# CLOUD PERFORMANCE & VALUE COMPARISON

Comparing 9 Major laaS Vendors With Data Centers in Europe May 2016



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A public cloud service provider (CSP) offers instantaneous, scalable virtual infrastructure with utility billing. While the public cloud laaS industry streamlines IT through these advantages, a lack of standardization in performance can lead to businesses overspending in order to obtain the necessary performance requirements for their applications.

INTRODUCTION

Cloud Spectator set out to test 9 of the largest, most well-known public cloud providers with data centers in Europe. The report measures and ranks CSPs using a comprehensive performance and price-performance methodology designed by Cloud Spectator specifically for the purpose of measuring cloud environments. The study documented in this report examines the performance of vCPU, memory, and block storage as well as the value (the CloudSpecs<sup>™</sup> Score) as defined by the relationship between price and performance.

In conjunction with a proper process for cloud vendor selection, this report serves to assist in the purchasing decision by assessing performance and price-performance in a holistic, industry view. The report is specifically designed to educate readers on the variation in performance and price-performance value across public cloud providers. Performance is a critical and often overlooked component when making a cloud purchase decision, but can have substantial impact on annual operating costs.

## WHY IS THIS INFORMATION NECESSARY?

A lack of transparency in the public cloud laaS marketplace for performance often leads to misinformation or false assumptions. Users and potential users may be led to view cloud computing as a commodity, differentiated mostly by services. The reality of performance in cloud computing, though, impacts the user differently from CSP to CSP, involving everything from the physical hardware (e.g., Intel or AMD, SSD or spinning disk), to the cost of the virtualized resources. By identifying environments based on performance rather than resource count, users are able to maximize value in the cloud.

## **MISCONCEPTIONS ABOUT PERFORMANCE IN CLOUD**

#### 1. VM performance is pretty much the same from CSP to CSP.

While CSPs often use the same terms to label resources (i.e., vCPUs, RAM or memory, and block storage), differences in the underlying hardware, architecture, and performance tuning lead to entirely different results from the same terms such as vCPUs. For example, on VM performance alone (the virtual processor and memory), the 9 laaS providers in this report exhibited a difference of 1.5x. With block storage performance, differences exceeded 30x.

#### 2. For performance, you get what you pay for.

When it comes to additional services such as support, security, geographical location, and managed services on CSPs, this may be true; however, regarding performance, this study found no correlation between price and performance. The study demonstrated the best-value CSPs in this report (defined as the ratio of price and performance as ranked by the CloudSpecs Score<sup>™</sup>) offer virtualized resources at the lowest prices. Similarly sized VMs within the 9 laaS providers displayed a spectrum of prices with a 2.5x difference between the least and most expensive CSPs.

# 3. Resource contention, known colloquially as the Noisy Neighbor Effect, is not a concern with most providers.

A public cloud environment offers multi-tenant physical hosts, which means a business may share the same physical resources with different users on the same hardware. With a lack of understanding of other users' activities, resource-hogging applications can affect the performance of other VMs on the host machine. While resource contention has been addressed by many of the largest providers in an attempt to stabilize VM performance, the block storage offerings still exhibit high levels of performance fluctuations, with over a 70X difference in IOPS output over the 24-hour test period of this study, which may be related to other activity on the same physical host as Cloud Spectator's test VMs. The fluctuation in performance evidenced in some CSPs can significantly affect hosted applications within those environments.

#### 3a. If Noisy Neighbor is a concern, then performance is too unpredictable.

In public cloud environments, some providers, especially major ones such as Amazon Web Services and Google Compute Engine, employ performance throttling among other strategies to deliver a consistent user experience regardless of the actual user load on the physical machine. This means that, while performance may be artificially low for the VM, the user will not see much change over time. See Performance by VM Size to view the performance variation of different CSPs over the 24-hour period of the study (on disk performance in particular, Google, one of the 9 laaS Providers in this study, demonstrated very stable performance).

# **EXECUTIVE SUMMARY**

## INTRODUCTION

This report examines the results of a study measuring and comparing the price-performance value\* of 9 CSPs within the European region. While the CSPs included in the study did not have to be headquartered in Europe, they must have at least one data center located within the European continent (see Methodology page 11).

The list of 9 CSPs included major providers like Amazon AWS, Google Compute Engine, Microsoft Azure, and IBM SoftLayer. Smaller CSPs, some of which specialize in high performance and aggressive pricing, can achieve higher CloudSpecs Scores<sup>™</sup> as a result.

\*Pricing may have changed on providers after the release of this report (5/7/2016).

## **PRICE-PERFORMANCE KEY FINDINGS**



- Value, defined as the ratio of price and performance (see Methodology page 16) varies by 4x when comparing the 9 CSPs.
- CenturyLink achieves the highest CloudSpecs Score<sup>™</sup> in the 9 cloud laaS providers ranking. This is largely due to high vCPU & memory performance and its inexpensive customizable pricing.
- While certain providers such as Rackspace may have achieved above-average performance for vCPU & memory, the price-performance value achieved by those providers were lower due to higher costs.
- Google and vCloud Air achieved the highest performance in the storage tests; however, lower average vCPU & memory performance resulted in a lower overall score.

