Cloud Vendor Benchmark 2015

Price-Performance Comparison
Among 15 Top IaaS Providers

Part 2.4: XLarge VMs Linux

May 2015

CLOUD SPECTATOR

Part 2.4: XLarge VMs Linux

CloudSpectator.com

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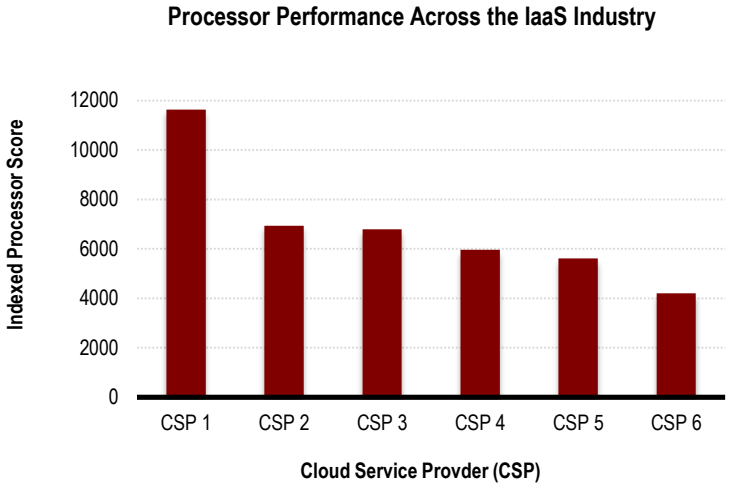
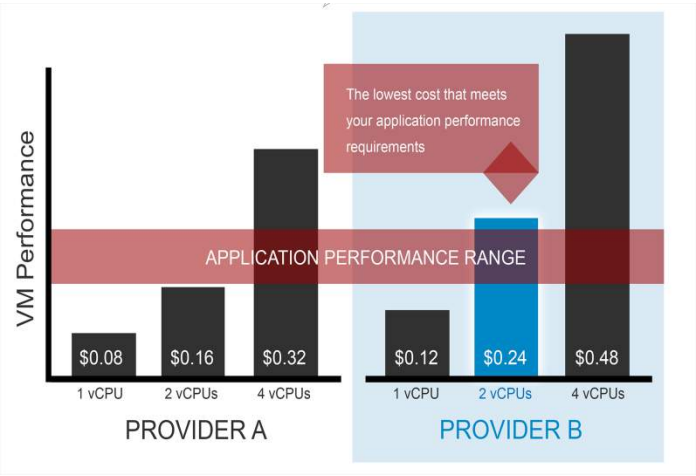
PREFACE

Performance and pricing are both key considerations in the public cloud industry, together having a substantial impact on annual operating costs. Cloud users may need fewer resources on better performing services, which can lower costs depending upon the price-performance ratio. Since many users only consider price and not price-performance, these users may be paying more because they require additional resources to achieve a desired level of performance. While some providers try to differentiate their offerings by cutting prices, others try to differentiate by focusing on improved performance. Recent examples of performance improvement include Rackspace's Performance Servers, Microsoft Azure's D-Series, and most recently, Amazon EC2's C4 family. This report examines the performance and the price-performance of the virtual machines included in the *Cloud Vendor Benchmark 2015 Part 1: Pricing Report*.

Why Does Performance Matter?

Differences in performance outputs of VMs across IaaS providers can greatly impact quality of service as well as annual operating costs. The graph on the right illustrates an example of the average processor performance from a sample of six Cloud Service Providers (CSPs) as studied by Cloud Spectator. CSP 1 has a processor performance three times as high as CSP 6 (names removed), which gives CSP 1 a notable advantage in many processor-intensive workloads. CSPs 2-5 exhibit a closer resemblance in processor performance, but do not offer nearly as much processing power as CSP 1 does.





The performance differences, as a result, will be further reflected in the operating costs of a cloud deployment. The graph on the left depicts a scenario where a 2 vCPU machine of provider B can meet the performance requirement of a certain application while a 2 vCPU machine of provider A cannot. Despite its higher unit price, clients can in fact save cost by deploying Provider B's 2 vCPU machine to run that application instead of a 4 vCPU machine on provider A, which is the lowest priced configuration that meets the application performance requirement for that specific provider. Therefore, understanding the price-performance output of different providers is critical since it allows clients to find the most cost-effective virtual machines that fit their application requirements and saves them money.

About the Cloud Vendor Benchmark 2015 Part 2: Performance and Price-Performance

The *Cloud Vendor Benchmark 2015 Part 1: Pricing* report compares pricing across vendors in the IaaS industry. The document did not assume performance differences across providers; for example, 1 vCPU on Amazon Web Services was considered equivalent to 1 vCPU on Rackspace Cloud. Comparisons were standardized by sets of minimum system requirements defined as Small, Medium, Large, Extra Large, and 2x Large (see

Appendix: VM Sizing for VM configuration information). For detailed information, please refer to the Part 1 report or contact Cloud Spectator at contact@cloudspectator.com.

Part 2 takes the pricing data and server sizes from Part 1 and incorporates CPU and memory performance testing. CPU and memory tests were conducted continuously over a 24-hour period across all of the VMs and providers examined in Part 1. Over the test period, more than 1.1 million data points were collected for the Linux OS (Ubuntu 14.04). By applying the results of the performance testing with the pricing and VM setups in Part 1, this report examines the value of the VMs with respect to performance, price-performance, and performance stability.

THIS REPORT ANALYZES ONLY THE XLARGE VM SETUP EXAMINED IN PART 1. EXACT VM SIZES USED CAN BE FOUND IN THE APPENDIX UNDER VM SIZES. RELATIVE PERFORMANCE RANKINGS WILL NOT BE THE SAME ACROSS DIFFERENT VM SIZES. FOR PERFORMANCE STUDIES ON ADDITIONAL VM SIZES, PLEASE VISIT CLOUD VENDOR BENCHMARK 2015 REPORTS.

Performance data was collected from CPU and memory tests. The CPU test includes 23 CPU-intensive tasks categorized between integer and floating point tasks. The memory test includes 4 memory-intensive tests measuring bandwidth. The aggregated CPU & memory test score includes a total of 27 tasks. All 27 tasks were run using the Geekbench 3 Test Suite. Performance results were categorized and analyzed in low, median and high scores. Price-performance was examined using hourly, monthly, annual and 3-year pricing. *The Cloud Vendor Benchmark 2015 Part 2: Performance and Price-Performance* is the largest public-facing performance and price-performance report on the IaaS industry.

Part 2 is divided into 10 separate reports with regard to different VM sizes and operating systems. **This report only examines the XLarge machines running Linux.** All data in this report is accurate as of April 1, 2015.

The IaaS Providers

Amazon EC2	DigitalOcean	Google Cloud	Internap	ProfitBricks
CenturyLink Cloud	Dimension Data	HP Helion	Joyent	Rackspace Cloud
CloudSigma	GoGrid	IBM SoftLayer	Microsoft Azure	Verizon Cloud

VM Pricing

Provider	Instance	vCPU	RAM	Storage (GB)	Hourly ($)	Monthly ($)	Annual ($)	3-Year ($)
AWS	m3.2xlarge	8	30	2 x 80 SSD	0.560	408.80	2989	5493
CenturyLink	customized	8	16	-	0.320	233.60	2803	8410
CloudSigma	customized	8	16	50 SSD	-*	181.16	1957	4891
DigitalOcean	highvol1	8	16	160 SSD	0.238	160.00	1920	5760
Dimension Data	customized	8	16	-	0.612	446.76	5361	16083
GoGrid	Standard XX-Large	16	16	800	0.960	525.60	4205	12614
Google	n1-standard-8	8	30	-	0.504	257.69	3092	9277
HP Helion	Standard 2XL	8	30	470	0.900	657.00	7884	23652
IBM SoftLayer	customized	8	16	25	0.416	285.60	3427	10282
Internap	B-8	8	30	160 SSD	0.640	467.20	5606	16819
Joyent	High Storage1	8	32	7680	0.863	629.99	7560	22680
Microsoft Azure	D4	8	28	400 SSD	0.680	496.40	5957	17870
ProfitBricks	customized	8	16	-	0.229	167.02	2004	6013
Rackspace	Compute1-30	16	30	-	0.790	576.70	6920	20761
Verizon	11	8	16	-	0.472	344.56	4135	12404

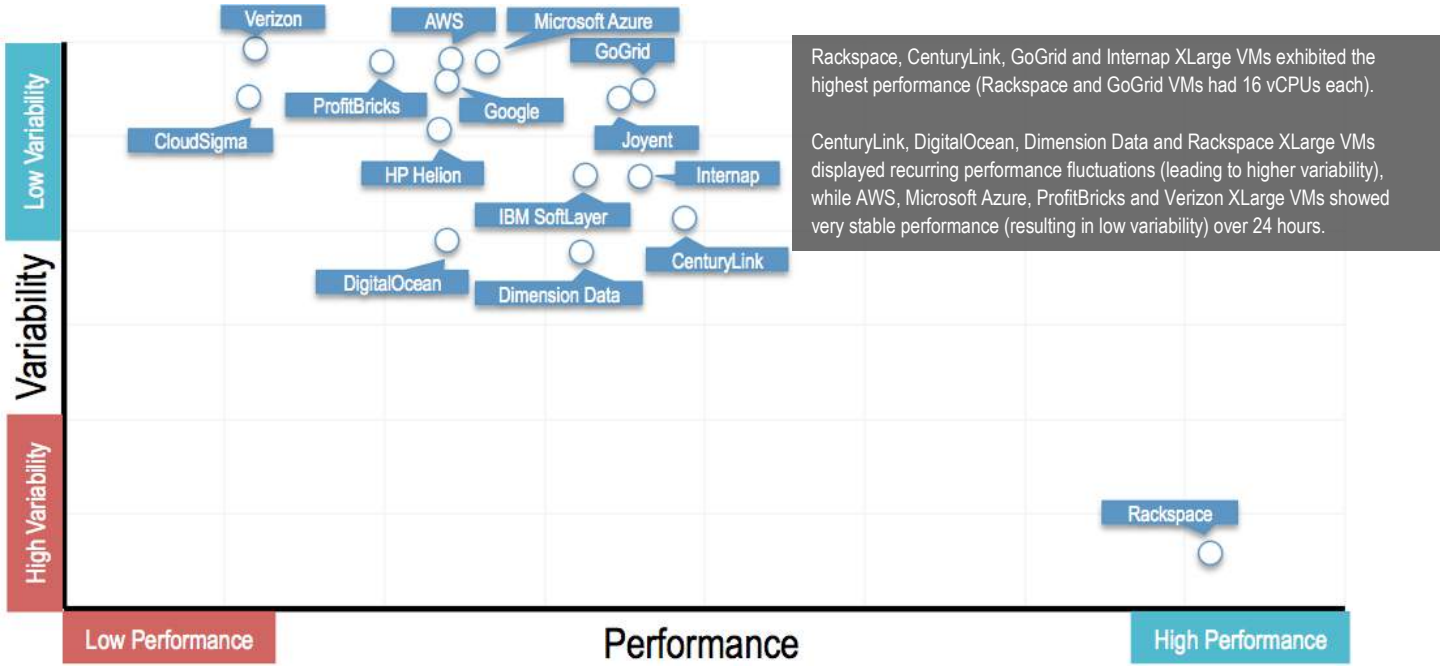
Prices in red reflect longer-term prices discounted from the hourly pricing.

**CloudSigma uses an algorithm to calculate its hourly pricing – burst pricing, which can be equal to or greater than monthly pricing. The price changes cannot be predicted ahead of time, and therefore CloudSigma's hourly pricing, along with its hourly price-performance values, is not included in this report.*

EXECUTIVE SUMMARY

Key Performance Findings

The following graph shows the relationship between the included VMs' performance and variability. The performance is represented by median aggregated CPU & memory scores, and the variability is the degree of score variation during the 24-hour repeated testing.

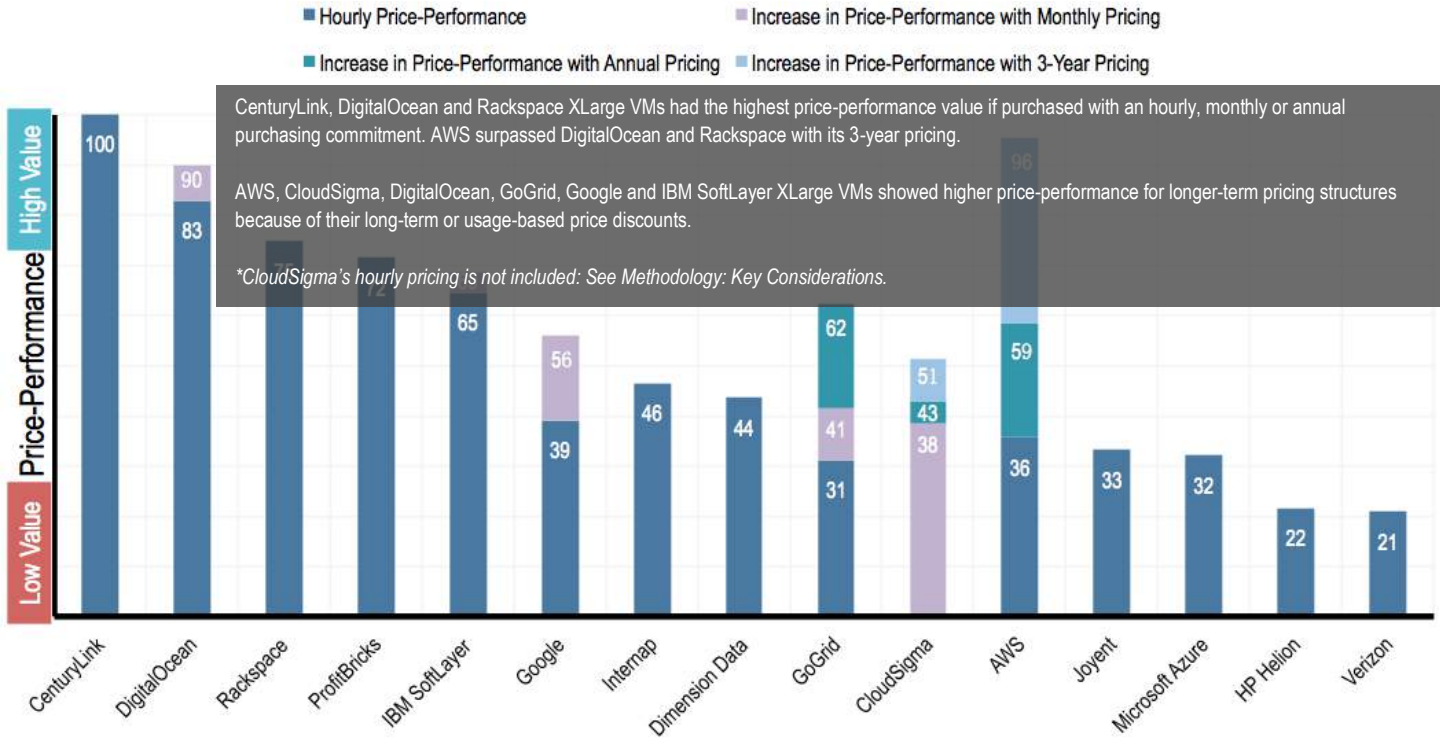


Rackspace, CenturyLink, GoGrid and Internap XLarge VMs exhibited the highest performance (Rackspace and GoGrid VMs had 16 vCPUs each).

CenturyLink, DigitalOcean, Dimension Data and Rackspace XLarge VMs displayed recurring performance fluctuations (leading to higher variability), while AWS, Microsoft Azure, ProfitBricks and Verizon XLarge VMs showed very stable performance (resulting in low variability) over 24 hours.

Key Price-Performance Findings

The following graph shows the CloudSpecs Scores™ of all included provider VMs representing their price-performance values, i.e., performance per unit of price. The scores were calculated using median aggregated CPU & memory performance scores. The providers are ranked by monthly CloudSpecs Scores™.



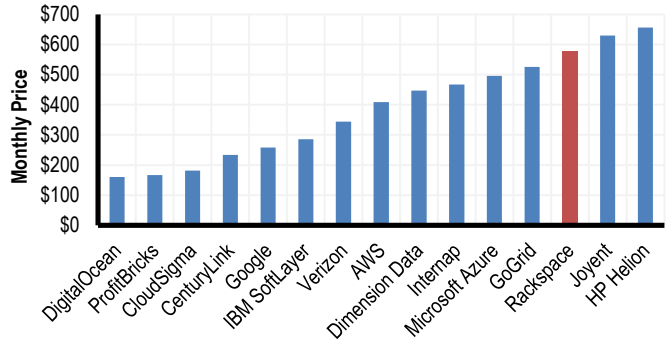
CenturyLink, DigitalOcean and Rackspace XLarge VMs had the highest price-performance value if purchased with an hourly, monthly or annual purchasing commitment. AWS surpassed DigitalOcean and Rackspace with its 3-year pricing.

AWS, CloudSigma, DigitalOcean, GoGrid, Google and IBM SoftLayer XLarge VMs showed higher price-performance for longer-term pricing structures because of their long-term or usage-based price discounts.

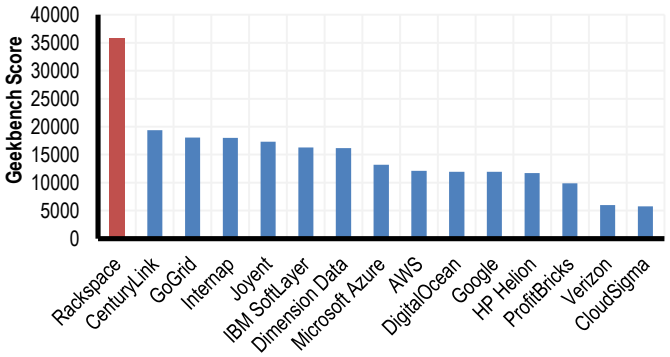
**CloudSigma's hourly pricing is not included: See Methodology: Key Considerations.*

Key Takeaway

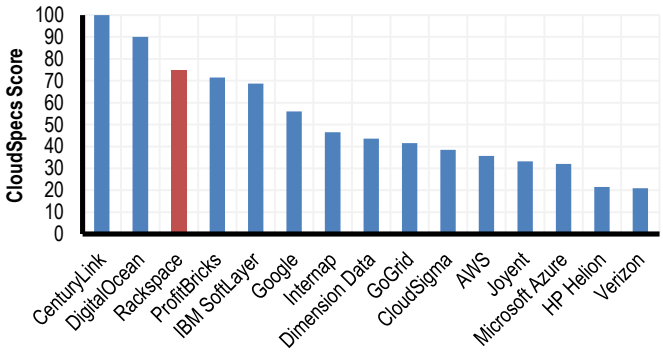
Monthly Pricing Ranking (Low to High) – XLarge VMs



Median Performance Ranking (High to Low) – XLarge VMs



Monthly Median Price-Performance Ranking (High to Low) – XLarge VMs



The three graphs on the left, which display rankings based on price, performance, and price-performance demonstrate the difference that may occur when comparing the same set of provider VMs using different criteria. Using Rackspace's XLarge VM as an example, while the VM ranks 13th in the monthly pricing comparison, its median performance output ranks first among the 15 providers, and its price-performance calculated using the data supporting the first two graphs ranks third. Selecting the right criteria when comparing across the cloud industry is essential in helping users optimize their decision-making process and outcome.

