	*GrandCloud Price (RMB)*
VM-A	1	0.5	99	34.75
VM-B	1	1.0		69.5
VM-C	1	1.5	199	
VM-D	1	2.0		139
VM-E	2	1.5	399	
VM-F	2	2.5	559	
VM-G	2	4.0		278
VM-H	4	4.0	899	
VM-I	4	8.0	1329	556
VM-J	8	16.0	1999	1112

Both Aliyun and GrandCloud use XEN as the underlying hypervisor. Based on the information obtained from within the VM's, we know that Aliyun is using a combination of Intel Xeon E5620 and Intel Xeon E5645, while GrandCloud is using AMD Opteron 6172. TABLE II provides detailed CPU property information including clock speed, the number of cores, the number of threads, as well as CPU benchmark data available publicly [2].

TABLE II. CPU PROPERTIES

CPU Model	CPU Properties				
	Clock Speed	*Cores*	*Threads*	*Passmark*	*Passmark / Thread*
Xeon E5620	2.4 GHz	4	8	4693	586
Xeon E5645	2.4 GHz	6	12	7784	648
Opteron 6172	2.1 GHz	12	12	6906	576

For both Aliyun and GrandCloud, the architecture of the backend physical cluster is unknown to the end user, and should be considered as a black box. To determine whether Aliyun and GrandCloud are practicing over-commit, a private IaaS cluster is established in our lab to provide reference data. The reference cluster uses Intel Xeon E5620 CPU, with Gigabyte Ethernet connections between all the physical servers, and a 8-Gigabyte fiber channel connection to the backend storage. The host operating system being used is Ubuntu 11.04 AMD64 Server Edition; while KVM is used as the underlying hypervisor.

VM instances from Aliyun are running Ubuntu 10.10 AMD64. VM instances from GrandCloud and the reference IaaS cluster are running Ubuntu 10.04 AMD64. Separate experiments on standalone physical servers indicate that the results of both benchmark methods being used in this study are very close on these two operating systems.

For each particular VM configuration, three VM instances are created. Among the above-mentioned three instances, we only report and discuss data obtained from the instance with the best performance.

B. UnixBench

UnixBench [3] is a benchmark suite that can be used to evaluate the overall performance of Unix-like systems. The original version of UnixBench was developed in 1983 at Monash University. Afterwards it was updated and revised by many people over the years. In this study we used the version "byte-unixbench" available from the Google Code website.

In the UnixBench benchmark suite, several different tests are carried out to evaluate the performance of the system. Based on the scores of the above-mentioned different tests, a system level score (System Benchmarks Index Score) is calculated. In this study, we use this system level score to compare the performance of different VM instances.

C. Hadoop wordcount

The Apache Hadoop project [4] provides a set of open-source software for scalable distributed computing. Nowadays Hadoop is commonly used to process large data sets across clusters of computers. In this study we use the wordcount application that is included in the official distribution as a benchmark tool. This application traverses through all the files in a specific directory on HDFS, counts the number of different words and the number of instances they appear in the files. When the total size of the files is big enough, the computation becomes both IO-intensive and CPU-intensive, which results in heavy work load on the system. Therefore, Hadoop wordcount is a very good simulation of a heavily loaded user application.

In this study we use a directory with three files as the input. The size of each file is about 600~700 MB, and the total size of the three files is 2 GB. During the test we run Hadoop wordcount against the above-mentioned directory, and record the time needed to complete the counting. Then we calculate the size of data that can be processed per second (2048 MB divided by the time needed to complete the counting, MB/s), which is used to represent the performance of the system being tested.

D. Test Procedures

For both the UnixBench and Hadoop wordcount tests, the test programs are executed on the VM being tested for 10 times, and the average number is taken as the test result. On average, a UnixBench test run takes about 60 minutes, while a Hadoop wordcount test run takes about 20 minutes. The waiting time between each test run varies from 1 to 2 hours. Therefore the test result represents the average performance through out the day.

To avoid performance impact introduced by the tests themselves, the tests are executed on different VM's one by one. That's, none of the tests are running on two different VM's simultaneously.

III. RESULTS AND DISCUSSIONS

A. *UnixBench*

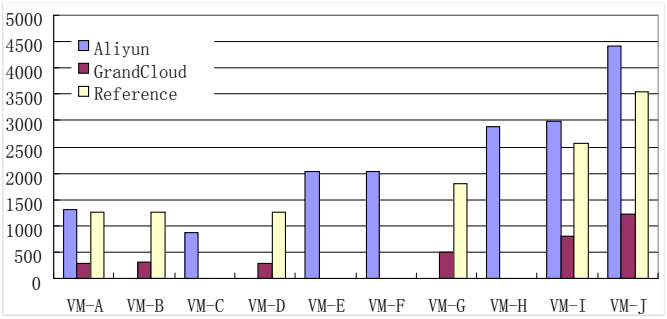

Figure 1. UnixBench Testing Results

Figure 1 shows the results obtained from UnixBench tests. For VM's from the same public IaaS provider, as the VM gets bigger, the performance gets better. For VM's with the same number of CPU cores, their testing results are approximately on the same level, while the amount of memory does not have much impact on the testing result. When the number of CPU cores doubles, the performance increases by approximately 50%.