## **VCPU & MEMORY PERFORMANCE KEY FINDINGS**



Chart 2.2: VM Performance and Variability Over 24 Hours

- The 9 ranked providers exhibited a difference of nearly 50% in vCPU & memory performance, emphasizing the need for performance testing to understand value.
- The differences in performance across the 9 providers demonstrates a strong mismatch of VM sizing and standardization in public cloud laaS; e.g., CenturyLink's Small VM nearly at the level of Google's Medium VM on vCPU and memory performance, allowing a user the possibility to utilize fewer resources and lower expenses for certain applications.
- Rackspace, Azure and Interoute achieved the best combination of low variability to high performance over the 24-hour test period, contributing to high value and predictable performance.
- The average vCPU & memory variability between the Top 1-5 and Top 6-9 for VM performance is relatively similar, with average CVs of 3.4% and 7.8% respectively.

## **BLOCK STORAGE PERFORMANCE KEY FINDINGS**



Chart 2.3: Block Storage Performance and Variability Over 24 Hours

- While disk performance variability exceeded 40% with some providers, Google demonstrated stable performance over the test period with variability of 2%, likely due to throttling to avoid resource contention.
- vCloud Air block storage sustains higher overall IOPS than all other CSPs. Google sustains higher IOPS, though, on Type 1 block storage testing, indicating better performance for applications with smaller block sizes.
- Differences in IOPS performance across CSPs exceed 9x in some categories of block storage testing (see Performance by VM Size on page 32).
- vCloud Air and Google offer the highest overall disk performance measured in the study with scores of 56 and 59 respectively, however performance variability between the two providers differs by over 20x. vCloud Air's performance variability measures at 40% while Google measures at 2%.

	vCPU & Mem	nory	Block Dis	k
	Performance Index	Variability	Performance Index	Variability
Amazon	77	14%	16	72%
Azure	93	2%	6	12%
CenturyLink	94	5%	38	28%
Dimension Data	71	10%	43	61%
Google	64	3%	59	2%
Interoute	88	3%	12	49%
Rackspace	96	2%	25	9%
SoftLayer	71	4%	12	3%
vCloud Air	90	5%	56	40%

Table 2.1: Performance and Variability of CSPs Over 24 Hours

Table 2.1 lists the indexed performance scores and variability percentages by CSP. These numbers are used in generating Charts 2.2 and 2.3.

The Performance Index is calculated by indexing the individual performance scores achieved by each VM category (categorized as Small, Medium, Large and Extra Large; see Methodology for more information) on a scale of 0-100 with 100 as the top score. An average across all VM categories is calculated to represent the Performance Index for each provider.

Variability is calculated as the average coefficient of variation (CV) that is the standard deviation expressed as a percentage of the mean performance for the VM categories of each CSP. Higher CV correlates to more fluctuation in performance (i.e., higher performance variability) over the test period.

The Cloud Spectator team designed this methodology to measure the performance of various public cloud infrastructure services. These results will provide general insight into the public cloud industry; however, businesses have varying needs when defining performance requirements, so businesses should apply testing methodologies relevant to their business and technical use cases to yield more relevant results.

METHODOLOGY

## **THE CRITERIA**

This report was modified from the original 2016 Top 10 Vendor Benchmark: Europe Report. CenturyLink has commissioned Cloud Spectator to create a modified report that includes larger, mass-market providers that they most directly compete with.

To be included in this report, each CSP must have the following:

- The CSP must have at least one data center located within the European continent. The CSP does not need to be headquartered in Europe.
- Self sign-up: a user must be able to sign up for a CSP's services online, rather than reaching out to a sales representative. Contact forms that request users to message the CSP for signup are not considered self sign-up.
- 3. Self-service: a user must be able to log into a portal that allows the user to provision, manage, and terminate virtual machines and other cloud-related services.
- Hourly billing intervals: the CSP must provide billing by the hour or less. Some CSPs offer billing by the minute.

5. Only providers with persistent block storage offerings are included in this study. Cloud

Spectator measured disk performance by running performance tests on block storage.

## THE SETUP

The team set up anonymous accounts on all cloud service providers. No accounts were credited, and no CSPs provided the team an account to provision Linux virtual machines. For all VMs, Ubuntu 14.04 images were operating systems of choice. In cases when Ubuntu 14.04 was not available, 12.04 was used; if no Ubuntu images were available, Debian was used. Virtual machines were tested according to four separate categories: Small, Medium, Large and Extra-Large. Each category contained a prerequisite allocation of VM resources.

Table 4A: VM Sizing							
vCPU COUNT	RAM COUNT (GB)	DISK COUNT (GB)					
2	4	100					
4	8	150					
8	16	200					
16	32	500					
	vCPUCOUNT 2 4 8 16	vCPUCOUNTRAM COUNT (GB)24488161632					

CSPs were segmented into two categories: (1) Packaged Offering CSPs and (2) Customizable Offering CSPs. Packaged Offering CSPs include providers such as Amazon Web Services (AWS) and Microsoft Azure, which deliver VMs based on pre-packaged sizes; for example, a customer can purchase an Instance size of c4.xlarge on AWS. Customizable Offering CSPs allow users to define custom VM sizes by setting resources such as vCPUs, RAM, and disk space. Only block storage was tested for disk because of its durability and persistence. This meant that CSPs such as DigitalOcean, which currently only offer local storage, were not included in the report. Only a single block storage size was paired and tested with each VM size. For other CSPs such as Amazon, which offers local and persistent block storage, the local storage was not measured and did not affect the performance or price-performance ranking of the CSP beyond the potential effect on pricing if local storage is included in packaged VM prices. For Packaged Offering CSPs, the team selected VMs that most closely corresponded to the four categories of sizes. For Customizable Offering CSPs, the team provisioned servers designed to the exact requirements of the four categories of sizes when possible.