The graphs from the previous page illustrate the differences among the providers in both performance and variability. The differences between VMs can be significant when both performance and variability are taken into account, even though the provider VMs' configurations were relatively controlled.

Understanding both the performance and the severity of performance variation is critical to successfully operating certain applications in the cloud. Just as low-performing virtual machines may not satisfy application performance requirements, high-performing but unstable machines may have diminished performance output periodically, which may fail to sustain the application's ability to run at full capacity. Thorough considerations should be applied to examine performance level and performance variability when users are selecting cloud environments in order to optimize their application operations and IT spend.

Price-performance analysis is critical for choosing the best-fit providers for specific use cases in order to avoid unnecessary IT overspending. Businesses looking for the most economical cloud infrastructure should examine the price and performance output of a target environment together to understand the performance per unit cost value they can expect.

METHODOLOGY

Price

Each provider's pricing information was gathered based on 5 separately sized server configurations. All data on the proceeding pages refer to the specific sizes listed in Table 1.1:

Table 1.1

SERVER	CPU CORES	RAM IN GB
Small	1	2
Medium	2	4
Large	4	8
XLarge*	**8**	**16**
2XLarge	16	32

**Only the XLarge size is used in this report.*

The above configuration sizes listed are treated as minimum requirements. Any provider server tested in this report must meet or exceed those requirements. The provider server with the lowest price that meets or exceeds the minimum requirements listed above is used. Local storage is not factored into the requirements.

The values within the *Cloud Vendor Benchmark 2015* reports only apply to the listed configurations that are serving as minimum requirements. Different target configurations will yield different results, i.e. the most expensive VMs with the listed configurations in this report may be the least expensive on other target configurations.

Monthly figures are calculated using 730 hours unless discounts apply.

Scaling resources in a Tiered Package structure would require the user(s) to select the next available tier that would fulfill the configuration's requirements. This may mean more resources than necessary.

The application(s) that would hypothetically run on the server configurations listed in Table 1.1 are not assumed to be optimized for cross-server performance; thus, scaling resources in a Tiered Package structure would require the user(s) to select the next available tier that would fulfill the configuration requirements. This may mean more resources than necessary. For example, the 2XLarge Server configuration of 16 vCPU cores and 32GB RAM would require a purchase of HP Helion's closest tiered package (CPU & RAM) that fulfills the requirements, which provides 16 vCPU cores, 120GB RAM, and 1770GB local storage.

Pricing is measured exclusively by the specification of cores and RAM. However, it is valid that vCPU performance, RAM performance, and even overall server performance can alter costs based on each user's application's specific needs.

Performance

CPU and memory performance information was collected and explored using the Geekbench 3 testing suite on Linux Ubuntu 14.04 systems from VMs of the same configurations that were used in the *Cloud Vendor Benchmark 2015 Part 1: Pricing* report. Note that some providers' VMs have more resources (CPU or memory) than others. No storage or network performance is included.

A total of 27 separate tasks were conducted for integer, floating point and memory functions: 13 tasks for integer calculations, 10 tasks for floating point calculations, and 4 tasks for memory function. Python scripts were used, and all providers offered Python 2.7. Screen was used to continue the Python scripts upon terminating an SSH session. All VMs were accessed via SSH; SSH Keys were used when available. An overall weighted performance score for each VM was calculated by aggregating performance results of all 27 tasks. Both single task performance comparisons and aggregated performance comparisons are presented in this report. For specific Geekbench testing, score calculation and score aggregation information, please visit the Geekbench official website: http://www.primatelabs.com/geekbench/.

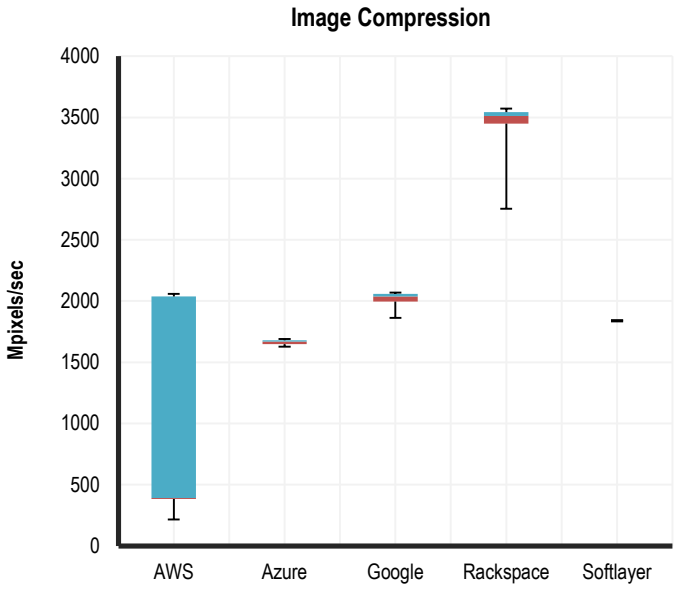
Tests and descriptions related to this report are described in the Table 1.2:

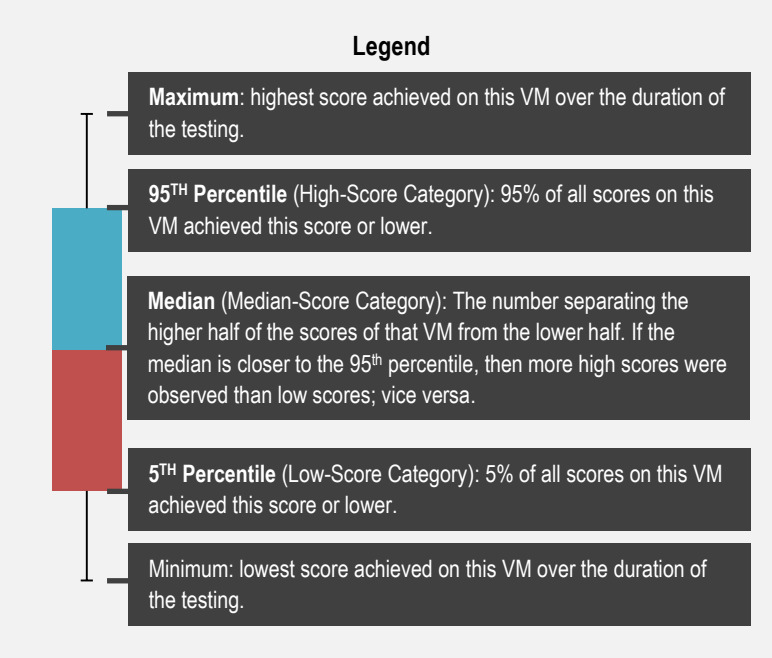
Table 1.2 Performance Tests and Descriptions

TEST	TOOL	TASK	DESCRIPTION
Integer	Geekbench 3	AES, Twofish, SHA1, SHA2, BZip2 Compression, BZip2 Decompression, JPEG Compression, JPEG Decompression, PNG Compression, PNG Decompression, Sobel, Lua, Dijkstra	Integer and Floating Point tasks together represent vCPU performance. The performance of all applications is highly dependent on the vCPU since the vCPU is responsible for the processing and orchestration of all applications.
Floating Point	Geekbench 3	Black Scholes, Mandelbrot, Sharpen Filter, Blur Filter, SGEMM, DGEMM, SFFT, DFFT, N-Body, Ray Trace	
Memory	Geekbench 3	STREAM Copy, STREAM Scale, STREAM Add, STREAM Triad	While memory performance is not considered one of the key bottlenecks in performance for many common applications, a subset of applications—particularly HPC and in-memory databases—is highly dependent on large sustained memory bandwidth.

The Geekbench test suite was installed and run on the same machine continuously for 24 hours in order to capture performance variation. Each round of testing generated one set of data points for every task mentioned above. As a result, 1,121,796 Linux OS data points were collected to examine the value provided across vendors in the market with respect to performance and performance stability.

The virtual machines' performance information was depicted using the minimum, 5th percentile, median, 95th percentile, and maximum scores retrieved from all data points collected for each of the tasks mentioned above during the 24 hours. 5th percentile, median and 95th percentile scores corresponded to low, median and high scores. 5th percentile and 95th percentile scores were used instead of minimum and maximum scores in order to exclude potential outliers. The information was then integrated into percentile graphs and value tables, which were 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 below:





	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	215	384	392	2038	2058	533	28.9%
Azure	1628	1649	1669	1679	1690	10	0.5%
Google	1864	1997	2038	2058	2068	18	1.0%
Rackspace	2755	3451	3512	3543	3574	49	2.7%
Softlayer	1833	1843	1843	1843	1843	1	0.1%

Variability was calculated by taking the percentage of each machine's standard deviation values (Stdev.) from the median of the Medians (median scores) of all VM. The calculation formula is:

*Variability = [Stdev.] / [median{Median}] * 100%*

Machines with variability scores higher than 5% were considered fluctuating, and their standard deviation (Stdev.) and variability scores (Variability) will be highlighted in red.

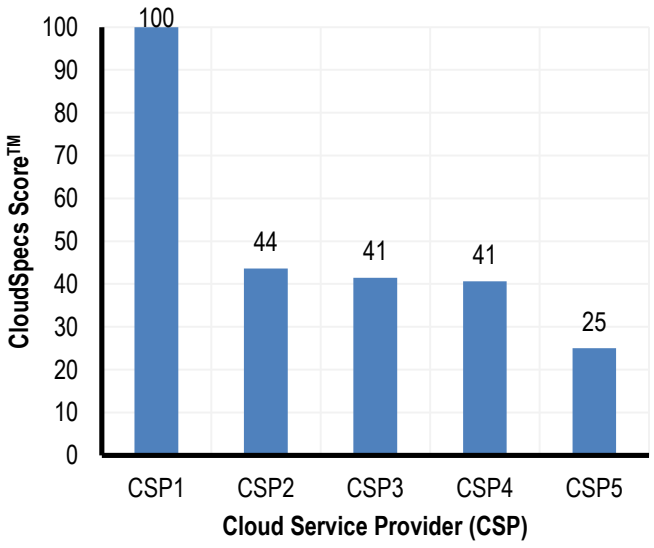
The variability score is designed to reflect the relative fluctuation of a machine in relationship with other VMs included in the same comparison. Therefore, the same variability value of different performance tasks can mean different fluctuation magnitudes. Standard deviation values (Stdev.), alternatively, can be used to compare the fluctuation sizes universally across different VMs and different tasks.

Price-Performance

Cloud Spectator's price-performance calculation, the CloudSpecs Score™, provides information on how much performance the user receives for each unit of cost. The CloudSpecs Score™ 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™ is:

price-performance_value = [VM performance score] / [VM cost]
best_VM_value = max{price-performance_values}
*CloudSpecs ScoreTM = 100*price-performance_value / best_VM_value*

In this report, Cloud Spectator uses the aggregated performance scores as the [VM performance score] to calculate each machine's CloudSpecs Score™.



The graph on the left is an example of how Cloud Spectator's price-performance analysis is visualized. The closer the score is to 100, the higher price-performance value it indicates. The score 100 represents the best-value VM among all in the comparison. The value is scaled; e.g., the VM from Cloud Service Provider 1 (CSP1) with a score of 100 gives 4x the value of the VM from CSP5 with a score of 25.

The CloudSpecs Scores™ of any VM can change depending on the participants in the comparison. For example, if the highest score in a comparison changes, the price-performance value represented by score 100 will change accordingly, and so will the other CloudSpecs Score™ values.

If you have questions regarding Cloud Spectator's price-performance calculation, please contact us at contact@cloudspectator.com.

Data in this report is accurate as of April 1st, 2015. The report will continue to be accurate for an undetermined duration.

Key Considerations

Listed below are both general and provider-specific notes on how price, performance and price-performance values were calculated and what assumptions were made. The assumptions made for this report may differ from specific use cases, and thus, impact the relevancy of the results.

- This report examines price and performance only. Certain providers may include certain features or services (e.g. 24x7 support) in their price. Features and services comparisons are not included in this report.
- Price figures reflect those of US data centers only, and eastern US data centers were used when there are price differences among US data centers.
- For monthly, annual and 3-year pricing, virtual servers are assumed to be running at 100% utilization of each month.
- There are assumed to be 730 hours in each month.
- Only base virtual machine prices are included. No add-ons that would affect pricing were considered.
- Virtual machine sizes meet or exceed the requirements listed above. The virtual machines with the lowest price that meet or exceed the minimum requirements are used. **Therefore, in this report, 16 vCPU machines were used on GoGrid and Rackspace and 8vCPU machines were used on the remaining providers in order to meet the criteria for selecting XLarge VMs according to the listed minimum requirements.**
- CloudSigma uses an algorithm to calculate its hourly pricing – burst pricing, which can be equal to or greater than monthly pricing. At the time Cloud Spectator checked, vCPU burst pricing was roughly 2x the cost of monthly pricing per hour, the RAM price was roughly 3x the cost of monthly pricing per hour, and the storage price was roughly 2x the cost of monthly pricing per hour. The price changes cannot be predicted ahead of time, and therefore CloudSigma's hourly pricing, along with its hourly price-performance values are not included in this report.
- The performance tests were administrated using a Python script written in Python 2.7, which ensured the continuous testing cycles over 24 hours.
- The VMs were deployed using Ubuntu 14.04 64-bit OS images. Using different images may yield different testing results from this report.
- Different provider VMs were based on different physical hardware. The influence of hardware on VM performance was not explored in this report.
- Some providers use more than one type of processor to host their VMs. Since Cloud Spectator only tested one random machine on each provider, the effect of this variable was not explored in this report.
- The CloudSpecs Scores™ cannot be compared against each other numerically over different graphs.

For any further questions or concerns regarding Cloud Spectator's *Cloud Vendor Benchmark 2015 Part 2.4: Performance and Price Performance (XLarge VM, Linux)*, please contact Cloud Spectator at (+1) 617 300 0711 or email us at contact@cloudspectator.com.

PERFORMANCE COMPARISON

Aggregated CPU & Memory Performance Analysis

Table 2.1 shows the Minimum, 5th percentile, median, 95th percentile, and maximum value of the aggregated CPU & memory performance scores for each VM. For test information, please refer to the Methodology: Performance section; for aggregation information, please see Appendix: Score Aggregation.

Table 2.1: Aggregated CPU & Memory Performance Scores – XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	10817	13007	4086	6429	8927	15714	8735	8970	10402	13368	13779	10990	8360	24907	5753
5th Per.	11860	15563	5004	9074	12017	17479	11587	10923	14358	16562	16524	12977	9631	27374	5851
Median	**12091**	**19372**	**5781**	**11952**	**16149**	**18084**	**11951**	**11735**	**16277**	**18002**	**17333**	**13211**	**9904**	**35779**	**5966**
95th Per.	12181	19763	6278	13710	16890	18499	12162	12312	16403	18918	17522	13308	10082	39254	6071
Max.	12265	19933	6559	16698	17030	19012	12408	12807	16461	19508	17598	13390	10270	39824	6164

Cloud Spectator ranks the VMs by their performance at the 95th percentile and 5th percentile (See *Figure 2.1 and Figure 2.2*), which are referenced as the High-Score Category and the Low-Score Category respectively. Rackspace, GoGrid and Internap VMs display consistent high rankings in both the High-Score Category and the Low-Score Category, while the rankings of CenturyLink, DigitalOcean and Dimension Data VMs experience considerable changes in performance values.