According to TABLE II, the per-thread performance of Aliyun's CPU is at the same level as the reference private IaaS. The UnixBench testing results show the same trend, therefore it is difficult to determine whether Aliyun is practicing over-commit. The per-thread performance of GrandCloud's CPU is only slightly lower than the reference private IaaS. However, GrandCloud's VM performance is much worse than VM of the same size from the reference private IaaS. This indicates that GrandCloud is probably practicing a significant degree of over-commit.

It should be noted that for Aliyun the performance of VM-C (for all three VM instances) is worse than VM-A, while VM-C is better configured (with 1GB more memory) and priced higher (with 100 RMB more) than VM-A. Further investigation into the issue shows that VM-A is running on Xeon E5645 (the better CPU), while VM-C is running on Xeon E5620 (the worse CPU). This can be considered as a problem in Aliyun's product design, and should be avoid in public IaaS services.

Figure 2 shows the calculated performance / price ratio with UnixBench test results. For VM's from the same public IaaS provider, as the VM gets bigger, the performance / price ratio gets lower.

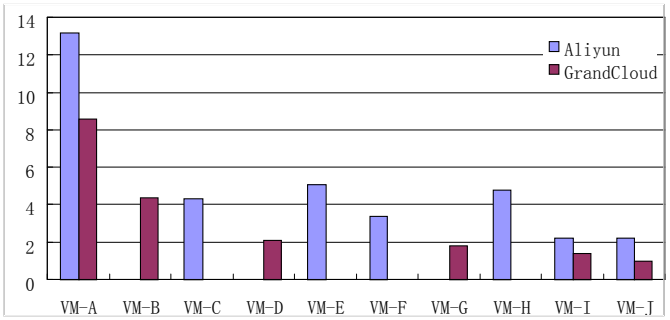

Figure 2. UnixBench Performance / Price Ratio

B. *Hadoop wordcount*

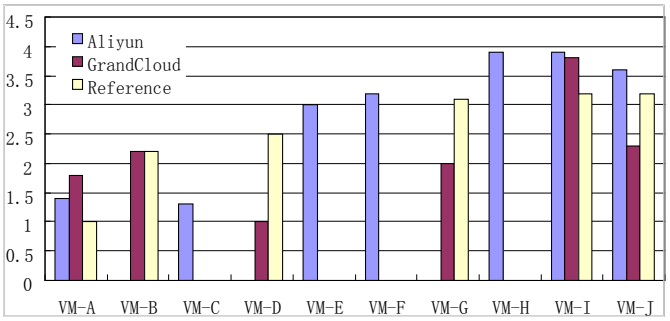

Figure 3. Hadoop wordcount Testing Results

Figure 3 shows the results obtained from Hadoop wordcount tests. For VM's from the reference private IaaS, as the VM gets bigger, the performance gets better with no exceptions. For VM's from Aliyun, as the VM gets bigger, the performance gets better, with the exception of VM-C and VM-J. For VM's from GrandCloud, the performance seems to be irrelevant to the VM configuration. This suggests that GrandCloud might be experiencing serious performance deterioration due to significant degree of over-commit.

It should be noted that for both Aliyun and the reference private IaaS, the Hadoop wordcount performance seems to be converging as the VM gets bigger. In particular, the performance of VM-G, VM-I and VM-J from the reference private IaaS environment are on the same level. Similarly, the performance of VM-H, VM-I and VM-J from Aliyun are on the same level. This is because the Hadoop wordcount application is both CPU-intensive and IO-intensive. As the VM gets bigger, the pressure on CPU gets released, and disk IO becomes the bottom neck. Since all VM's in a particular IaaS environment share the same architecture, it is reasonable to assume that their disk IO performance are on the same level, which lead to similar Hadoop wordcount performance for all bigger VM's.

The root cause for the two exceptions (VM-C and VM-J) in Aliyun tests is that VM-C and VM-J are running on Xeon E5620, while other VM's are running on Xeon E5645 (the better CPU). Considering the fact that VM-J (8 CPU cores and 16 GB memory) is twice the size of VM-I (4 CPU cores and 8 GB memory), and its price is also 50% higher, such level of performance would be very unsatisfactory for public IaaS end users.