For each CSP, the team provisioned three copies of VMs for each size; i.e., three Small, three Medium, three Large, and three Extra-Large VMs were provisioned. All VMs were provisioned and tested simultaneously for 24 hours. This means that, for each CSP, twelve various-sized VMs were running from the account on the corresponding provider for 24 hours.

Please note that some CSPs do not offer any VMs with resource allocations that would qualify for the Extra Large size.

## SIMULTANEOUS TESTING OVER TIME

Three resources were examined to compare performance: vCPU, memory, and storage. Performance tests were run in continuous, iterative sequence according to the following order: vCPU tests and memory tests followed by block storage tests. Each complete sequence of testing comprised a single cycle, and cycles repeated without pause for the duration of 24 hours. Different providers completed varying numbers of cycles within the 24-hour time limit, and the number of cycles completed was impacted by the performance levels of the resources tested (higher performance allows each test to be completed faster).

Testing over several iterations impacted the ranking of performance for CSPs. In an uncontrollable multi-tenant environment, VM performance can be affected by issues that arise with neighboring VMs. While these issues may be mitigated with resource planning as a responsibility of the CSP, sometimes performance levels cannot be guaranteed or sustained in the public cloud; therefore,

measuring to examine sustainable performance is just as important on a public cloud as measuring to examine achieved performance. This is why the Cloud Spectator team chose to test over a period of 24 hours.

Three VMs of each category size were tested in parallel. Single-VM performance may not necessarily be reflective of the potential performance a CSP's VMs can achieve if the provisioned VM is faulty for any number of reasons. Measuring more than a singular VM of each size mitigates the possibility that the performance may be an unusual outlier due to a VM provisioning issue, so results are a more accurate reflection of a VM type's potential performance.

At other times, the physical host itself may experience issues, affecting all VMs residing on it. By provisioning all VMs simultaneously, Cloud Spectator may increase the possibility of measuring on multiple physical hosts with different users and resource contention issues, which would be more representative of a VM size's performance. While all of these processes are implemented to increase the accuracy of the measurements, it should be noted that these practices cannot guarantee 100% accuracy. Even by provision three of the same VMs of each category, the VMs still have the possibility of residing on the same physical host depending on the provider's capacity.

## DATA COLLECTION

Throughout the 24-hour period of testing across all qualified and tested providers in this report, Testing was conducted between October and December 2015.

The list of CSPs ranked in the listed 9 was produced based on the CloudSpecs Score<sup>™</sup>, which is a price-performance ratio of the cost and median performance output of the VM. Each VM size category received a VM CloudSpecs Score<sup>™</sup> and block storage CloudSpecs Score<sup>™</sup>, which were

averaged to calculate a CloudSpecs Score<sup>™</sup> for the VM. All 9 tested CSPs were ranked according to price-performance; the report details the findings of each provider.

## **TESTING USED**

Table 4B: Testing Tools

TEST	TOOL	TASKS
vCPU Testing	Geekbench 3	Integer and Floating Point
Memory	Geekbench 3 (using STREAM)	Reads and writes
Block Disk	Fio	Reads and writes

## vCPU and Memory

vCPU performance was measured with integer and floating point tasks from the Geekbench 3 benchmark suite. The Geekbench 3 benchmark suite was also used in collecting memory bandwidth data, which was used to measure the performance of the system memory (RAM).

Table 4C: Testing Specifics						
CATEGORY	TYPE 1	TYPE 2				
Block Size	4KB	128KB				
File Size	5GB	128MB				

Table 4D: Total Files Used in Block Storage Testing

SIZE	TYPE 1	TYPE 2
Small	1	2
Medium	2	4
Large	4	8
Extra Large	8	16

## Storage

Storage performance was measured using fio. Two storage scenarios were run to capture performance data: Type 1 and Type 2. In both scenarios, random and sequential IOPS were recorded as the indicator of performance over a test period of 60 seconds. Type 1 used a large file size with a small block size, while Type 2 used a small file size with a large block size. The total number of files used in testing varied with the category of VM.

## **RANKING CALCULATION**

The list of 9 CSPs were determined by calculating the median performance of both vCPU-memory and storage with the monthly cost corresponding to each VM size for two price-performance scores per VM size (one for vCPU-memory and one for storage). The resulting ratios were normalized in relation to the highest-value provider for each resource, which receives a score of 100. Then the two price-performance scores for each VM size were averaged together to get one score per VM size. The providers were then ordered based on their value across all each VM size, and then their scores were averaged for all VM sizes to come up with a final score.