Figure 2.1: CPU & Memory Performance Rank by 95th Percentile (High-Score Category) – XLarge VMs

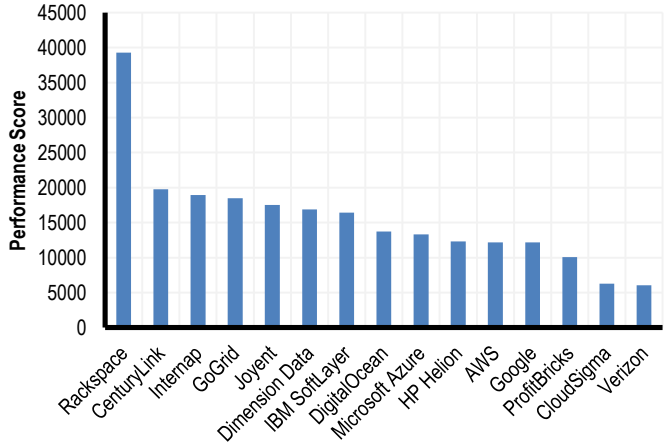
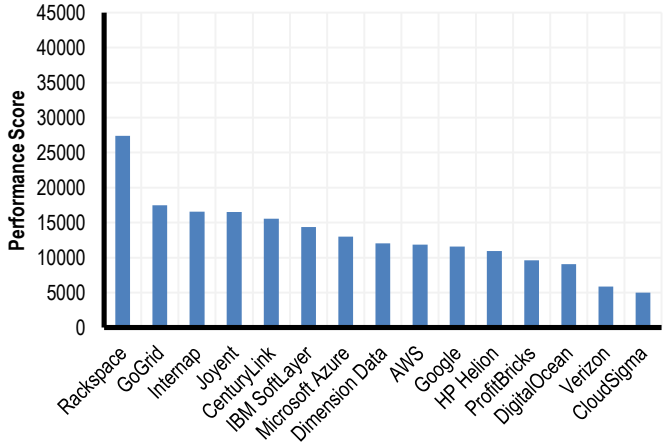


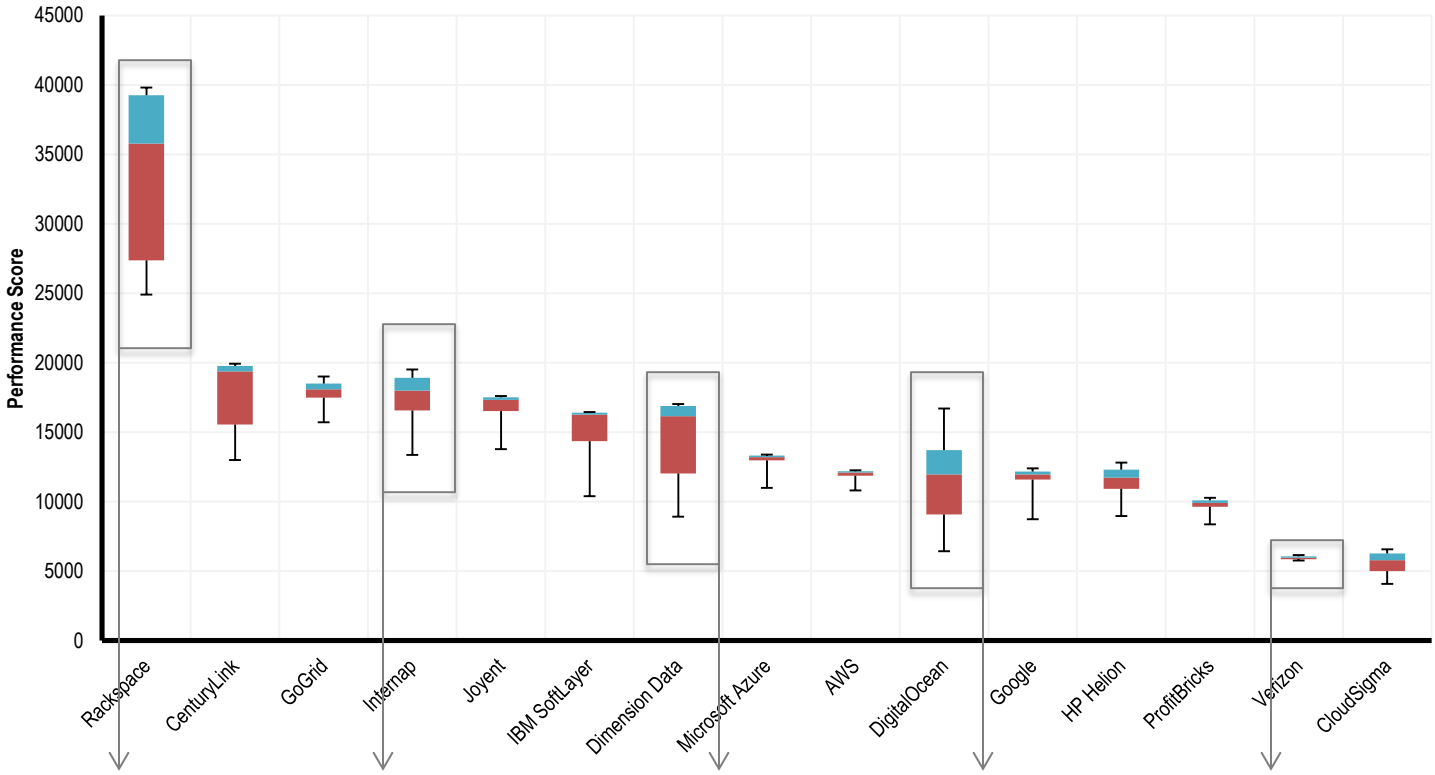
Figure 2.2: CPU & Memory Performance Rank by 5th Percentile (Low-Score Category) – XLarge VMs



The changes in performance rankings were due to the performance variations detected during the 24-hour testing period. In order to visualize the performance variations, Cloud Spectator introduces a percentile graph (*See Figure 2.3*). Figure 2.3 ranks the VMs by their median performance while incorporating the minimum, 5th percentile, median, 95th percentile, and maximum scores. For legend and instructions on reading the percentile graph, please refer to the Methodology: Performance section.

The graph indicates that the CenturyLink, Dimension Data and DigitalOcean VMs had wide ranges of performance levels that covered the performance ranges of their neighboring providers, which caused their performance rankings to shift when comparing across Low- and High-Score Categories. The Rackspace VM showed the highest variability but the performance variation did not affect its ranking. The percentile graph displays the importance of testing over time to capture a performance range instead of using single point-in-time performance data points to determine a virtual machine's comparative performance level in the market.

Figure 2.3: CPU & Memory Performance Percentile Graph – XLarge VMs – Ranked by Median



Rackspace's performance graph shows a median line closer to the 95th percentile line than to the 5th percentile line, and the three lines are considerably distant from each other. This shows a **negative fluctuation**, and the fluctuation is relatively large in this comparison.

Internap's performance graph displays a median line equally diving between the 95th percentile line and the 5th percentile line. The minimum line stretches longer than the maximum line. This indicates a **neutral fluctuation**, with some extremely low scores.

Dimension Data's performance graph shows a median line closer to the 95th percentile line than to the 5th percentile line, and the minimum line stretches longer than the maximum line. This indicates a **negative fluctuation**, with one or more points of extremely low scores.

DigitalOcean's performance graph shows a median line closer to the 95th percentile line than the 5th percentile line, and both the maximum and the minimum line stretch out significantly. This indicates a **negative fluctuation**, with one or more extreme scores on both high and low ends.

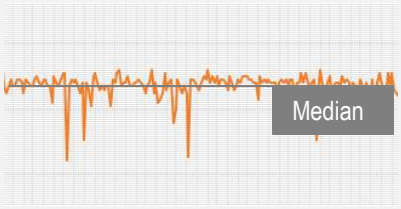
Verizon has its 95th percentile line, median line and 5th percentile line closely compact together, and neither the minimum nor the maximum line stretches outward significantly. This indicates a highly stable performance pattern where **very little fluctuation** was detected.

Neutral Fluctuation:
One type of fluctuation where the scores spread evenly above and below median.

Example:

Negative Fluctuation:
One type of fluctuation where the scores below median have a larger magnitude.

Example:



Positive Fluctuation:
One type of fluctuation where the scores above median have a larger magnitude.

Example:

In order to perceive each VM's overall performance fluctuation numerically, Cloud Spectator calculated each VM's aggregated performance variability score by averaging the performance variability scores of the 27 individual tasks (see *Table 2.2*). The variability scores indicate that DigitalOcean, Dimension Data and Rackspace VMs had high CPU & memory performance fluctuations, as shown by their relatively large range of performance scores in *Figure 2.3*. For performance variability score calculation information, see Methodology: Performance.

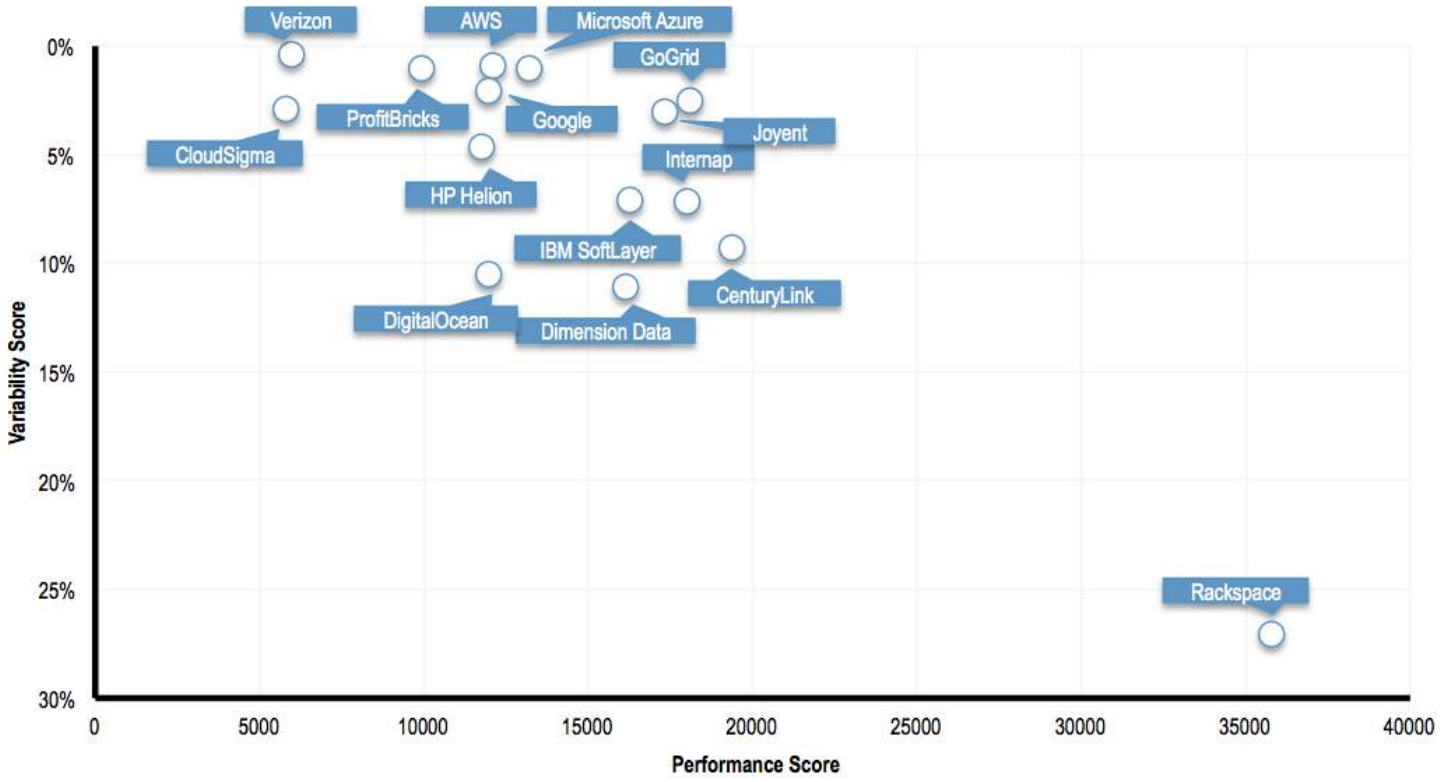
Table 2.2: Aggregated CPU & Memory Performance Variability – XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Variability	0.9%	9.3%	2.9%	10.5%	11.1%	2.5%	2.0%	4.6%	7.1%	7.1%	3.0%	1.0%	1.0%	27.1%	0.4%

It is worth noting that since the performance variability scores of different tasks vary within the same VM, an average variability score can only be seen as a rough indication of a provider VM's overall fluctuation. For specific variability information for individual tasks, see Appendix: Individual Tasks.

Figure 2.4 is a matrix incorporating both the performance scores and the variability scores of every VM. The x-axis shows the median CPU & memory performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the CPU & memory performance variability, with the more stable VMs above the less stable VMs. In the top right corner are providers with both high performance and high stability. Most VMs have a performance score between 5000 and 20000 with variability lower than 7%.

Figure 2.4: CPU & Memory Performance-Variability Matrix – XLarge VMs



Aggregated CPU Performance Analysis

Cloud Spectator aggregated the scores of all CPU integer and CPU floating point tasks to form the CPU performance scores. Table 2.3 shows the minimum, 5th percentile, median, 95th percentile, and maximum CPU performance scores as well as CPU performance variability scores, which were calculated by averaging the variability scores of all CPU tasks. For test information, please refer to the Methodology: Performance section; for aggregation information, please see Appendix: Score Aggregation; for performance variability score calculation information, see Methodology: Performance.

Table 2.3: Aggregated CPU Performance and Variability Scores – XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	12838	14719	4834	6927	10865	19241	10322	10501	12152	15243	16342	12843	9861	28825	6433
5th Per.	13860	17645	5842	10028	13972	21356	13601	12745	17093	18999	19666	15282	11432	31741	6548
Median	**14063**	**22292**	**6775**	**13428**	**19120**	**22068**	**13974**	**13399**	**19486**	**20396**	**20571**	**15563**	**11758**	**42033**	**6686**
95th Per.	14153	22764	7380	15491	20036	22549	14189	13928	19622	21267	20788	15673	11963	46241	6812
Max.	14249	22967	7720	19109	20205	23175	14461	14440	19688	21947	20870	15761	12146	46886	6924
Variability	0.6%	10.2%	3.0%	10.8%	12.5%	2.5%	1.8%	2.9%	8.2%	4.9%	2.9%	1.2%	1.1%	30.0%	0.4%

The CPU performance and variability scores are similar to the CPU & memory scores, given that the CPU & memory scores consisted mainly of CPU scores. The CPU & memory performance scores and CPU performance scores are not comparable numerically, i.e., a score of 2000 in CPU & memory performance is not the same as a score of 2000 in CPU performance, because of the difference in calculation process. CenturyLink, DigitalOcean, Dimension Data and Rackspace VMs exhibited a high degree of CPU performance fluctuation. The performance ranking with variability patterns is shown in *Figure 2.5*.

Figure 2.5: CPU Performance Percentile Graph – XLarge VMs – Ranked by Median

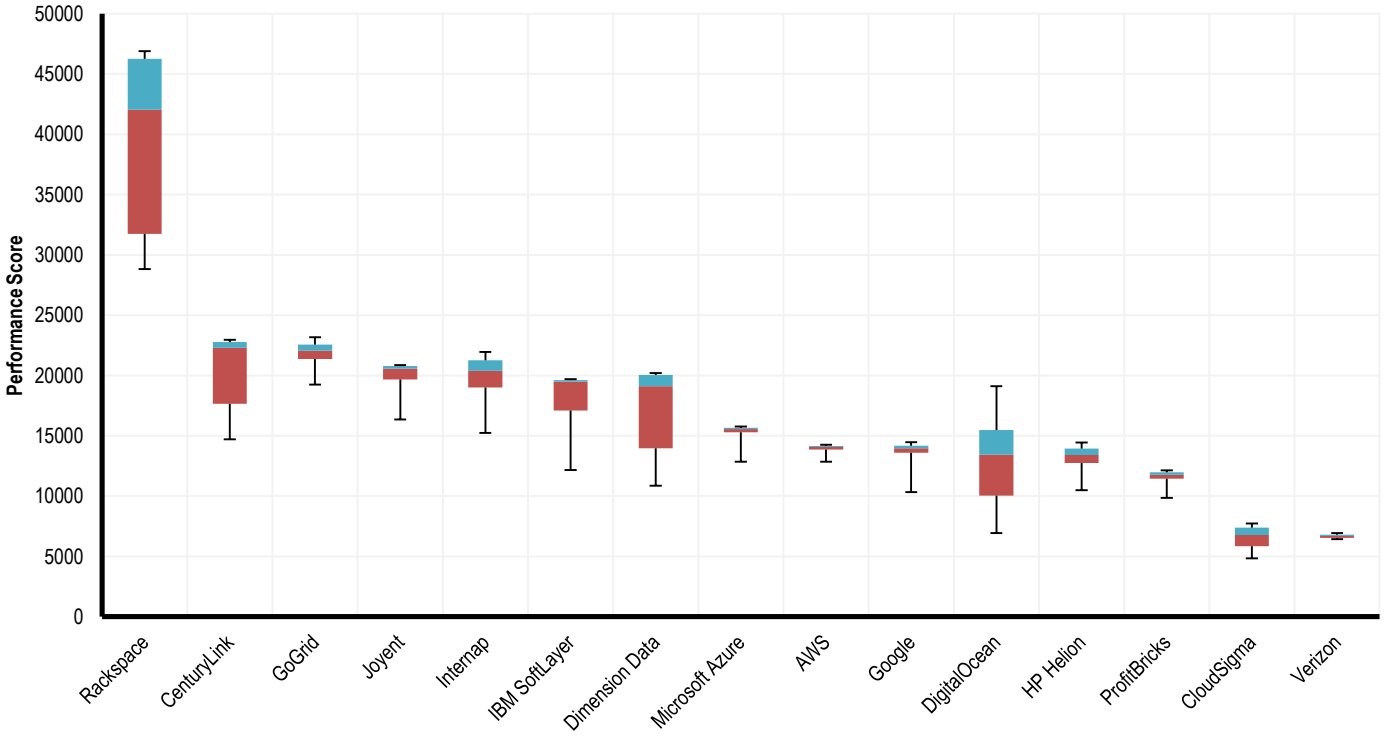
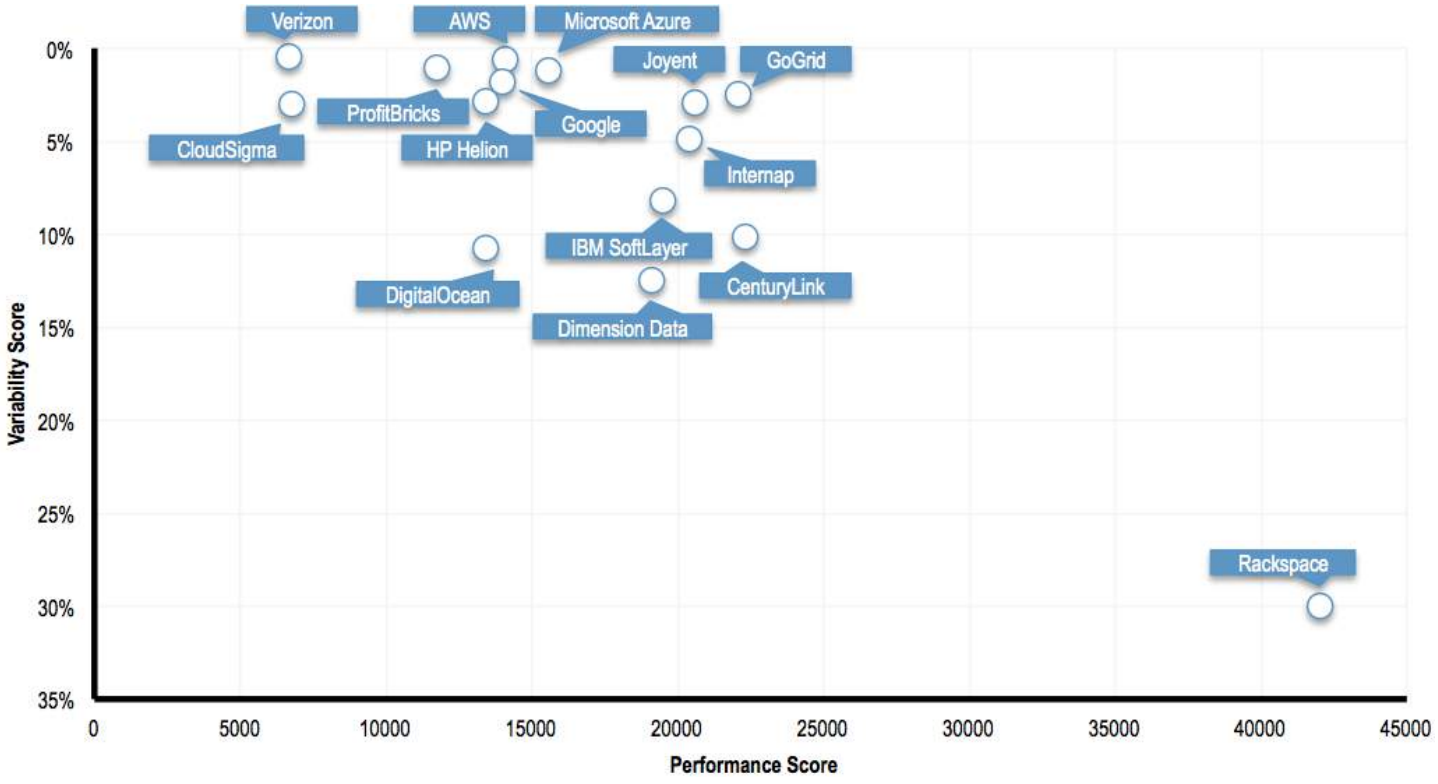


Figure 2.5 shows that Rackspace, CenturyLink and GoGrid are the top three providers for XLarge VM CPU performance. It is important to keep in mind that the VMs from Rackspace and GoGrid were 16 vCPU machines, while 8 vCPU machines were used on the remaining providers based on Cloud Spectator's selection criteria consistent with that of the *Cloud Vendor Benchmark 2015 Part 1: Pricing* report. For detailed information, see Preface: VM Configurations and Pricing.