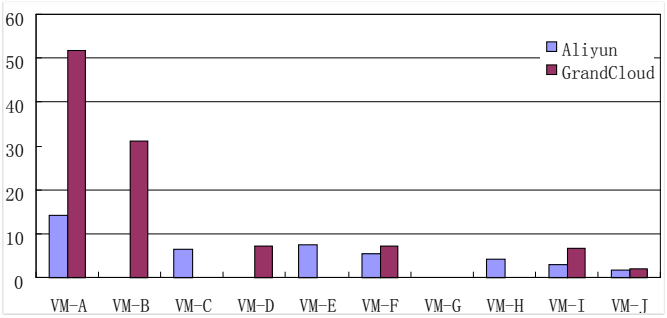

Figure 4. Hadoop wordcount Performance / Price Ratio

Figure 4 shows the calculated performance / price ratio with Hadoop wordcount test results. Similar to the performance / price ratio results obtained from the UnixBench tests, for VM's from the same public IaaS provider, as the VM gets bigger, the performance / price ratio gets worse.

C. *Vertical Scaling vs Horizontal Scaling*

The Hadoop wordcount test results are daunting for application developers. What should one do when an application is heavily loaded and needs more processing power? In Aliyun, upgrading to a bigger VM might solve the problem in the short term, but won't do in the long run. In GrandCloud, the result of upgrading to a bigger VM might be totally unexpected.

There exist two methods to add more resources to a particular application. One method is to add more resources to a single processing node, which is called vertical scaling. The other is to add more processing nodes to the cluster, which is called horizontal scaling. In the above-mentioned tests, we have seen that vertical scaling failed to increase the performance of the Hadoop wordcount application. It is worthwhile to study whether horizontal scaling will help.

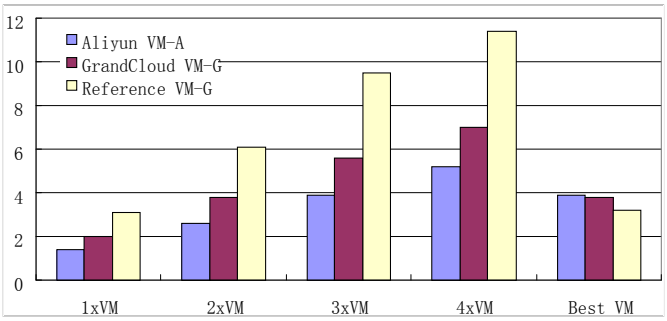

Figure 5. Hadoop wordcount Horizontal Scaling Testing Results

Figure 5 shows the results obtained from Hadoop wordcount horizontal scaling tests. For Aliyun, up to 4 VM-A's are used to compose the Hadoop cluster. For GrandCloud and the reference private IaaS environment, up to 4 VM-G's are used to compose the Hadoop cluster. The testing results are then compared with the VM with the best performance in the previous single node tests. It can be seen that as more VM's are added to the cluster, the performance of the cluster grows almost linearly. For Aliyun, a cluster with 3 VM-A's beats the single big VM with the best performance. For GrandCloud and the reference private IaaS environment, a cluster with 2 VM-G's beats the single big VM with the best performance.

The significant performance increase in the Hadoop cluster should be attributed to HDFS, a distributed file system that releases the disk IO pressure on each computing node.

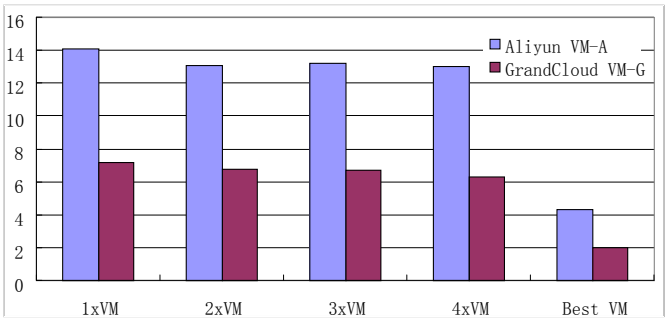

Figure 6. Hadoop wordcount Horizontal Scaling Performance / Price Ratio

Figure 6 shows the calculated performance / price ratio with Hadoop wordcount horizontal scaling test results. It can be seen that for both Aliyun and GrandCloud, adding more VM's into the cluster does not significantly change the performance / price ratio. More importantly, the performance / price ratio of the cluster is much better than a single VM with the best performance. Therefore, it is both technically and economically feasible to practice horizontal scaling when an application needs more computing resources.

IV. CONCLUSIONS

This paper compares the VM performance of Aliyun and GrandCloud using test results obtained from UnixBench and Hadoop wordcount. It is found that VM specifications such as the number of CPU cores and the amount of memory can no longer be used as references for VM performance. In both UnixBench and Hadoop wordcount tests, as the VM gets bigger, the performance / price ratio gets lower. In Hadoop wordcount tests, a cluster with several smaller VM's provides much better performance and performance / price ratio as compared to a bigger VM. For applications that are both CPU-intensive and IO-intensive such as Hadoop wordcount, it is recommended to practice horizontal scaling when an application needs more computing resource.

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