## **PRICE-PERFORMANCE VALUE (THE CLOUDSPECS SCORE)**

Cloud Spectator's price-performance calculation, the CloudSpecs Score<sup>TM</sup>, provides information on how much performance the user receives for each unit of cost. The CloudSpecs Score<sup>TM</sup> is an indexed, comparable score ranging from 0-100 indicative of value based on a combination of cost and performance. The calculation of the CloudSpecs Score<sup>TM</sup> is: price-performance\_value = [VM performance score] / [VM cost] best\_VM\_value = max{price-performance\_values} CloudSpecs Score<sup>TM</sup> = 100\*price-performance\_value / best\_VM\_value

#### **CPU and Memory**

Cloud Spectator used the median Geekbench 3 performance scores as the [VM performance score] to calculate each machine's CPU and memory CloudSpecs Score<sup>™</sup>.

#### **Block Storage**

For both storage scenarios, median sequential r/w and median random r/w IOPS are used as the [VM performance score] to calculate each machine's Type 1 and Type 2 storage CloudSpecs Score<sup>™</sup>. Type 1 and Type 2 scores were averaged to calculate a single block storage CloudSpecs Score<sup>™</sup>.

#### Overall

Overall storage CloudSpecs Score<sup>™</sup> was calculated by averaging block storage and vCPU-memory price-performance scores together so that they have equal weight for each VM size. Then, all resulting VM size scores were averaged together. For block storage performance, the normalized sequential and random CloudSpecs Scores<sup>™</sup> were averaged together. Then, the Type 1 and Type 2 CloudSpecs Scores<sup>™</sup> were averaged together to create a single storage CloudSpecs<sup>™</sup> score per VM size. Then, the overall CPU, memory and storage CloudSpecs Scores<sup>™</sup> were calculated by averaging the CPU and memory CloudSpecs Score<sup>™</sup> and overall storage CloudSpecs Score<sup>™</sup> for each VM size. All VM size scores were then averaged for each provider and normalized to get the final scores on the scale from 1 to 100.

## VARIABILITY

Variability is calculated by taking the coefficient of variation (CV) of each VM size's individual performance data points. The CVs are averaged for all VM sizes per CSP. The coefficient of variation is the standard deviation expressed as a percentage of the mean.

## **CONSIDERATIONS**

#### Limitations within the Methodology

The laaS industry lacks a standard methodology for evaluating CSPs. While the most effective methodology for measuring value of a CSP varies among use cases, the methodology developed by Cloud Spectator for this study was designed to capture performance statistics based on synthetic

performance uniquely adopted for cloud infrastructure, which requires steps including extended testing over a period of time and running multiple VMs in parallel.

#### VM Sizes

The performance data in this report only applies to the tested VM and block sizes. Larger VMs may yield better results with both VM scores and block storage scores. Larger block sizes may also yield better block storage performance scores. Not all CSPs offered the Extra Large size (see Methodology page 12) for testing. In those cases, the CloudSpecs Score<sup>™</sup> was calculated by averaging the three available sizes.

#### **Pricing Calculations and Discounts**

In this report, Cloud Spectator used monthly pricing to calculate the cost of VMs on providers. Some providers offer sustained-use discounts based on a monthly interval, while others discount for monthly commitments. Certain providers offer similar discounts on an annual basis or longer; these longer-term discounts were not factored into the analysis. Where available, monthly discounting was factored into the pricing calculations; therefore, for longer or shorter time commitments, the rankings may change.

#### The Ranking System

The 9 providers ranked in this report were chosen based on a calculation that considers both performance and cost of the environments. The performance results of vCPU, memory, and block storage are all included in the calculation. While some providers may exhibit high performance on vCPU, memory, and/or block storage, those CSPs may not necessarily rank high in the listed 9 depending on the cost of their environments as compared to their competitors.

#### **Additional Features and Costs**

Only the VM, block storage, and costs of those two components were examined in this study. Additional features, such as support costs (where applicable), public and private networks, traffic, and other services that may increase the overall cost of a CSP's offering, were not examined in the report. Depending on the types of use cases, the features not examined may impact the overall rankings. However, if a user can select between different base infrastructure options that have a difference in performance (e.g. SSD vs. magnetic storage), the options yielding higher performance outputs were chosen.

## DATA CENTER LOCATIONS

All VMs were provisioned in the European data centers of each CSP. For providers with more than one European data center, the most location with lower pricing was chose. If all locations were priced equally, the location closest to the regional HQ was chosen. Specific locations, as described by each CSP, are listed in Table 4E.

Table 4E: Data Ce	nter Locations
Provider	Data Center Location
Amazon	EU (Ireland)
Azure	Northern Europe
CenturyLink	GB1
Dimension Data	Amsterdam
Google Compute	Europe-West1
IBM SoftLayer	AMS01
Interoute	London
Rackspace UK	London
vCloud Air	Europe UK 1

# PRICE-PERFORMANCE VALUE

This section examines the price-performance value (i.e., the CloudSpecs Score<sup>™</sup>) of the 9 laaS providers. The CloudSpecs Score<sup>™</sup> is calculated as the ratio between the price, defined as the monthly cost of the VM and block storage, and median performance of the VM and block storage. For more information on the calculation of the CloudSpecs Score<sup>™</sup>, please see the Methodology.

CenturyLink's offering achieves the highest CloudSpecs Score<sup>™</sup> in this study (a CloudSpecs Score<sup>™</sup> of 100). CSPs such as vCloud Air, which achieved high performance scores in the previous section, ranked lower overall due to higher costs of infrastructure.