CenturyLink, DigitalOcean, Dimension Data and Rackspace VMs displayed high CPU performance variability, while AWS, Microsoft Azure, ProfitBricks and Verizon VMs showed high stability with their variability scores being equal to or lower than 1.5%. Since the performance variability scores of different tasks vary within the same VM, an average variability score can only be seen as a rough indication of a provider VM's overall fluctuation. For specific variability information for individual tasks, see Appendix: Individual Tasks.

The CPU performance-variability matrix is shown in *Figure 2.6*. The x-axis shows the median CPU performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the CPU performance variability, with the more stable VMs above the less stable VMs. In the top right corner are VMs with both high performance and high stability. Most VMs have a performance score between 5000 and 20000 with variability lower than 7%.

Figure 2.6: CPU Performance-Variability Matrix – XLarge VMs



Aggregated Memory Performance Analysis

Cloud Spectator aggregated the scores of all memory tasks to form the memory performance scores. *Table 2.4* shows the minimum, 5th percentile, median, 95th percentile, and maximum memory performance scores as well as memory performance variability scores, which were calculated by averaging variability scores of all memory tasks. For test information, please refer to the Methodology: Performance section; for aggregation information, please see Appendix: Score Aggregation; for performance variability score calculation information, see Methodology: Performance.

Table 2.4: Aggregated Memory Performance and Variability Scores – XLarge VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	2734	6157	1092	4436	1174	1607	2386	2846	3401	5867	3525	3580	2353	9238	3034
5th Per.	3858	7236	1652	5256	4194	1969	3529	3635	3414	6812	3957	3756	2426	9908	3062
Median	**4205**	**7688**	**1808**	**6051**	**4264**	**2146**	**3858**	**5079**	**3444**	**8423**	**4381**	**3804**	**2492**	**10763**	**3086**
95th Per.	4292	7760	1870	6586	4308	2301	4055	5846	3530	9522	4457	3849	2559	11303	3108
Max.	4333	7795	1917	7056	4332	2361	4195	6276	3550	9752	4508	3908	2766	11573	3121
Variability	3.0%	4.4%	2.2%	8.8%	3.0%	2.9%	3.4%	14.9%	0.7%	20.0%	3.4%	0.0%	0.8%	10.1%	0.0%

Similar to what was mentioned in the CPU performance section, the CPU & memory performance scores and memory performance scores are not comparable numerically, i.e., a score of 2000 in CPU & memory performance is not the same as a score of 2000 in memory performance, because of the difference in calculation process. HP Helion, Internap and Rackspace VMs exhibited high memory performance fluctuation. The performance ranking with variability patterns is shown in *Figure 2.7*.

Figure 2.7: Memory Performance Percentile Graph – XLarge VMs – Ranked by Median

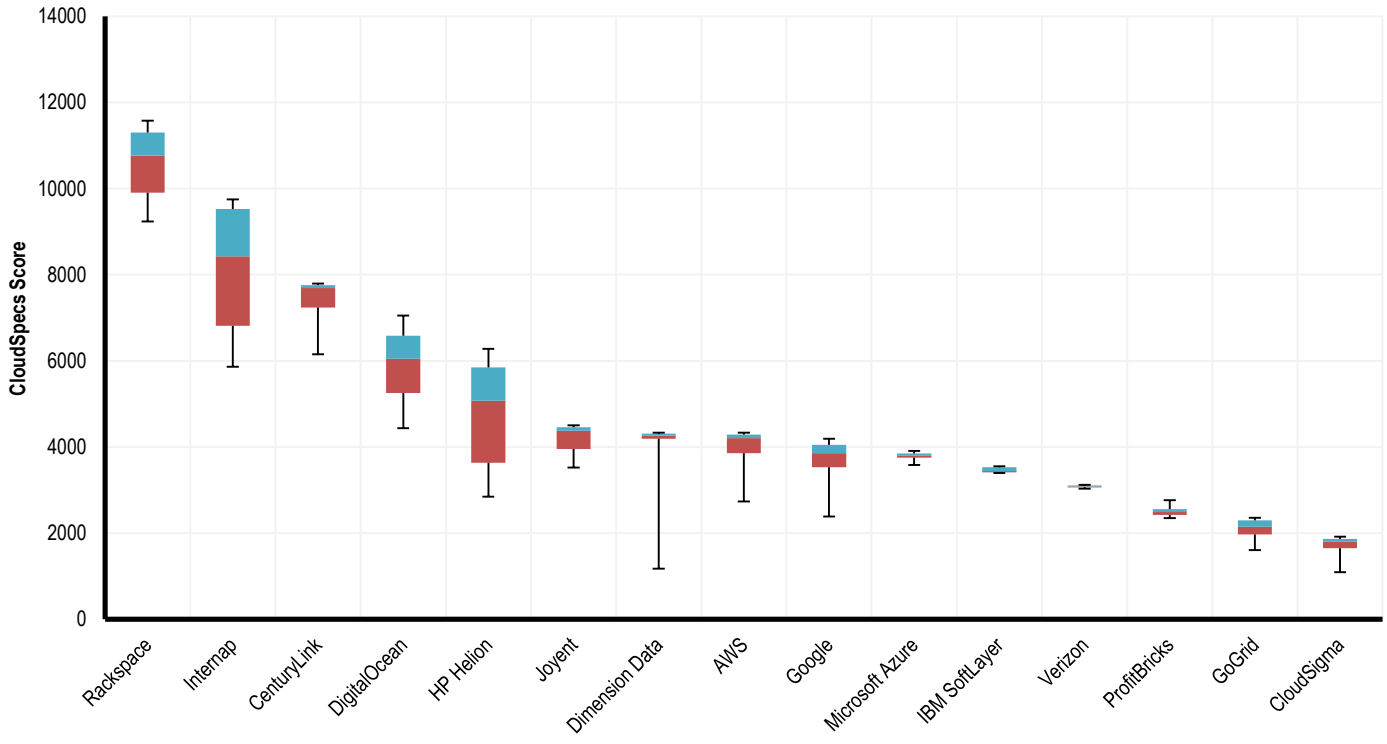
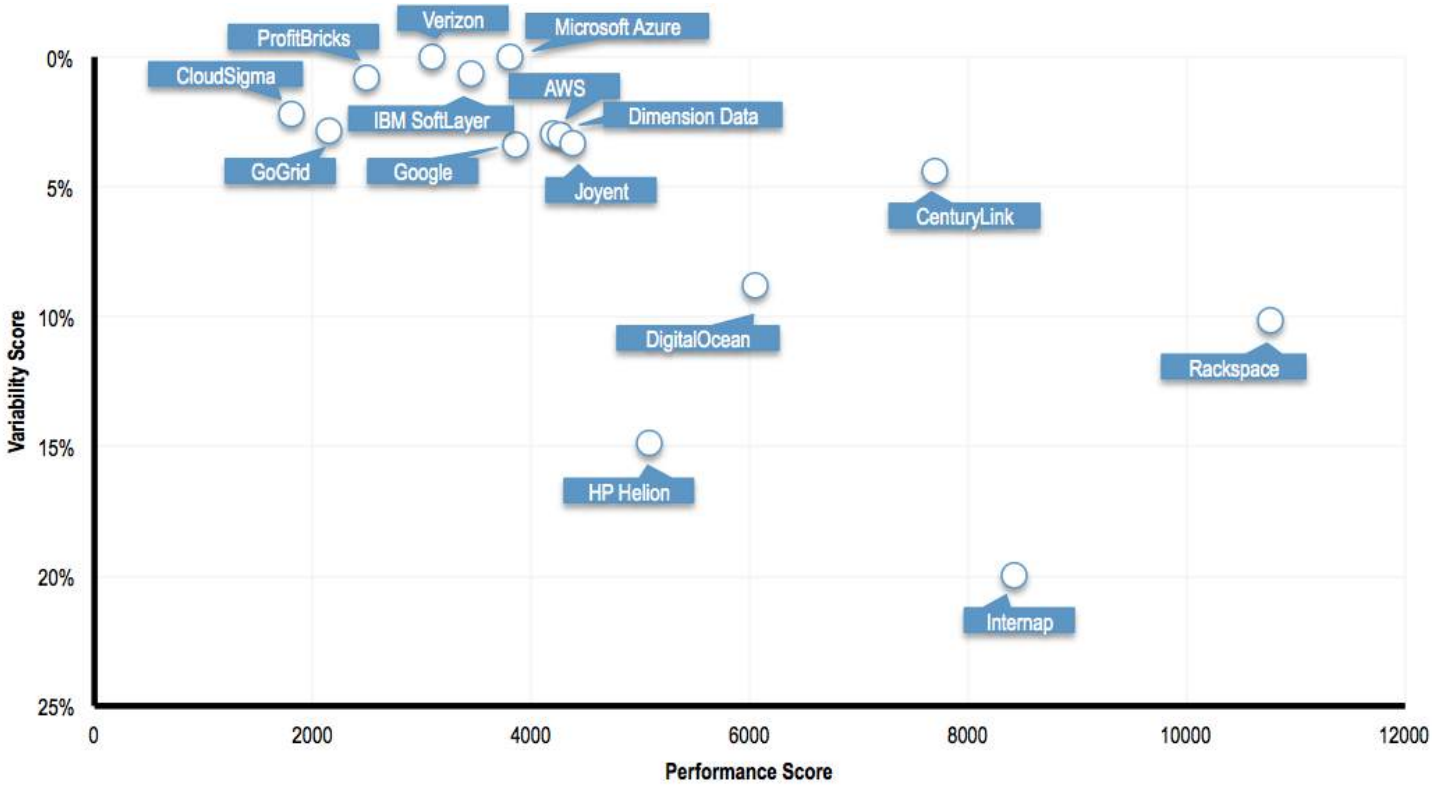


Figure 2.7 shows that Rackspace, Internap and CenturyLink are the top three providers for XLarge VM memory performance. HP Helion, Internap and Rackspace VMs displayed high memory performance variability, while IBM SoftLayer, Microsoft Azure, ProfitBricks and Verizon VMs showed high stability with their variability scores being equal to or lower than 1%. Since the performance variability scores of different tasks vary within the same VM, an average variability score can only be seen as a rough indication of a provider VM's overall fluctuation. For specific variability information for individual tasks, see Appendix: Individual Tasks.

The memory performance-variability matrix is shown in *Figure 2.8*. The x-axis shows the median memory performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the memory performance variability, with the more stable VMs above the less stable VMs. In the top right corner are providers with both high performance and high stability. Most VMs have a performance score between 2000 and 5000 with variability lower than 5%.

Figure 2.8: Memory Performance-Variability Matrix – XLarge VMs



Individual Task Performance Analysis

Cloud Spectator conducted analysis for each task tested in this report to show the performance rankings and performance fluctuation for all provider VMs tested. Percentile graphs and information tables are produced and can be found in Appendix: Individual Tasks. In general, the AES, SHA1, PNG Decompression, Sobel, Lua, SFFT, DFFT, N Body and STREAM Copy tasks yielded larger overall variability within the VMs, while smaller fluctuations were observed for the rest of the tasks. The VM rankings are relatively stable across tasks within the same categories (i.e. integer, floating point or memory), while some changes in rankings can be observed across the categories.

On an individual level, Rackspace, GoGrid, CenturyLink and Internap VMs had the highest performance rankings across all providers for the majority of tasks. Rackspace's VM displayed the highest performance output for all 27 tasks, with its median performance scores sometimes nearly doubling the next VM in ranking. GoGrid's VM ranked second in 16 out of 27 tasks, and exhibited high scores for all but the AES task.

CenturyLink, DigitalOcean, Dimension Data and Rackspace VMs displayed recurring fluctuations in all tasks included in the testing. A summary of their variability scores is provided in Table 2.5:

Table 2.5: High Variability VM Summary – XLarge VMs

	High Variability Score*	Low Variability Score*	Average Variability Score	Variability Pattern
CenturyLink	17.2%	3.3%	9.3%	Mostly negative fluctuations
DigitalOcean	18.1%	6.1%	10.5%	Mostly negative and neutral fluctuations
Dimension Data	17.1%	3.0%	11.1%	Mostly negative fluctuations
Rackspace	41.1%	7.4%	27.1%	Mostly negative and neutral fluctuations

**High/low variability scores were obtained by eliminating the max/min scores and selecting the second highest/lowest scores of each VM. This procedure ensures a more realistic score range, which shows general trends without being skewed by extreme scores.*

The CenturyLink VM showed an average variability of 9.3%, with 90% of the variability scores ranging between 3.3% and 17.2%, mostly negative fluctuations; the DigitalOcean VM showed an average variability of 10.5%, with 90% of the variability scores ranging between 6.1% and 18.1%, mostly negative and neutral fluctuations; the Dimension Data VM showed an average variability of 11.1%, with 90% of the variability scores ranging between 3.0% and 17.1%, mostly negative fluctuations; and the Rackspace VM showed an average variability of 27.1%, with 90% of the variability scores ranging between 7.4% and 41.1%, mostly negative and neutral fluctuations as well. All variability scores can be viewed in the performance analysis tables. These recurring fluctuations across tasks explain the aggregated performance variations exhibited by CenturyLink, DigitalOcean, Dimension Data and Rackspace VMs, which resulted in the aggregated performance ranking changes when comparing between the low scores and high scores. For variability calculation information, see Methodology: Performance.

AWS, Microsoft Azure, ProfitBricks and Verizon VMs showed little fluctuation in all tasks included in the testing. A summary of their performance fluctuation is provided in Table 2.6:

Table 2.6: Low Variability VM Summary – XLarge VMs

	High Variability Score (95%)	Low Variability Score (5%)	Average Variability Score	Variability Pattern
AWS	2.9%	0.0%	0.9%	-
Microsoft Azure	2.0%	0.0%	1.0%	-
ProfitBricks	1.8%	0.5%	1.0%	-
Verizon	0.8%	0.0%	0.4%	-

The AWS VM showed an average variability of 0.9%, with 90% of the variability scores ranging between 0.0% and 2.9%; the Microsoft Azure VM showed an average variability of 1.0%, with 90% of the variability scores ranging between 0.0% and 2.0%; the ProfitBricks VM showed an average variability of 1.0%, with 90% of the variability scores ranging from 0.5% and 1.8%; and the Verizon VM showed an average variability of 0.4%, with 90% of the variability scores ranging from 0.0% and 0.8%. No variability patterns are attributed to VMs with variability scores less than 5%. All variability scores can be viewed in the performance analysis tables. The small degree of variability of these provider VMs indicates stable aggregate performance outputs during the 24-hour testing. For variability calculation information, see Methodology: Performance.