## **OVERALL CLOUDSPECS RANKING**

The ranking of the 9 CSPs based on CloudSpecs Score<sup>™</sup> is displayed in Chart 6A.

Value based on price-performance in this study is ranked in relation to the highest-value CSP, CenturyLink. A difference in value of 2.5x exists between CenturyLink, the highest-ranked CSP, and IBM SoftLayer, the lowest-ranked CSP in the 9 providers.



CSP

The following sections (vCPU and Memory Value and Block Storage Value) illustrate the individual Value scores segregated by section, which are the scores used to calculate the overall CloudSpecs<sup>™</sup> ranking. CenturyLink achieves the highest CloudSpecs<sup>™</sup> ranking in the vCPU and Memory Value category, while Google achieves the highest CloudSpecs<sup>™</sup> ranking in the Block Storage Value category. CenturyLink scores highest overall.



## VCPU AND MEMORY VALUE

## **BLOCK STORAGE VALUE**





CSP

## PERFORMANCE

This section examines the performance of the 9 laaS providers ranked in this report. This section does not use the CloudSpecs Score<sup>™</sup>, which is used to rank providers and can be found in the Price-Performance section of the report.

The period of 24-hour testing across 3 parallel machines for each category of VMs demonstrated much higher overall stability of performance in the vCPU and memory components for all providers, as compared to block storage performance over the same period. Performance differences are more noticeable as VMs scale up in size (e.g., the XL size), although a noticeable difference exists in the small VM category as well.

For detailed information on performance scores by VM size, see Performance by VM Size on page 32.

## **VCPU AND MEMORY PERFORMANCE**

Performance values between CSPs on vCPU and memory increase with the size of the VM. The chart below illustrates the vCPU and memory performance across the Small, Medium, Large and Extra-Large VMs:

- The Small VM category exhibits a difference of 2.4x between the highest and lowestperforming CSP VMs; The Extra Large VM category exhibits a difference of 1.5x between the highest and lowest-performing CSP VMs.
- The providers' performance scales on average 1.9x as they increase to the next higher VM size. SoftLayer scales the most between sizes at an average rate of 2.3x, while CenturyLink is the lowest at 1.7x.



## **BLOCK STORAGE PERFORMANCE**

Because the relationship in performance between providers remained similar with both the random and sequential operations, only results from the sequential tests are displayed in this section. Detailed results and random results can be found in the Performance by VM Size on page 32. Each varying disk size corresponded with a VM category (see Methodology page 12). Two disk scenarios were measured: Type 1 and Type 2. More information on the two scenarios can be found in the Methodology (page 11).

- Block storage is not standard across CSPs in regards to hardware, architecture, or performance. A difference of more than 70x exists between highest and lowest-performing block storage offerings across CSPs.
- In disk scenario Type 1, certain CSPs exhibit a noticeable scale in performance as the size of the disk is increased (along with the disk size, the number of files are increased as well). In Type 2, the scale is less linear for the majority of providers, despite the increase in size of the disk and the number of files created on the disk. This may be due to factors such as throttled performance of the VM, and the amount of IOPS a certain VM size can access, or the larger 128K block size.



Chart 5B: Scenario Type 1 - Sequential Performance (Median Scores Displayed)

Chart 5C: Scenario Type 2 - Sequential Performance (Median Scores Displayed)



# PRICING

This section outlines the cost of the VMs and block storage for each size examined in the study across all CSPs. Additional services, unless required (such as vCloud Air support), are not included in the final cost of the VMs. Only the cost of the VM and tested block storage were factored into the final cost. Keep in mind that some providers may charge for add-on services such as support, while other providers include it into the cost of the VMs.

A separate section on traffic costs across CSPs is included as well to highlight the impact of additional considerations that may be involved in pricing, which can impact the final cost of CSP infrastructure.

Pricing for the report updated on 5.7.2016

## **OVERALL PRICING**

The final monthly cost of each VM category for each CSP is calculated as the cost of the VM and the cost of the attached block storage. The six least-expensive providers demonstrate consistent, low pricing across all VM sizes.



#### Table 7A: Monthly Cost of VMs Across CSPs

	Small	Medium	Large	Extra Large
Amazon	€ 87.10	€ 169.31	€ 329.49	€ 668.11
Azure	€ 93.57	€ 182.54	€ 357.66	€ 723.40
CenturyLink	€ 63.19	€ 120.51	€ 229.29	€ 470.30
DimensionData	€ 148.33	€ 277.16	€ 515.34	€ 1,069.67
Google	€ 59.43	€ 111.30	€ 207.49	€ 430.09
Interoute	€ 97.76	€ 188.52	€ 363.04	
Rackspace	€ 114.59	€ 205.72	€ 365.46	€ 776.91
SoftLayer	€ 115.70	€ 202.03	€ 341.76	€ 694.20
vCloud	€ 73.91	€ 142.47	€ 274.23	€ 559.17

## PRICING BY VM CATEGORY

Costs of servers remain fairly linear as VM categories scale larger in size. Among the 9 CSPs, Dimension Data, Rackspace and Azure are the most expensive, while Google, CenturyLink, and vCloud Air are the least expensive.







Chart 7C: Monthly Cost of Medium VMs



Chart 7D: Monthly Cost of Large VMs







## **TRAFFIC COSTS**

Table 7B illustrates bandwidth pricing for egress traffic by GB, which varies depending on the CSP.

All providers in the table offer free ingress traffic. For use cases heavily involving egress traffic,

readjusting price-performance value to calculate for the increased traffic may alter the results of the 9 provider rankings within this report.

0				/					
	First 1 GB	First 5GB	Up to 1TB	1 to 5 TB	5 to 10 TB	Next 40 TB	Next 100 TB	Next 50 TB	Next 300 TB
Amazon	€ 0.00	€ 0.08	€0.08	€ 0.08	€ 0.08	€ 0.08	€ 0.06	€ 0.04	€ 0.04
Azure	€ 0.00	€ 0.00	€0.07	€0.7	€ 0.07	€ 0.07	€ 0.06	€ 0.04	€ 0.04
CenturyLink	€ 0.04	€ 0.04	€ 0.04	€ 0.04	€ 0.04	€ 0.04	€ 0.04	€ 0.04	€ 0.04
Dimension Data	€ 0.13	€ 0.13	€ 0.13	€ 0.13	€ 0.13	€ 0.10	€0.10	€ 0.08	€ 0.08
Google	€ 0.12	€ 0.12	€0.12	€ 0.11	€ 0.11	€ 0.08	€ 0.08	€ 0.08	€ 0.08
IBM SoftLayer <sup>1</sup>	€ 0.00	€ 0.00	€ 0.08	€ 0.08	€ 0.08	€ 0.08	€ 0.08	€ 0.08	€ 0.08
Interoute <sup>2</sup>	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rackspace	€ 0.11	€ 0.11	€0.11	€ 0.11	€ 0.11	€ 0.09	€ 0.07	€ 0.07	€ 0.05
vCloud Air <sup>3</sup>	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00

#### Table 7B: Egress Traffic Costs Across CSPs (per GB)

<sup>1</sup> IBM SoftLayer offers the first 250GB free, with additional transfer at a flat fee or lower costs if bandwidth packages are purchased

<sup>2</sup> Interoute does not charge for data transfer to the Internet as long as adherence to their fair use policy is met

<sup>3</sup> vCloud Air On Demand is offering free data in/out as part of a limited time promotion (no indication of promotion end date)

# **PERFORMANCE BY VM SIZE**

## **UNDERSTANDING THE CHARTS**

VM performance is illustrated using percentile scores retrieved from all data points collected. 5th percentile and 95th percentile scores are often used instead of minimum and maximum scores in order to exclude potential outliers. Median scores are used instead of mean to avoid values being skewed by outliers. The information has been integrated into percentile graphs and value tables designed to visualize performance variation captured while testing over time. An example of the performance percentile graph along with a corresponding value table is displayed in Chart 8:



## **SMALL VMs**



Chart 8A.1: VM Performance (Small VMs)

#### Table 8A.1: vCPU & Memory Performance (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	3713	3955	3986	3998	4017	16	0%
Azure	4184	5023	5148	5481	5718	161	3%
CenturyLink	5157	5282	5368	5442	5466	50	1%
Dimension Data	2864	3007	3243	4374	4453	500	14%
Google	2014	3346	3388	3451	3484	80	2%
Interoute	4392	4434	4590	4667	4694	85	2%
Rackspace	4756	4811	4864	4914	4953	32	1%
SoftLayer	1873	1884	2265	2276	2279	176	8%
vCloud Air	4584	4818	4995	5192	5309	121	2%



Table 8A.2: Sequential Block Disk Performance Type 1 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	750	753	755	766	2848	341	41%
Azure	0	46	86	111	126	20	24%
CenturyLink	422	664	939	1293	1580	189	20%
Dimension Data	93	146	424	783	989	197	45%
Google	1664	1690	1741	1773	1821	25	1%
Interoute	83	165	326	910	1444	234	59%
Rackspace	476	484	547	617	628	52	10%
SoftLayer	398	410	412	412	412	1	0%
vCloud Air	93	146	482	930	1158	245	49%



#### Table 8A.3: Random Block Disk Performance Type 1 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	300	300	300	301	2669	396	104%
Azure	5	23	38	46	51	7	20%
CenturyLink	256	560	843	1183	1502	189	22%
Dimension Data	91	170	435	752	863	189	42%
Google	1526	1546	1586	1616	1649	22	1%
Interoute	76	168	305	815	1214	194	54%
Rackspace	478	482	544	613	623	52	9%
SoftLayer	105	410	412	412	412	25	6%
vCloud Air	83	119	303	650	768	169	50%



#### Chart 8A.4: Sequential Block Disk Performance Type 2 (Small VMs)

## Table 8A.4: Sequential Block Disk Performance Type 2 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	102	102	102	102	908	159	118%
Azure	111	425	494	502	504	37	8%
CenturyLink Dimension	656	998	1500	1944	2488	266	18%
Data	1639	2319	5314	9407	11986	2110	40%
Google	497	519	519	519	519	1	0%
Interoute	96	131	262	497	716	117	42%
Rackspace	780	867	979	1088	1155	71	7%
SoftLayer	199	199	199	202	202	1	1%
vCloud Air	493	1046	2161	4009	7318	960	42%