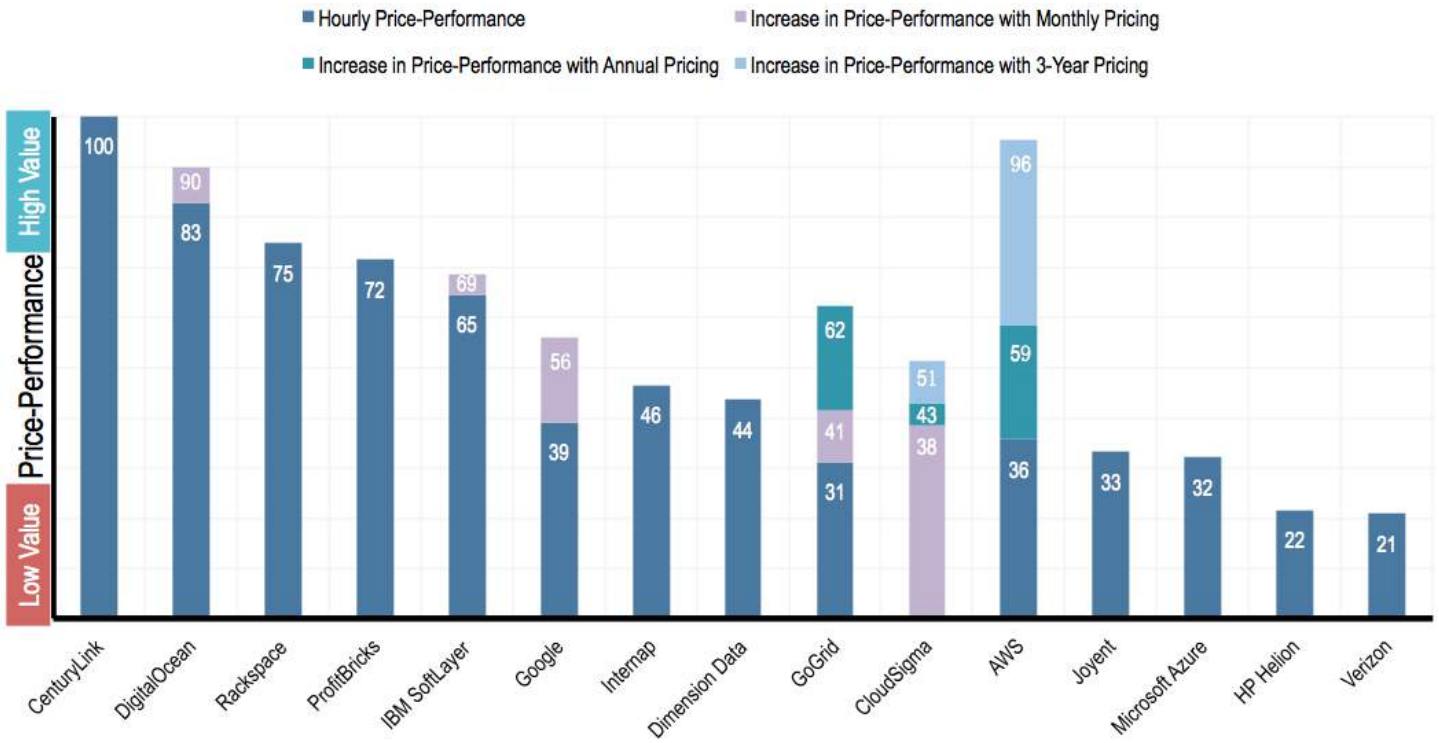
CenturyLink, Dimension Data, IBM SoftLayer and Rackspace VMs exhibited performance outliers on the lower end for many of the tasks tested. This implies that some extremely low, but infrequent scores were detected over the course of the 24-hour continuous testing.

PRICE-PERFORMANCE COMPARISON

Price-performance value is illustrated by Cloud Spectator's index – the CloudSpecs Score™. The CloudSpecs Score™ is calculated by combining performance scores with hourly, monthly, annual and 3-year pricing. In this study, the aggregated CPU & memory score was used to represent performance. For details on the CloudSpecs Score™ calculation, see Methodology: Price-Performance; for VM performance information, see Performance Comparison; for VM pricing information, see Preface: VM Configurations and Pricing.

Figure 3.1 shows the price-performance comparison of VMs with hourly, monthly, annual and 3-year pricing using the median aggregated CPU & memory performance scores. The CloudSpecs Score™ in *Figure 3.1* was calculated using the equivalent hourly pricing of all pricing commitment durations, and referenced the highest price-performance score of all price-performance values as 100. The VM ranking is based on the monthly CloudSpecs Score™; monthly, annual and 3-year CloudSpecs Score™ increases are added on top of the hourly scores.[1]

Figure 3.1: Median CPU & Memory Aggregated Price-Performance of All Pricing Models – XLarge VMs – Ranked in Monthly Values



**CloudSigma's hourly price-performance is not calculated because its burst hourly pricing is not a set value. See Methodology: Key Considerations for more details.*

For the median-score performance results, the CenturyLink VM had the highest price-performance values. DigitalOcean, Rackspace and ProfitBricks VMs exhibited high price-performance value for hourly and monthly pricing, and the AWS VM exhibited high price-performance values for longer-term pricing where discounts applied. AWS, CloudSigma, DigitalOcean, GoGrid, Google and IBM SoftLayer VMs all showed increased price-performance with long-term discounted pricing. AWS, CloudSigma, GoGrid and Google VMs' long-term price-performance resulted in ranking increases.

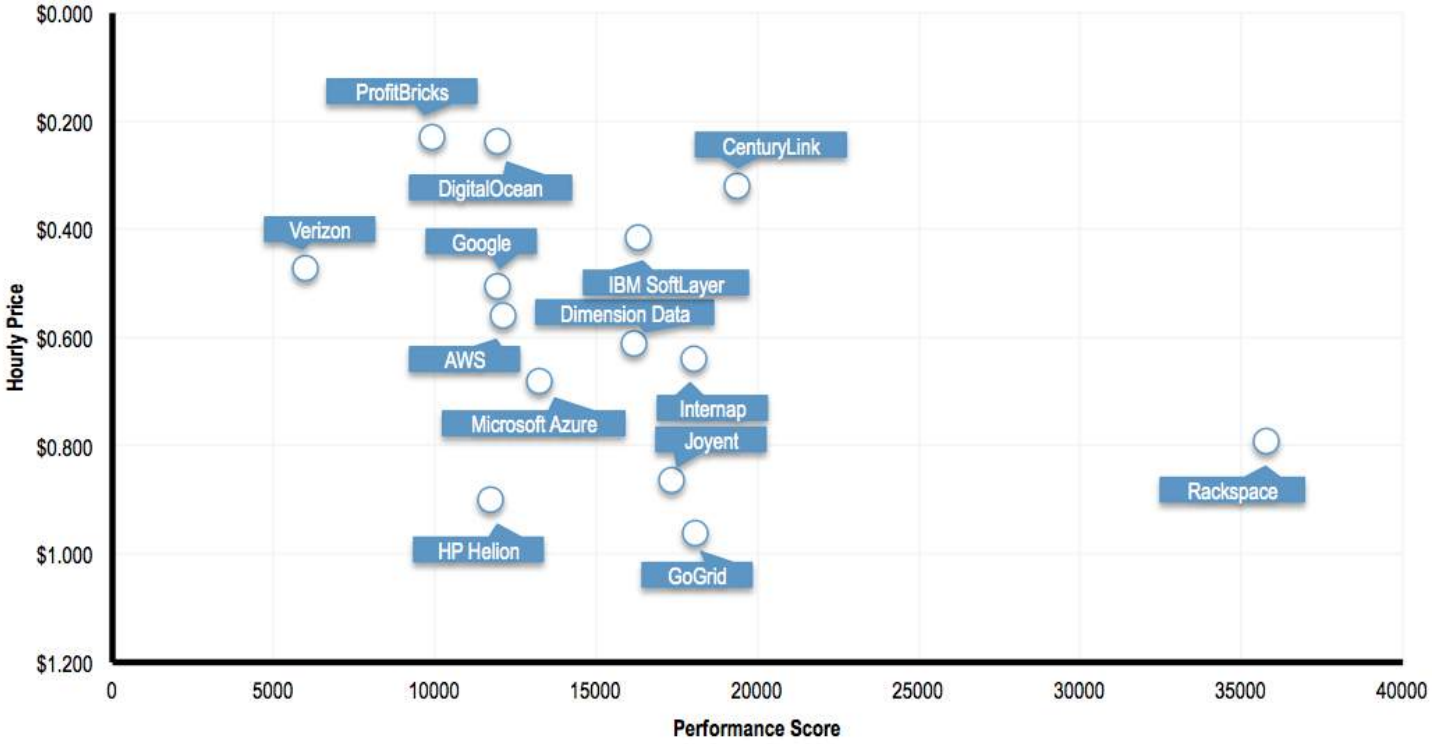
The graphs on the next few pages show the relationship between price and performance for hourly, monthly, annual and 3-year pricing individually, using median performance data, and display the CloudSpecs Score™ price-performance comparison for each pricing model using low scores, median scores and high scores (correspondingly 5th percentile, median and 95th percentile performance values) separately. In each graph, the CloudSpecs Score™ was calculated using the highest price-performance value within the given commitment timeframe (hourly, monthly, annual or 3-year). The CloudSpecs Scores™ of different graphs are not comparable to each other.

[1] In this case, the longer-term pricing models always produce CloudSpecs Scores™ equivalent to larger or than the shorter-term pricing models, because longer-term prices are always equal to or less than shorter-term prices.

Price-Performance with Hourly Pricing

Figure 3.2 presents hourly VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the hourly cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.2: Price-Performance Matrix with Hourly Pricing – XLarge VMs



**CloudSigma's hourly price-performance is not calculated because its burst hourly pricing is not a set value. See Methodology: Key Considerations for more details.*

Figure 3.3 – 3.5 are price-performance rankings using the CloudSpecs Score™ calculation. The providers are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and hourly prices.

Figure 3.3: Low-Score Category Price-Performance – XLarge VMs (Hourly)

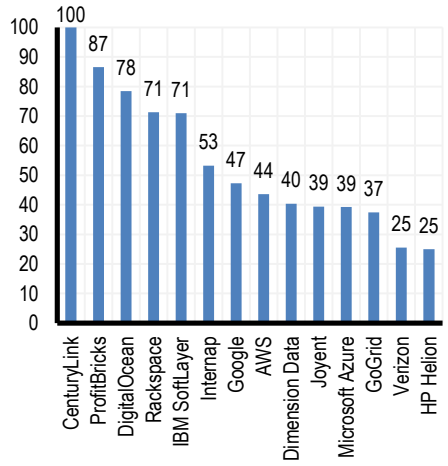


Figure 3.4: Median-Score Category Price-Performance – XLarge VMs (Hourly)

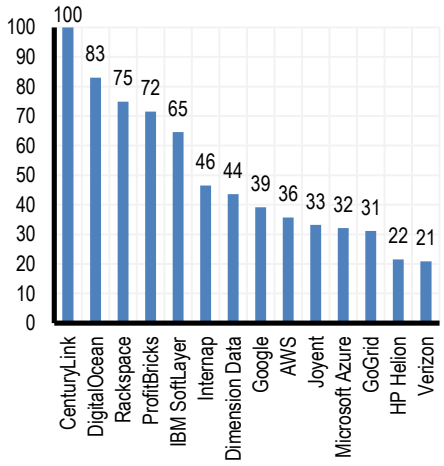
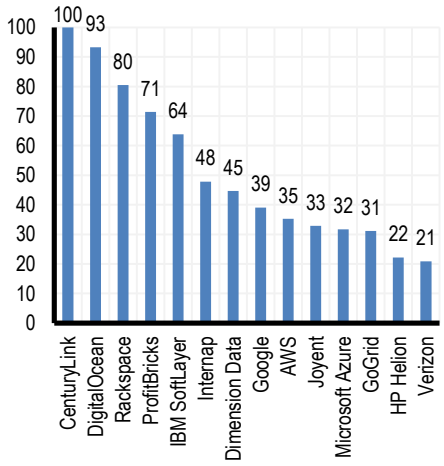


Figure 3.5: High-Score Category Price-Performance – XLarge VMs (Hourly)



**CloudSigma's hourly price-performance is not calculated because its burst hourly pricing is not a set value. Methodology: Key Considerations for more details.*

Price-Performance with Monthly Pricing

Figure 3.6 presents monthly VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the monthly cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.6: Price-Performance Matrix with Monthly Pricing – XLarge VMs

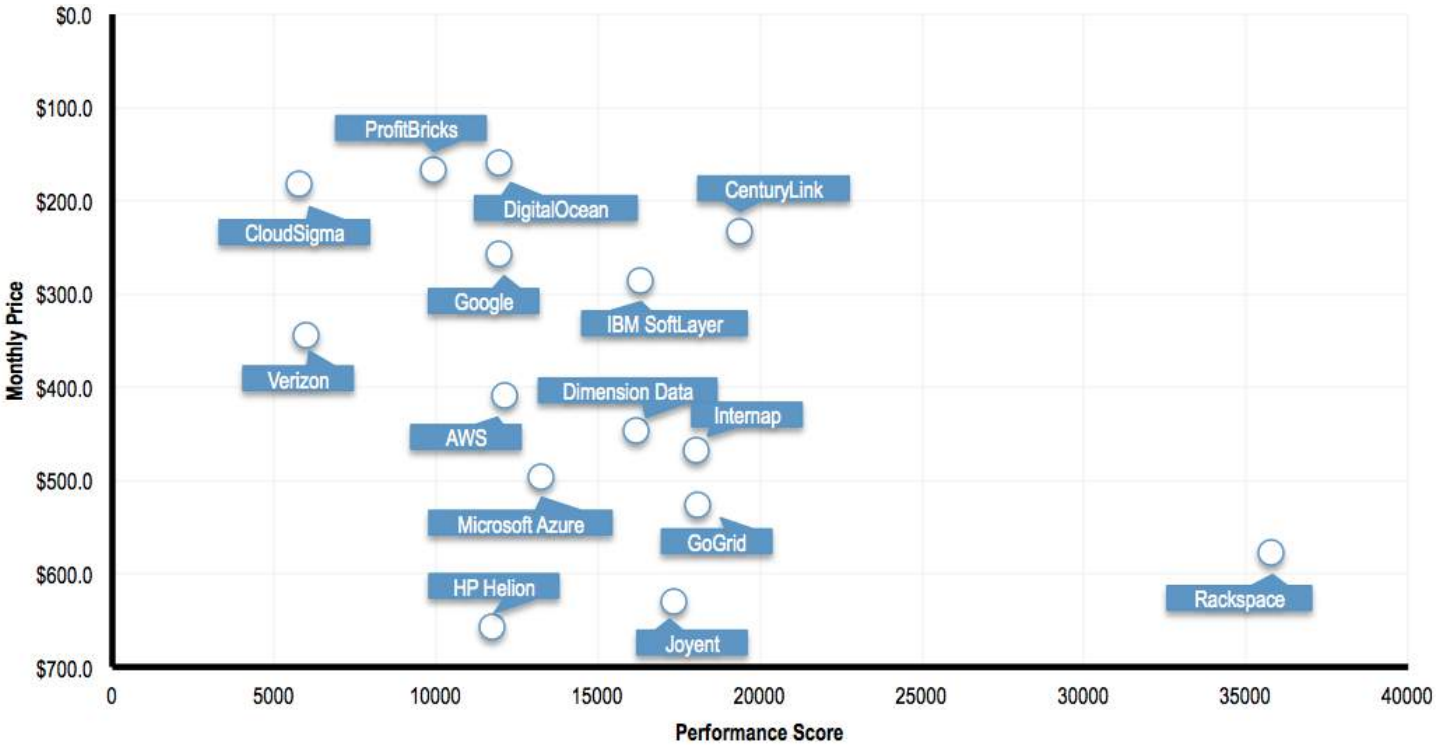


Figure 3.7 – 3.9 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and monthly prices.

Figure 3.7: Low-Score Category Price-Performance – XLarge VMs (Monthly)

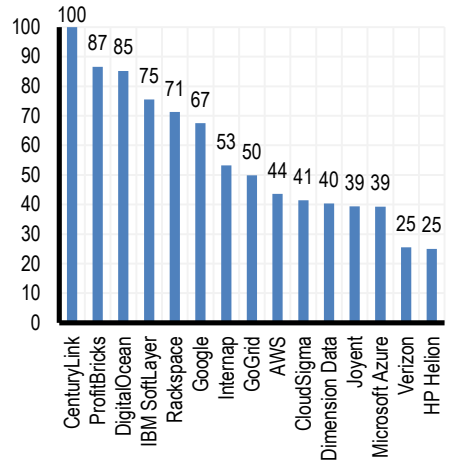


Figure 3.8: Median-Score Category Price-Performance – XLarge VMs (Monthly)

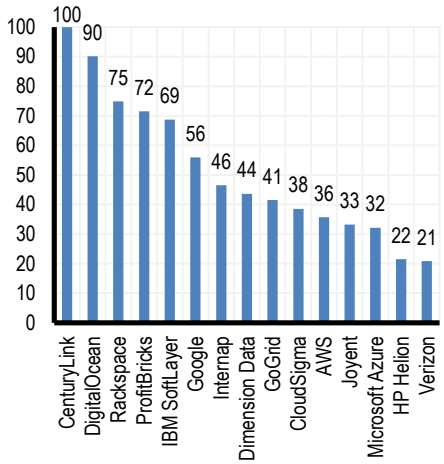
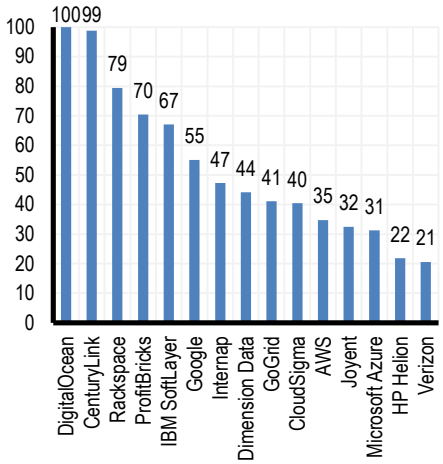


Figure 3.9: High-Score Category Price-Performance – XLarge VMs (Monthly)



Price-Performance with Annual Pricing

Figure 3.10 presents annual VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the annual cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.10: Price-Performance Matrix with Annual Pricing – XLarge VMs

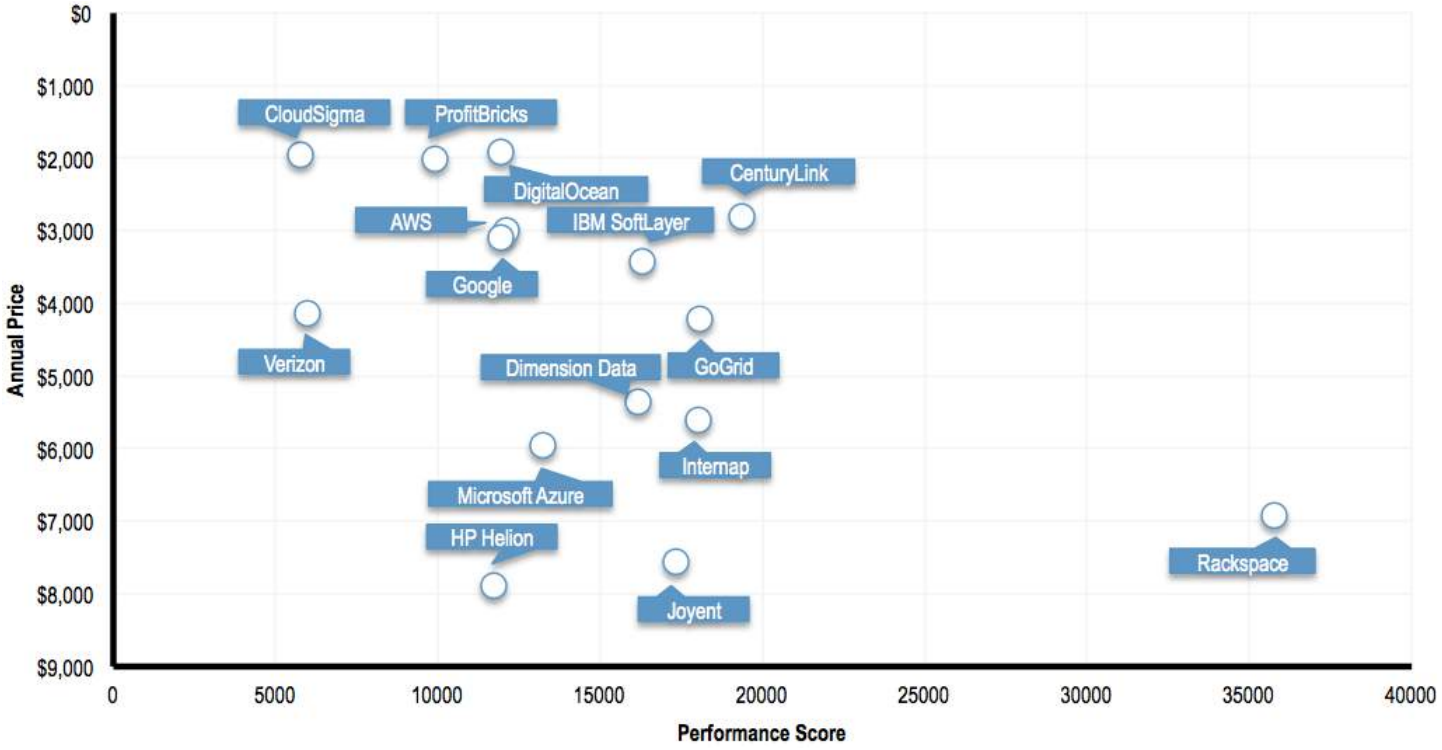


Figure 3.11 – 3.13 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and annual prices.