Chart 8A.5: Random Block Disk Performance Type 2 (Small VMs)

Table 8A.5: Random Block Disk Performance Type 2 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	102	102	102	102	908	156	117%
Azure	28	418	492	502	504	41	9%
CenturyLink	553	836	1506	2112	2464	348	23%
Dimension Data	1392	2322	5146	8808	12097	2004	39%
Google	518	518	518	518	518	0	0%
Interoute	101	133	257	521	840	120	42%
Rackspace	799	900	1034	1159	1236	83	8%
SoftLayer	185	199	199	202	202	1	1%
vCloud Air	319	1008	2075	4796	7050	1153	49%

## **MEDIUM VMs**



Chart 8B.1: VM Performance (Medium VMs)

#### Table 8B.1: vCPU & Memory Performance (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	7301	7664	7790	13769	13859	2821	29%
Azure	8652	9227	9397	9611	9733	126	1%
CenturyLink	9466	10009	10298	10473	10502	157	2%
Dimension Data	5853	6390	7930	8210	8250	726	10%
Google	4591	5936	6422	6547	6699	253	4%
Interoute	8443	8589	9010	9049	9083	167	2%
Rackspace	8570	9075	9675	9728	9750	231	2%
SoftLayer	7831	8180	8232	8289	8316	36	0%
vCloud Air	8561	9290	9801	10295	10378	326	3%



Chart 8B.2: Sequential Block Disk Performance Type 1 (Medium VMs)

Table 8B.2: Sequential Block Disk Performance Type 1 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	1106	1107	1118	1529	3004	374	29%
Azure	15	93	163	204	253	34	21%
CenturyLink	1006	1228	1768	2352	2869	361	20%
Dimension Data	182	283	611	1639	2240	412	56%
Google	3092	3392	3455	3564	3618	58	2%
Interoute	208	369	637	1612	2605	375	50%
Rackspace	1081	1088	1119	1271	1282	76	7%
SoftLayer	393	411	411	412	418	1	0%
vCloud Air	167	403	1031	1766	2238	426	41%



Chart 8B.3: Random Block Disk Performance Type 1 (Medium VMs)

Table 8B.3: Random Block Disk Performance Type 1 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	450	450	452	605	3004	469	79%
Azure	2	45	73	89	98	13	19%
CenturyLink	397	1097	1650	2103	2504	322	20%
Dimension Data	161	269	589	1365	1730	346	51%
Google	2734	3099	3162	3249	3299	51	2%
Interoute	218	337	582	1482	2406	364	53%
Rackspace	1078	1084	1116	1271	1280	77	7%
SoftLayer	207	411	411	413	413	13	3%
vCloud Air	176	330	857	1451	2049	360	42%



Chart 8B.4: Sequential Block Disk Performance Type 2 (Medium VMs)

Table 8B.4: Sequential Block Disk Performance Type 2 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	153	153	153	257	1281	181	82%
Azure	62	452	494	501	504	27	6%
CenturyLink	872	1114	1562	2075	2490	298	19%
Dimension Data	1622	3192	4810	7134	12200	1316	26%
Google	664	711	711	711	711	2	0%
Interoute	101	134	215	453	803	108	44%
Rackspace	746	825	992	1155	1181	104	11%
SoftLayer	188	199	199	201	201	1	1%
vCloud Air	300	896	5927	8913	11218	2340	42%



Chart 8B.5: Random Block Disk Performance Type 2 (Medium VMs)

Table 8B.5: Random Block Disk Performance Type 2 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	153	153	154	257	1279	180	81%
Azure	157	436	493	501	503	34	7%
CenturyLink	572	1044	1362	1850	2237	247	18%
Dimension Data	1768	2473	3850	6744	8880	1280	31%
Google	709	709	709	709	709	0	0%
Interoute	101	129	215	469	793	112	46%
Rackspace	819	887	1050	1228	1251	107	10%
SoftLayer	185	199	199	201	201	1	1%
vCloud Air	268	558	5268	7948	9638	2213	45%

## LARGE VMs



Chart 8C.1: VM Performance (Large VMs)

#### Table 8C.1: vCPU & Memory Performance (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	7588	7721	14114	14155	14188	3012	25%
Azure	16162	16919	17345	17600	17739	216	1%
CenturyLink	13146	13657	16807	18007	18648	1422	9%
Dimension Data	10209	11957	14419	15146	15260	1019	7%
Google	9437	11422	11830	11976	12182	216	2%
Interoute	13407	14705	16431	16516	16640	701	4%
Rackspace	17319	17560	17817	17961	18218	125	1%
SoftLayer	13940	14335	15666	15733	15770	498	3%
vCloud Air	12613	14123	16280	18773	19121	1511	9%



## Table 8C.2: Sequential Block Disk Performance Type 1 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	1110	1111	1487	1507	3004	356	25%
Azure	39	145	248	306	344	48	20%
CenturyLink	680	2092	2875	3614	4741	481	17%
Dimension Data	256	389	877	2358	3746	630	58%
Google	3852	4110	5329	5517	5571	345	7%
Interoute	366	593	994	2525	4100	603	52%
Rackspace	1406	1458	1671	1859	1878	155	9%
SoftLayer	972	1030	1031	1032	1050	4	0%
vCloud Air	273	579	1497	2623	3825	656	42%