Figure 3.11: Low-Score Category Price-Performance – XLarge VMs (Annual)

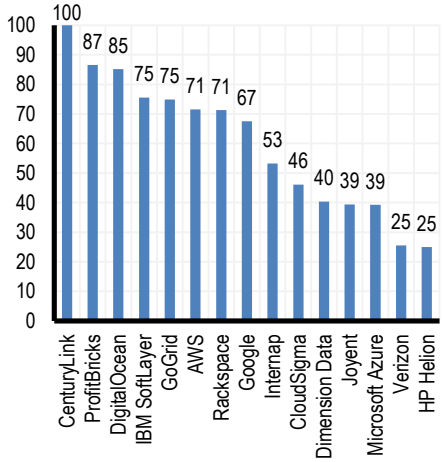


Figure 3.12: Median-Score Category Price-Performance – XLarge VMs (Annual)

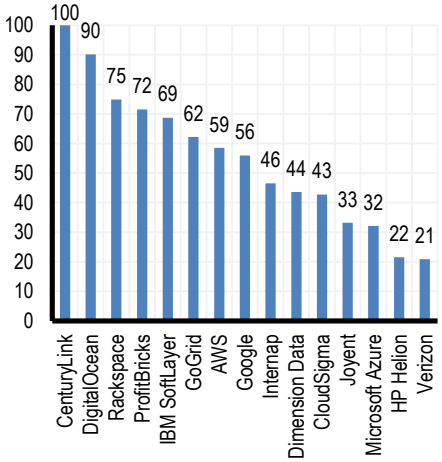
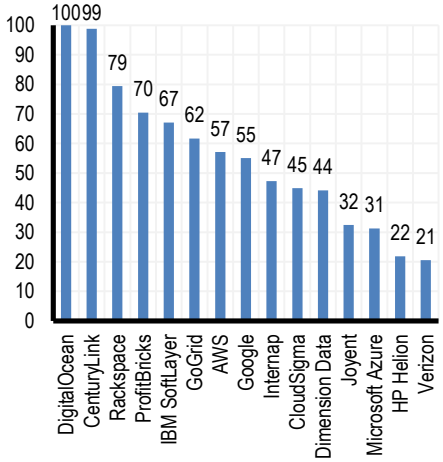


Figure 3.13: High-Score Category Price-Performance – XLarge VMs (Annual)



Price-Performance with 3-Year Pricing

Figure 3.14 presents 3-year VM prices and their performance values. The x-axis represents the median CPU & memory performance scores, with lower scores on the left and higher scores on the right. The y-axis represents the 3-year cost of the VMs, with lower prices on the top and higher prices on the bottom.

Figure 3.14: Price-Performance Matrix with 3-Year Pricing – XLarge VMs

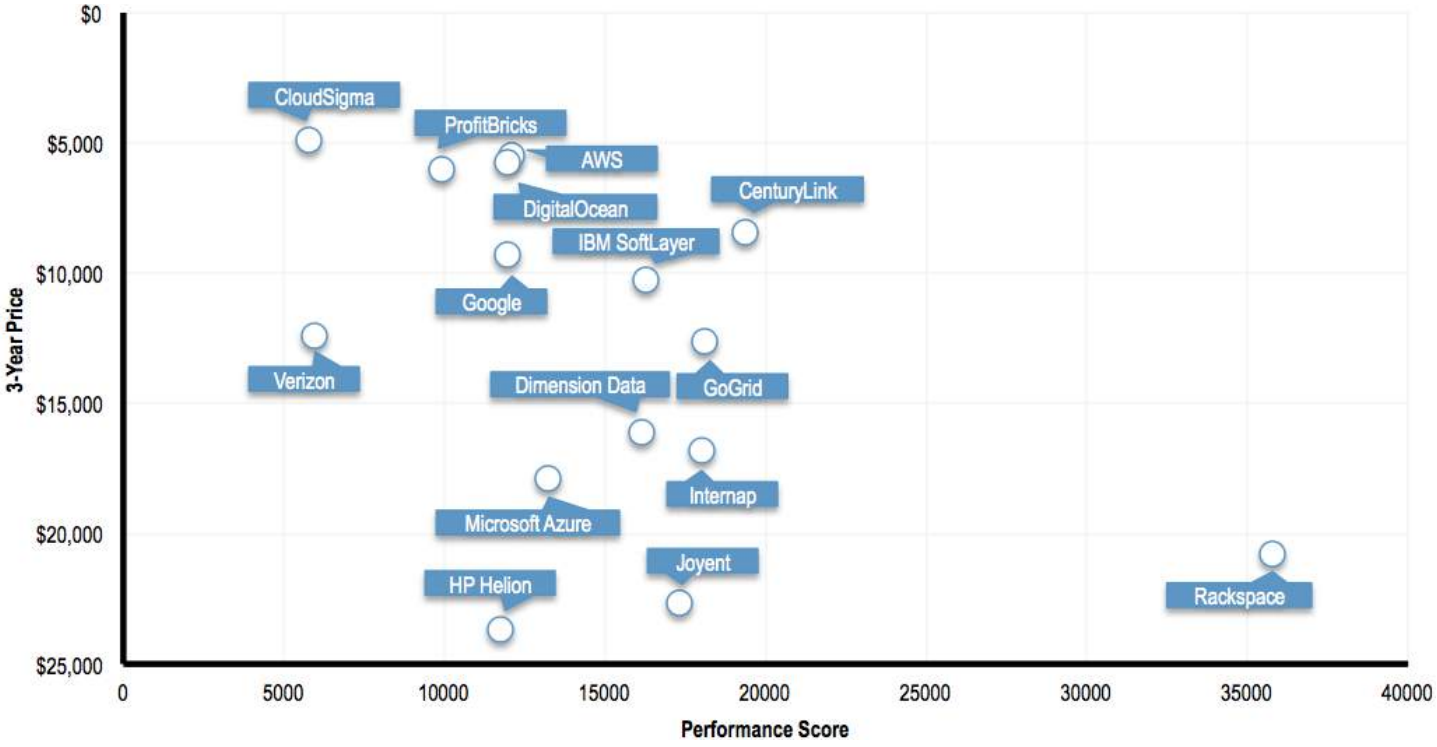


Figure 3.15 – 3.17 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and 3-year prices.

Figure 3.15: Low-Score Category Price-Performance – XLarge VMs (3-Year)

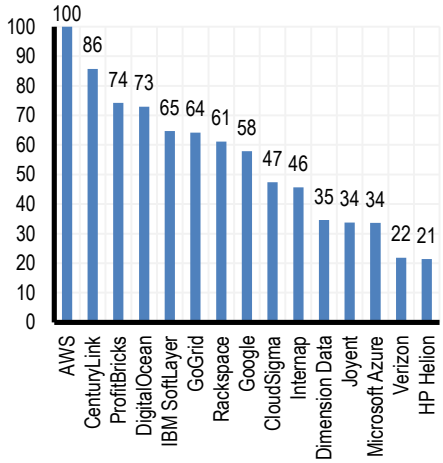


Figure 3.16: Median-Score Category Price-Performance – XLarge VMs (3-Year)

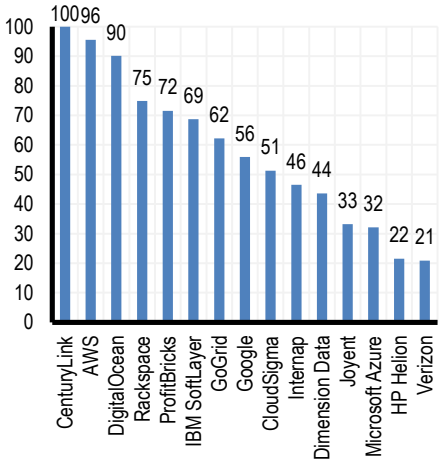
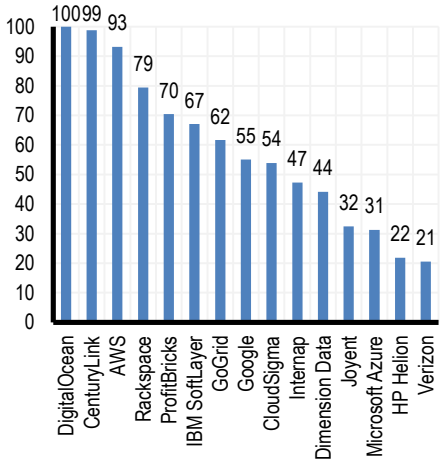


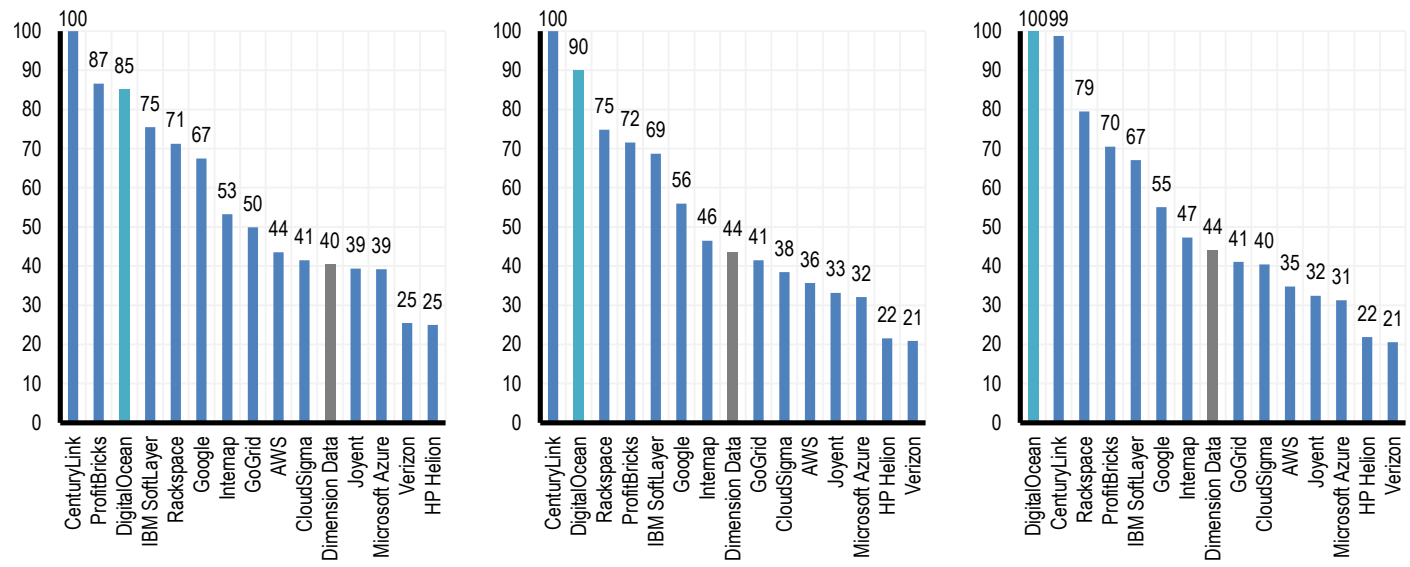
Figure 3.17: High-Score Category Price-Performance – XLarge VMs (3-Year)



Overall, CenturyLink and DigitalOcean VMs had the highest rankings in low, median and high CloudSpecs scores of all pricing intervals. The CenturyLink VM led most Low- and Median-Score Categories, and the DigitalOcean VM had the highest price-performance in the High-Score Categories. For the 3-year low-score price-performance comparisons, the AWS VM ranked the highest with its 3-year discount pricing.

Changes in rankings can be seen when switching among the Low-, Median- and High-Score Categories, indicating large price-performance value ranges of some VMs during the testing period.

Figure 3.18: Comparing Price-Performance with Monthly Pricing – XLarge VMs



As illustrated below using the monthly examples, the DigitalOcean VM's price-performance ranking moved up from the Low-Score Category to the High-Score Category, and the Dimendion Data VM had higher price-performance ranking in the Median- and High-Score Categories than the Low-Score Category..

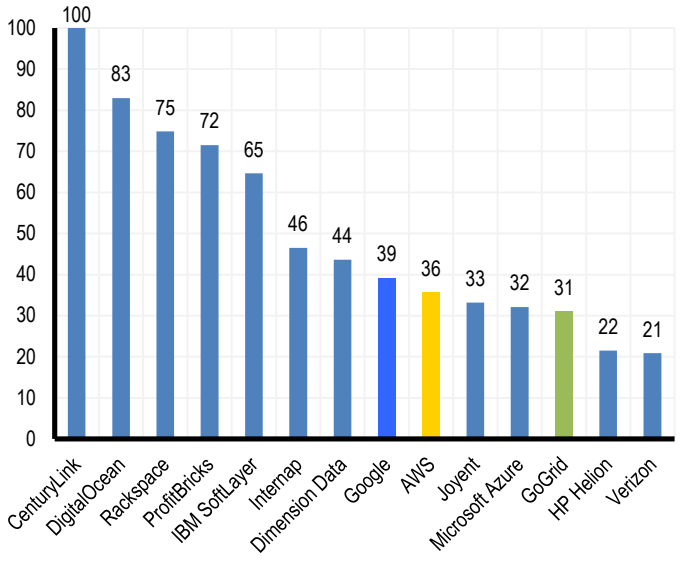
The price-performance value ranges reflected by the three categories are consistent with their performance variations, which are shown in the section Performance Comparison.

When viewing the graphs across pages, and as shown in *Figure 3.1*, commitment duration has an impact on price-performance ranking changes as well. In general, AWS, CloudSigma, GoGrid and Google VMs' price-performance rankings increase as the pricing structure changes to longer-term prices, because they all offer discounts that increase with longer time commitments (i.e., AWS offers a 39% discount on its annual pricing and a 63% discount on its 3-year pricing[2]; CloudSigma offers a 10% discount on its annual pricing and a 25% discount on its 3-year pricing; GoGrid offers a 25% discount on its monthly pricing and a 50% discount on its annual pricing; Google discounts pricing for persistent full usage). The trend is illustrated below using median performance as an example:

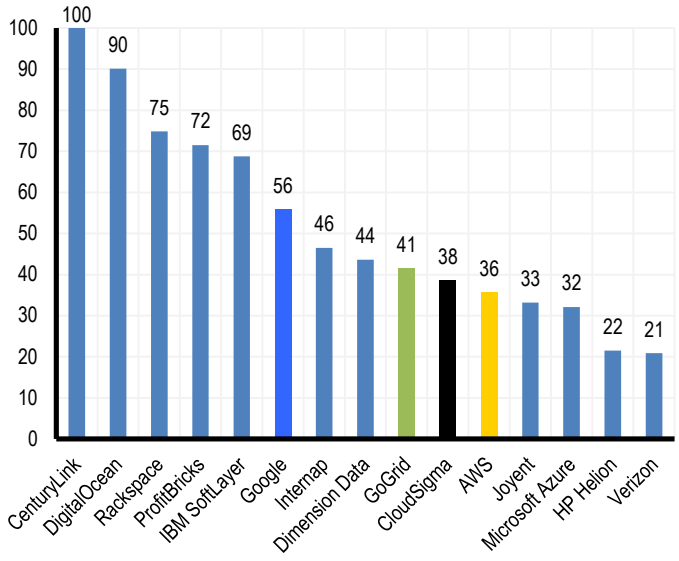
[2] This AWS discount information only applies to the m3.2xlarge instance at their Virginia data center assuming full payment upfront. Any changes in conditions may change the discount information for both annual and 3-year pricing.