## Table 8C.3: Random Block Disk Performance Type 1 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	450	450	606	609	3004	467	72%
Azure	34	73	114	135	148	19	17%
CenturyLink	360	1950	2673	3443	4405	514	19%
Dimension Data	258	381	776	2032	2774	516	55%
Google	3541	3794	4876	5064	5155	315	7%
Interoute	402	577	937	2479	4246	646	57%
Rackspace	1411	1436	1628	1850	1882	160	10%
SoftLayer	325	1032	1034	1034	1036	52	5%
vCloud Air	238	452	1118	2046	3046	512	44%



#### Chart 8C.4: Sequential Block Disk Performance Type 2 (Large VMs)

#### Table 8C.4: Sequential Block Disk Performance Type 2 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	153	153	256	257	1281	192	74%
Azure	331	461	495	502	505	17	4%
CenturyLink	523	685	1362	1912	2557	386	29%
Data	1059	1741	5064	9592	13366	2419	47%
Google	902	902	903	903	903	0	0%
Interoute	126	155	231	472	1114	112	43%
Rackspace	683	736	950	1104	1142	123	13%
SoftLayer	197	200	201	202	202	0	0%
vCloud Air	1846	3445	5471	7850	9053	1351	24%



Chart 8C.5: Random Block Disk Performance Type 2 (Large VMs)

Table 8C.5: Random Block Disk Performance Type 2 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	153	153	255	256	1276	184	72%
Azure	199	464	495	502	504	26	5%
CenturyLink	448	654	1234	1782	2142	338	28%
Dimension Data	936	1880	4028	7786	11048	1799	42%
Google	883	895	901	901	902	2	0%
Interoute	128	157	223	396	1075	104	42%
Rackspace	721	781	1023	1184	1217	135	14%
SoftLayer	199	201	201	202	202	0	0%
vCloud Air	444	2867	4686	7433	8490	1352	28%

## **EXTRA LARGE VMs**



Chart 8D.1: VM Performance (XLarge VMs)

#### Table 8D.1: vCPU & Memory Performance (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	28269	32532	32931	33232	33380	275	1%
Azure	22286	24225	26603	30825	32765	2048	8%
CenturyLink	15956	16167	21137	28760	29648	4629	21%
Dimension Data	7927	8508	10316	11121	11700	783	8%
Google	16329	17235	20328	30499	32047	5189	23%
Rackspace	18296	20538	21594	21901	22448	477	2%
SoftLayer	13319	14309	14885	15463	15867	358	2%
vCloud Air	24251	25169	27133	31098	33073	1792	6%



#### Chart 8D.2: Sequential Block Disk Performance Type 1 (Xlarge VMs)

## Table 8D.2: Sequential Block Disk Performance Type 1 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	2747	2980	2990	2994	2996	16	1%
Azure	99	316	407	491	502	57	14%
CenturyLink Dimension	1223	1897	3433	4514	5458	786	24%
Data	34	49	86	2847	3563	1029	138%
Google	6379	6578	6908	7055	7112	148	2%
Rackspace	1867	1928	2136	2166	2179	100	5%
SoftLayer	2024	2066	2068	2069	2102	3	0%
vCloud Air	220	637	2048	3523	3849	880	42%



#### Chart 8D.3: Random Block Disk Performance Type 1 (Xlarge VMs)

## Table 8D.3: Random Block Disk Performance Type 1 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	1508	1509	1511	2991	2992	433	26%
Azure	73	140	182	214	231	24	14%
CenturyLink Dimension	267	450	2967	4053	4902	1389	59%
Data	34	49	86	2685	3074	966	136%
Google	5834	6012	6316	6437	6522	133	2%
Rackspace	1863	1923	2129	2157	2173	99	5%
SoftLayer	421	2052	2064	2066	2067	141	7%
vCloud Air	261	650	1637	2924	3293	649	39%



#### Chart 8D.4: Sequential Block Disk Performance Type 2 (Xlarge VMs)

#### Table 8D.4: Sequential Block Disk Performance Type 2 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	974	978	983	1280	1281	87	8%
Azure	279	452	499	502	505	20	4%
CenturyLink Dimension	522	706	1113	1646	2211	300	27% 82%
Google	1898	1921	1921	4895 1922	1922	2	0%
Rackspace	639	737	860	999	1008	95	11%
SoftLayer	199	199	201	202	202	1	0%
vCloud Air	1363	4409	6736	8909	9393	1506	22%



Chart 8D.5: Random Block Disk Performance Type 2 (Xlarge VMs)

## Table 8D.5: Random Block Disk Performance Type 2 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
Amazon	636	636	637	1245	1255	175	25%
Azure	308	474	499	503	503	17	3%
CenturyLink Dimension	314 189	420	1009 624	1547 4063	1913 4834	369 1419	39% 94%
Google	1896	1921	1921	1922	1922	2	0%
Rackspace	692	779	915	1054	1068	102	11%
SoftLayer	188	200	202	202	203	1	1%
vCloud Air	2127	3060	5634	7910	9007	1449	26%

# **ABOUT CLOUD SPECTATOR**

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