Figure 3.19: Price-Performance with Median Scores – XLarge VMs

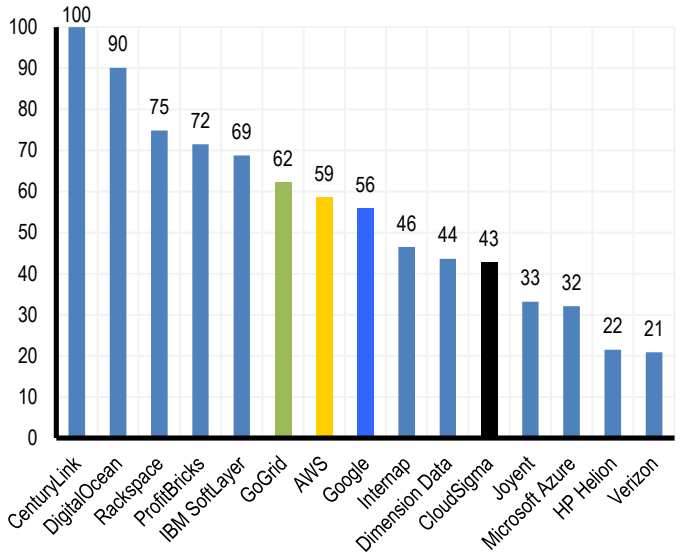
Hourly Price-Performance



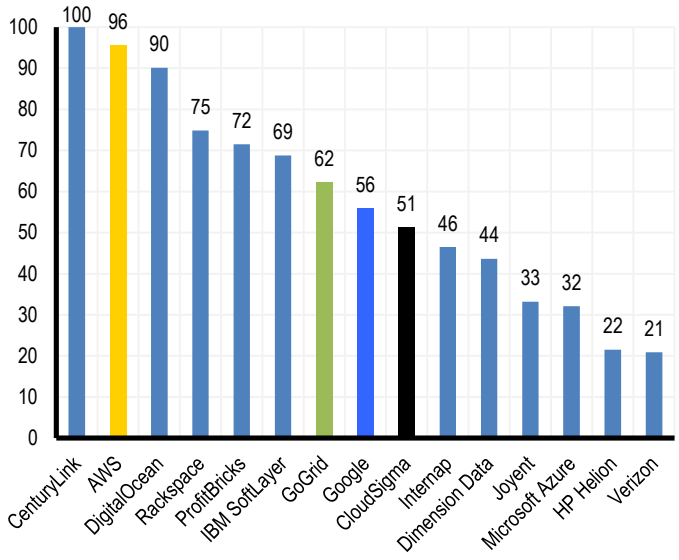
Monthly Price-Performanc



Annual Price-Performance



3-Year Price-Performance



AWS, CloudSigma, GoGrid and Google VMs' price-performance rankings increase as the pricing structure changes to longer-term prices, because they all offer discounts that increase with longer time commitments.

GENERAL OBSERVATIONS

As cloud adoption increases and more cloud users compare services, considering performance alongside price will help them lower their annual operating costs and achieve greater value. Deploying VMs with outstanding price-performance not only ensures value, but also enables optimized resource allocation and prevents IT overspending. In this report, Cloud Spectator tested the XLarge size VMs of 15 top providers in the industry and examined their performance and price-performance values against each other.

The results carry two key messages:

1. Both performance levels and performance variability can vary greatly among provider VMs of similar configurations.

The performance data in this report illustrates the discrepancies among VMs in both performance and variability, and shows that the differences between VMs can be significant when both performance and variability are measured, even if the provider VMs are selected with controlled configurations.

Understanding both the performance level and the severity of performance variation is critical to successfully operating certain applications in the cloud. Just as low performing machines may not satisfy application performance requirements, high performing but unstable machines may have diminished performance output periodically, which may fail to support the application's ability to run at full capacity. Thorough considerations should be applied to examine performance levels and performance variability when users are selecting cloud environments in order to optimize their application operations.

2. Comparing cloud provider VMs based on price, performance and price-performance yields different results.

When comparing the same set of provider VMs using price, performance and price-performance, the results may be quite different. Using Rackspace's XLarge VM as an example, while the VM ranks 13th in the monthly pricing comparison, its median performance output ranks 1st among the 15 providers, and its price-performance calculated using the data supporting the first two graphs ranks third. In this case, selecting the right criteria when comparing across the cloud industry is essential in helping users optimize their decision-making process and outcome.

Price-performance analysis is critical for choosing the best-fit VMs for specific use cases in order to avoid unnecessary IT overspending. Businesses looking for the most economical cloud infrastructure should examine the price and performance output of a targeted VM together to understand the performance per unit cost they can expect.

As the cloud industry continues to become more competitive, it is important to make data-driven decisions with sufficient and accurate information. If you have questions about comparing cloud provider VMs, please call or email Cloud Spectator at +1 617-300-0711 or contact@cloudspectator.com.

RELATED STUDIES

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APPENDIX

VM Sizing

The table below outlines the specific VMs used for each pricing and price-performance comparison. VMs outside the scope of the XLarge VM report are also included in the tables. For price-performance comparisons for Small, Medium, Large and 2XLarge VMs, see Cloud Vendor Benchmark 2015 Reports.

VM Size	Provider	Instance	vCPU	RAM	STORAGE (GB)
Small	AWS	t2.small	1	2	EBS only
	CenturyLink	customized	1	2	-
	CloudSigma	customized	1	2	50 SSD
	DigitalOcean	standard2	2	2	40 SSD
	Dimension Data	customized	1	2	-
	GoGrid	Standard Medium	2	2	100
	Google	n1-standard-1	1	3.75	-
	HP Helion	Standard Small	2	2	10
	IBM SoftLayer	customized	1	2	25
	Internap	B-1	1	4	20 SSD
	Internap (Windows)	A-2	2	2	40 SSD
	Joyent	standard3	1	3.75	123
	Joyent (Windows)	standard4	2	7.5	738
	Microsoft Azure	D1	1	3.5	50 SSD
	Microsoft Azure (Windows)	A2 Basic	2	3.5	60
	ProfitBricks	customized	1	2	-
	Rackspace	General1-2	2	2	40 SSD
	Verizon	3.5	1	3.5	-
Medium	AWS	t2.medium	2	4	EBS only
	CenturyLink	customized	2	4	-
	CloudSigma	customized	2	4	50 SSD
	DigitalOcean	standard4	2	4	60 SSD
	Dimension Data	customized	2	4	-
	GoGrid	Standard Large	4	4	200
	Google	n1-standard-2	2	7.5	-
	HP Helion	Standard Medium	2	4	50
	IBM SoftLayer	customized	2	4	25
	Internap	B-2	2	8	40 SSD
	Joyent	standard4	2	7.5	738
	Microsoft Azure	D2	2	7	100 SSD
	Microsoft Azure (Windows)	A3 Basic	4	7	120

	ProfitBricks	customized	2	4	-
	Rackspace	General1-4	4	4	80 SSD
	Verizon	4	2	4	-
Large	AWS	m3.xlarge	4	15	2 x 40 SSD
	CenturyLink	customized	4	8	-
	CloudSigma	customized	4	8	50 SSD
	DigitalOcean	standard5	4	8	80 SSD
	Dimension Data	customized	4	8	-
	GoGrid	Standard X-Large	8	8	400
	Google	n1-standard-4	4	15	-
	HP Helion	Standard Large	4	8	130
	IBM SoftLayer	customized	4	8	25
	Internap	B-4	4	15	80 SSD
	Joyent	Standard5	4	15	1467
	Microsoft Azure	D3	4	14	200 SSD
	Microsoft Azure (Windows)	A4 Basic	8	14	240
	ProfitBricks	customized	4	8	-
	Rackspace	General1-8	8	8	160 SSD
	Verizon	7	4	8	-
XLarge	AWS	m3.2xlarge	8	30	2 x 80 SSD
	CenturyLink	customized	8	16	-
	CloudSigma	customized	8	16	50 SSD
	DigitalOcean	highvol1	8	16	160 SSD
	Dimension Data	customized	8	16	-
	GoGrid	Standard XX-Large	16	16	800
	Google	n1-standard-8	8	30	-
	HP Helion	Standard 2XL	8	30	470
	IBM SoftLayer	customized	8	16	25
	Internap	B-8	8	30	160 SSD
	Joyent	High Storage1	8	32	7680
	Microsoft Azure	D4	8	28	400 SSD
	Microsoft Azure (Windows)	A7	8	56	605
	ProfitBricks	customized	8	16	-
	Rackspace	Compute1-30	16	30	-
	Verizon	11	8	16	-
2XLarge	AWS	r3.4xlarge	16	122	1 x 320 SSD
	CenturyLink	customized	16	32	-
	CloudSigma	customized	16	32	50 SSD
	DigitalOcean	highvol3	16	48	480 SSD
	Dimension Data	-	-	-	-
	GoGrid	High RAM 4XL	16	64	40

Google	n1-standard-16	16	60	-
HP Helion	Standard 8XL	16	120	1770
IBM SoftLayer	customized	16	32	25
Internap	B-16	16	60	320 SSD
Joyent	-	-	-	-
Microsoft Azure	D14	16	112	800 SSD
ProfitBricks	customized	16	32	-
Rackspace	Compute1-60	32	60	-
Verizon	-	-	-	-

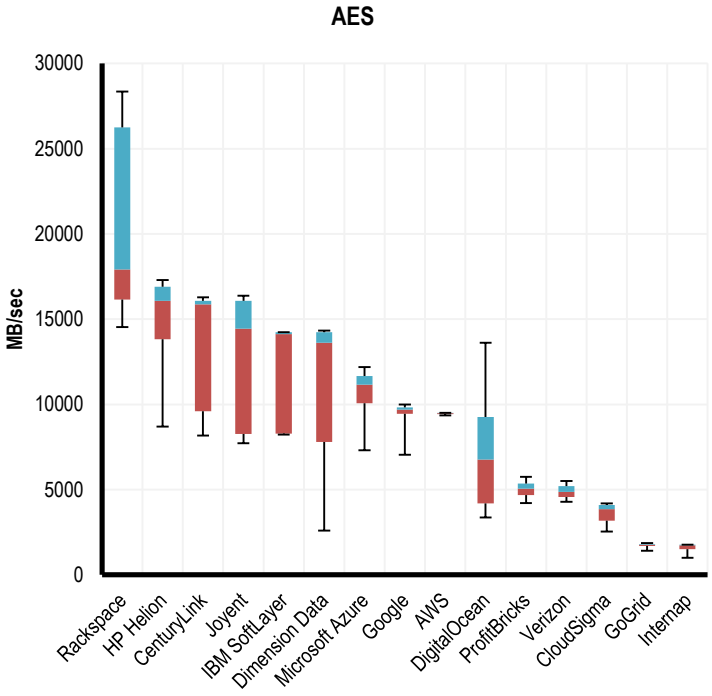
VM Processor Information

Provider	OS	Python Version	Processor (XLarge)
AWS	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2670 v2
CenturyLink	Ubuntu 14.04	2.7	Intel Xeon CPU E502650 v2
CloudSigma	Ubuntu 14.04	2.7	AMD Opteron Processor 6380
DigitalOcean	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2630L v2
Dimension Data	Ubuntu 14.04	2.7	Intel Xeon CPU E5-4650
GoGrid	Ubuntu 14.04	2.7	Intel Xeon X5650
Google	Ubuntu 14.04	2.7	Intel Xeon CPU
HP Helion	Ubuntu 14.04	2.7	Intel Core 2 Duo T7700
IBM SoftLayer	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2650 v2
Internap	Ubuntu 14.04	2.7	Common KVM processor
Joyent	Ubuntu 14.04	2.7	Intel Xeon E5645
Microsoft Azure	Ubuntu 14.04	2.7	AMD Opteron Processor 4171 HE
ProfitBricks	Ubuntu 14.04	2.7	AMD Opteron 62xx (Gen 4 Class Opteron)
Rackspace	Ubuntu 14.04	2.7	Intel Xeon CPU E5-2670 v2
Verizon	Ubuntu 14.04	2.7	Intel Xeon CPU E31265L

Individual Tasks

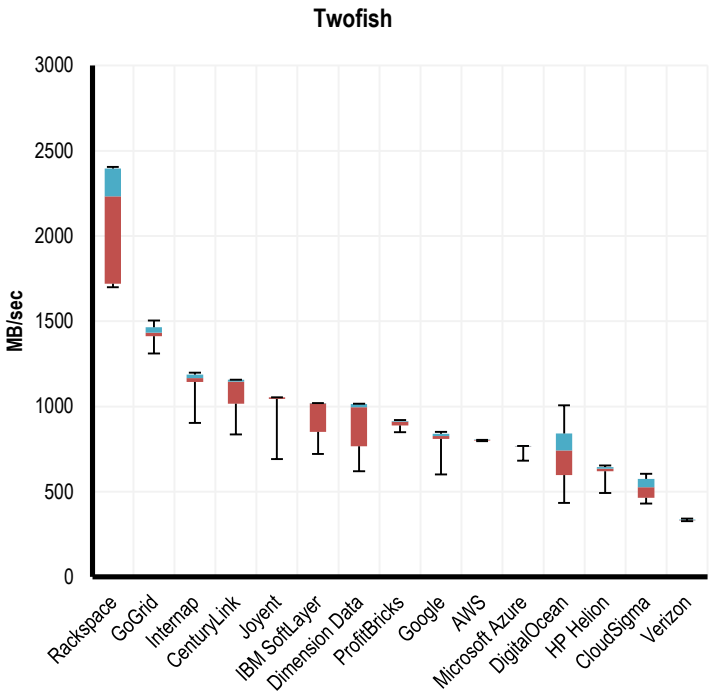
The following tables and graphs describe the performance ranking through each individual task. The rankings are from high to low based on median.

CPU Integer – AES: The AES workload encrypts a generated text string using the advanced encryption standard (AES). AES is used in security tools such as SSL, IPsec, and GPG. Geekbench uses the AES-NI instructions when they are available. When the AES-NI instructions are not available, Geekbench uses its own software AES implementation.



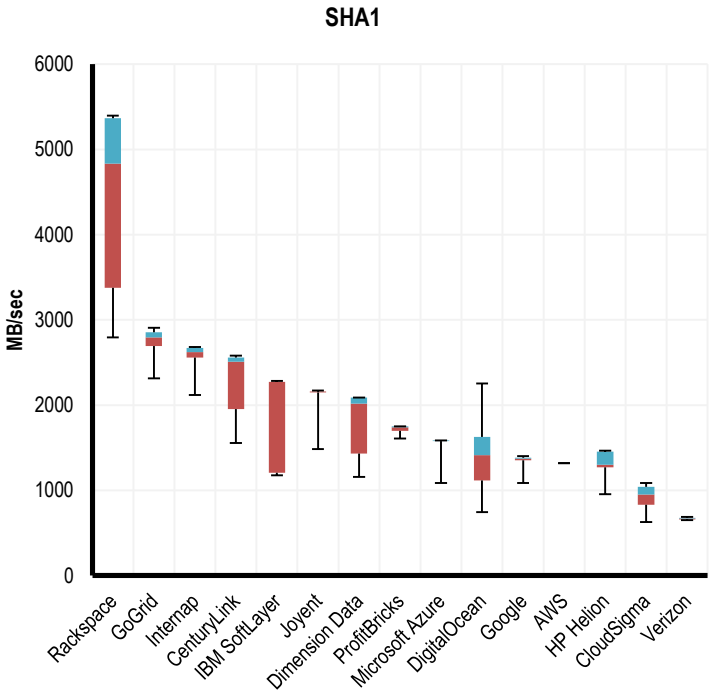
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	9359	9441	9482	9503	9513	17	0.2%
CenturyLink	8182	9595	15872	16077	16282	2321	23.9%
CloudSigma	2550	3177	3860	4095	4188	290	3.0%
DigitalOcean	3369	4200	6758	9257	13619	1754	18.1%
Dimension Data	2591	7792	13619	14234	14336	2416	24.9%
GoGrid	1423	1700	1772	1802	1864	46	0.5%
Google	7055	9452	9697	9820	10004	243	2.5%
HP Helion	8704	13829	16077	16896	17306	1203	12.4%
IBM SoftLayer	8233	8281	14131	14234	14234	1412	14.6%
Internap	1006	1516	1741	1772	1782	83	0.9%
Joyent	7721	8264	14438	16077	16384	3195	32.9%
Microsoft Azure	7311	10071	11162	11674	12186	459	4.7%
ProfitBricks	4209	4690	5059	5366	5755	207	2.1%
Rackspace	14541	16148	17920	26245	28365	3044	31.4%
Verizon	4280	4577	4874	5202	5509	186	1.9%

CPU Integer – Twofish: The Twofish workload also encrypts a text string, but it uses the Twofish algorithm. Twofish is from the family of encryption algorithms known as "Feistel ciphers." It is included in the OpenPGP standard.



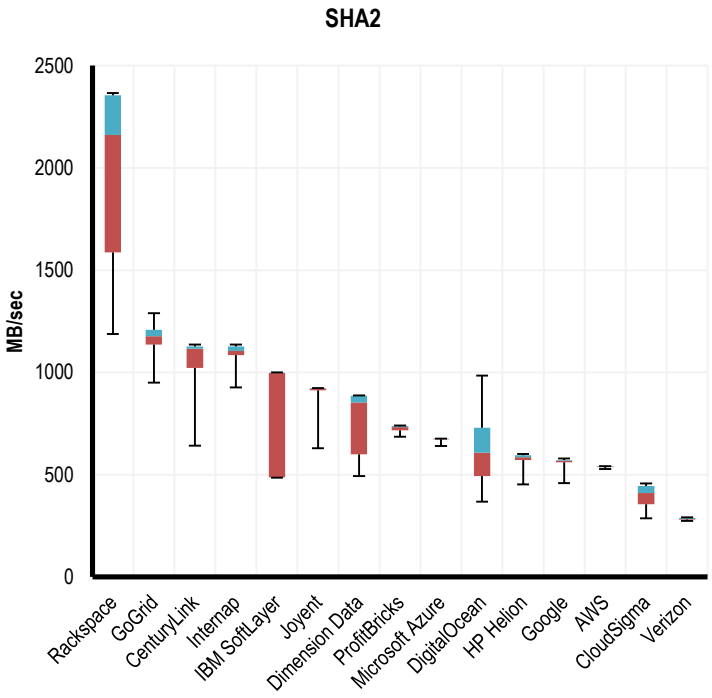
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	796	801	805	805	805	1	0.1%
CenturyLink	836	1017	1147	1157	1157	53	5.8%
CloudSigma	431	464	527	576	605	33	3.6%
DigitalOcean	434	599	742	842	1008	81	8.9%
Dimension Data	621	766	996	1015	1016	79	8.7%
GoGrid	1311	1413	1434	1464	1505	16	1.8%
Google	602	809	828	839	852	16	1.8%
HP Helion	493	621	636	644	654	10	1.1%
IBM SoftLayer	722	851	1018	1020	1020	63	6.9%
Internap	904	1144	1167	1188	1198	22	2.4%
Joyent	692	1044	1055	1055	1055	13	1.4%
Microsoft Azure	682	764	767	768	769	5	0.5%
ProfitBricks	850	889	911	916	920	9	1.0%
Rackspace	1700	1720	2232	2396	2406	253	27.8%
Verizon	328	331	334	337	342	2	0.2%

CPU Integer – SHA1: SHA1 is a cryptographic hash algorithm: given a binary input it generates a "hash" or "digest" of the input. SHA1 is designed so that the hash may be computed quickly, but it is difficult to find a string that generates a given hash. SHA1 may be used, for example, to encrypt passwords by storing the hash instead of the password text. The SHA1 workload uses a text string as input.



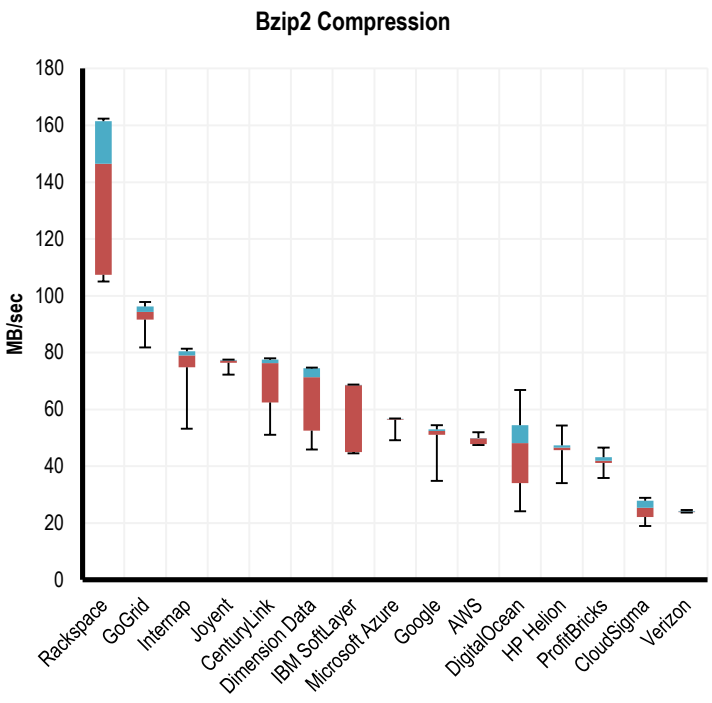
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1321	1321	1321	1321	1321	0	0.0%
CenturyLink	1556	1956	2509	2560	2580	188	10.8%
CloudSigma	627	832	950	1043	1085	68	3.9%
DigitalOcean	746	1118	1413	1628	2253	173	9.9%
Dimension Data	1157	1434	2017	2089	2089	218	12.5%
GoGrid	2314	2693	2796	2857	2908	59	3.4%
Google	1085	1352	1372	1382	1403	18	1.0%
HP Helion	955	1270	1300	1454	1464	61	3.5%
IBM SoftLayer	1178	1205	2273	2273	2284	257	14.8%
Internap	2120	2557	2621	2673	2683	63	3.6%
Joyent	1485	2150	2161	2161	2171	32	1.8%
Microsoft Azure	1085	1577	1577	1587	1587	22	1.3%
ProfitBricks	1608	1700	1741	1751	1751	17	1.0%
Rackspace	2796	3376	4833	5366	5396	693	39.8%
Verizon	651	660	669	679	689	5	0.3%

CPU Integer – SHA2: SHA2 solves the same problem as SHA1, but is more secure: SHA1 has a known vulnerability to "collision attacks." Although these attacks are still impractical and SHA1 is still widely used, it is being gradually replaced by SHA2.



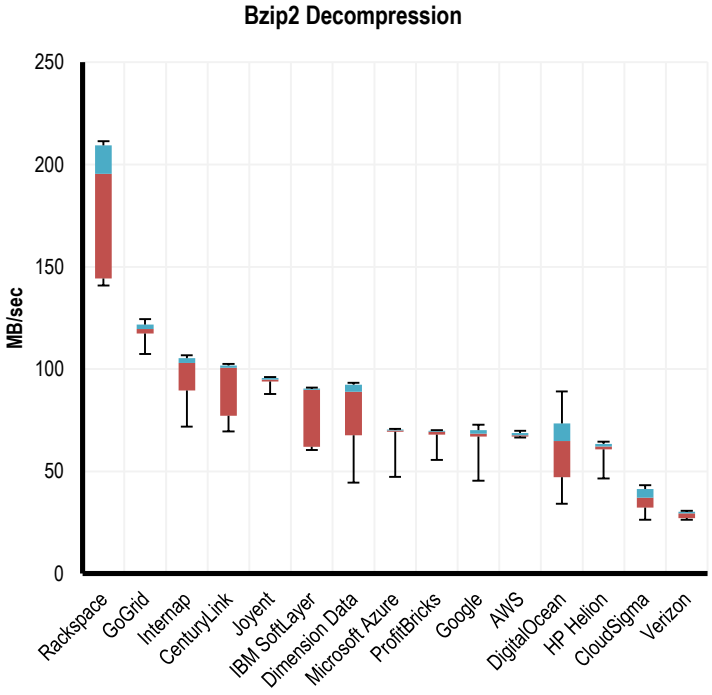
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	528	537	539	542	543	1	0.1%
CenturyLink	643	1023	1116	1126	1137	57	7.8%
CloudSigma	287	356	411	446	457	28	3.8%
DigitalOcean	369	493	608	730	984	79	10.8%
Dimension Data	494	599	854	886	888	95	13.0%
GoGrid	950	1137	1178	1208	1290	26	3.5%
Google	459	561	568	572	580	6	0.8%
HP Helion	453	572	586	595	601	12	1.6%
IBM SoftLayer	486	487	997	999	1001	129	17.6%
Internap	928	1085	1106	1126	1137	19	2.6%
Joyent	629	913	922	923	924	10	1.4%
Microsoft Azure	641	673	675	676	676	3	0.4%
ProfitBricks	686	717	734	738	740	7	1.0%
Rackspace	1188	1587	2161	2355	2365	253	34.5%
Verizon	274	280	284	288	292	2	0.3%

CPU Integer – Bzip2 Compression: BZip2 is a compression algorithm. The BZip2 workloads compress and decompress an ebook formatted using HTML. Geekbench 3 uses bzlib version 1.0.6 in the BZip2 workloads.



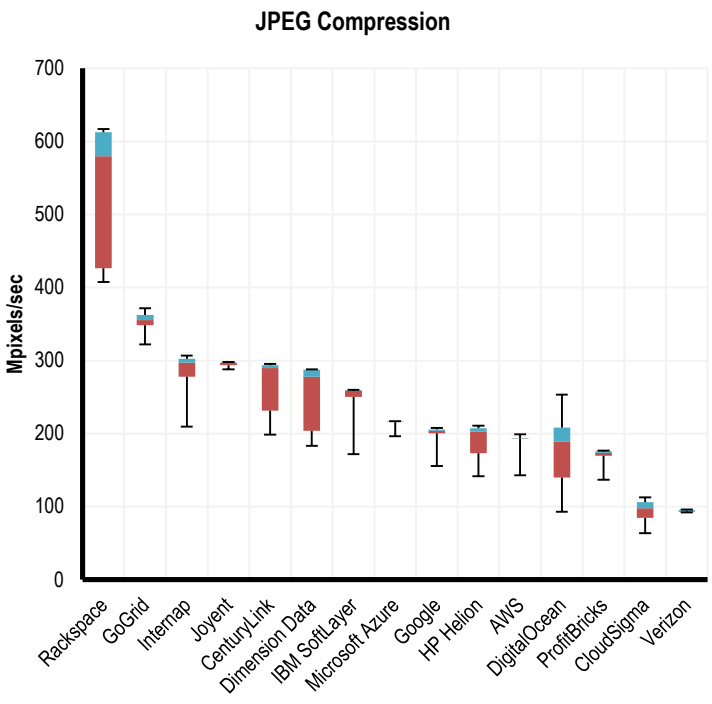
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	47.5	47.8	49.8	50.0	52.0	0.5	0.9%
CenturyLink	51.1	62.5	76.3	77.5	78.0	4.4	7.8%
CloudSigma	19.0	22.1	25.4	27.9	28.9	1.5	2.7%
DigitalOcean	24.1	34.0	48.2	54.4	66.9	6.1	10.8%
Dimension Data	45.9	52.5	71.4	74.5	74.7	7.4	13.0%
GoGrid	81.8	91.6	94.3	96.2	97.8	0.9	1.7%
Google	34.9	51.1	52.4	53.0	54.4	1.0	1.8%
HP Helion	34.1	45.7	46.6	47.4	54.3	0.5	0.8%
IBM SoftLayer	44.5	44.9	68.5	68.7	68.8	5.3	9.3%
Internap	53.2	74.9	79.0	80.5	81.4	1.6	2.8%
Joyent	72.3	76.4	77.2	77.4	77.5	0.0	0.0%
Microsoft Azure	49.2	56.4	56.6	56.7	56.8	0.0	0.0%
ProfitBricks	35.9	41.2	41.9	43.2	46.6	0.4	0.7%
Rackspace	105.0	107.4	146.5	161.4	162.4	19.3	34.1%
Verizon	23.7	23.8	24.0	24.3	24.6	0.0	0.0%

CPU Integer – Bzip2 Decompression: BZip2 is a compression algorithm. The BZip2 workloads compress and decompress an ebook formatted using HTML. Geekbench 3 uses bzlib version 1.0.6 in the BZip2 workloads.



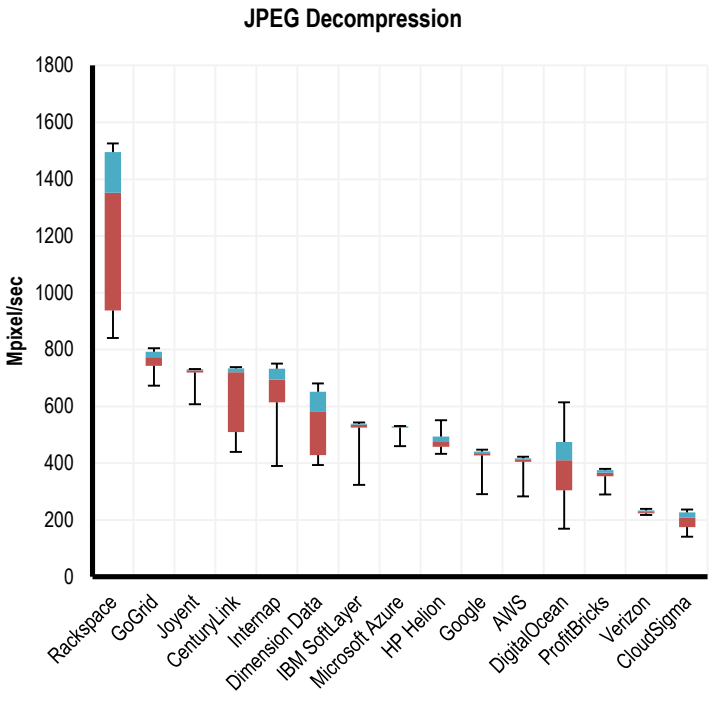
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	66.6	67.1	67.6	68.7	69.9	0.0	0.0%
CenturyLink	69.6	77.2	100.6	101.8	102.6	6.8	9.7%
CloudSigma	26.4	32.3	37.2	41.4	43.2	2.6	3.7%
DigitalOcean	34.2	47.2	64.9	73.5	89.1	7.6	10.8%
Dimension Data	44.5	67.7	88.9	92.3	93.3	8.4	12.0%
GoGrid	107.4	117.4	119.6	121.9	124.5	1.2	1.7%
Google	45.4	67.0	68.5	70.2	72.8	1.4	1.9%
HP Helion	46.6	60.8	62.2	63.5	64.5	0.6	0.9%
IBM SoftLayer	60.4	62.0	89.9	90.5	91.0	7.0	9.9%
Internap	71.8	89.5	103.0	105.3	106.7	5.0	7.1%
Joyent	87.8	94.0	94.9	95.6	96.2	0.0	0.0%
Microsoft Azure	47.3	69.3	70.0	70.5	70.8	0.7	1.0%
ProfitBricks	55.6	67.9	69.3	69.9	70.2	0.7	1.0%
Rackspace	140.9	144.3	195.5	209.3	211.4	22.1	31.5%
Verizon	26.3	27.1	29.5	30.2	30.7	0.6	0.8%

CPU Integer – JPEG Compression: The JPEG workloads compress and decompress one digital image using lossy JPEG format. The workloads use libjpeg version 6b.



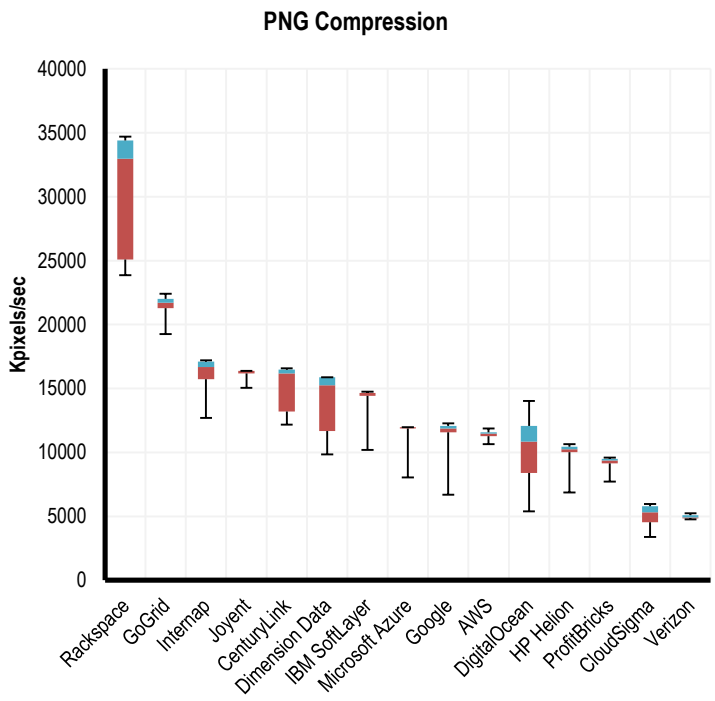
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	143.0	193.2	193.5	193.7	199.1	1.0	0.5%
CenturyLink	198.7	231.5	289.6	293.7	295.3	16.9	7.8%
CloudSigma	63.7	84.8	97.9	106.1	112.7	6.7	3.1%
DigitalOcean	93.0	140.1	188.8	208.2	253.6	20.2	9.3%
Dimension Data	183.3	203.9	277.7	287.7	288.0	16.1	7.4%
GoGrid	322.1	348.6	355.4	362.5	371.5	3.6	1.6%
Google	155.6	200.4	203.9	205.5	207.9	2.0	0.9%
HP Helion	141.8	173.1	202.8	207.6	210.7	13.4	6.2%
IBM SoftLayer	172.1	250.3	259.1	259.7	259.9	15.3	7.1%
Internap	209.5	277.7	297.0	302.6	306.7	3.9	1.8%
Joyent	287.9	293.7	297.0	297.7	298.0	1.0	0.5%
Microsoft Azure	196.3	216.0	216.5	216.8	217.2	1.0	0.5%
ProfitBricks	137.0	169.6	173.7	176.0	176.9	1.7	0.8%
Rackspace	407.7	426.3	579.8	612.5	617.1	55.4	25.6%
Verizon	92.1	92.9	93.9	95.1	96.2	0.0	0.0%

CPU Integer – JPEG Decompression: The JPEG workloads compress and decompress one digital image using lossy JPEG format. The workloads use libjpeg version 6b.



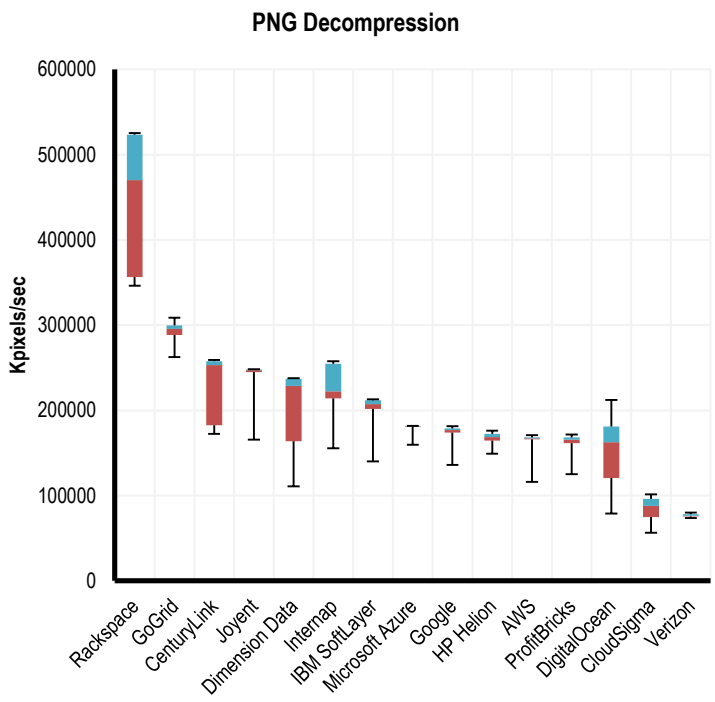
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	283.0	405.3	411.3	417.4	423.3	4.1	0.8%
CenturyLink	439.9	510.0	720.6	733.6	738.6	62.5	11.8%
CloudSigma	141.2	175.2	208.7	226.5	236.5	16.4	3.1%
DigitalOcean	169.4	304.8	410.7	475.2	614.2	56.7	10.7%
Dimension Data	393.8	429.0	580.7	651.7	680.4	67.1	12.7%
GoGrid	672.5	742.7	773.2	792.5	804.9	15.4	2.9%
Google	291.5	427.7	435.0	441.2	448.1	8.7	1.6%
HP Helion	433.1	457.6	475.0	493.4	551.3	9.5	1.8%
IBM SoftLayer	324.0	525.6	535.4	538.8	543.0	31.7	6.0%
Internap	389.8	614.0	694.5	732.9	750.6	47.5	9.0%
Joyent	608.1	719.3	727.3	729.9	732.1	7.3	1.4%
Microsoft Azure	460.5	525.1	527.9	529.4	531.2	5.3	1.0%
ProfitBricks	289.8	354.3	366.3	375.1	379.9	3.7	0.7%
Rackspace	840.9	937.6	1351.7	1495.0	1525.8	157.7	29.9%
Verizon	217.7	223.4	228.2	234.0	239.7	2.3	0.4%

CPU Integer – PNG Compression: The PNG workloads also compress and decompress a digital image, but they do so using the PNG format. The workloads use libpng 1.6.2.



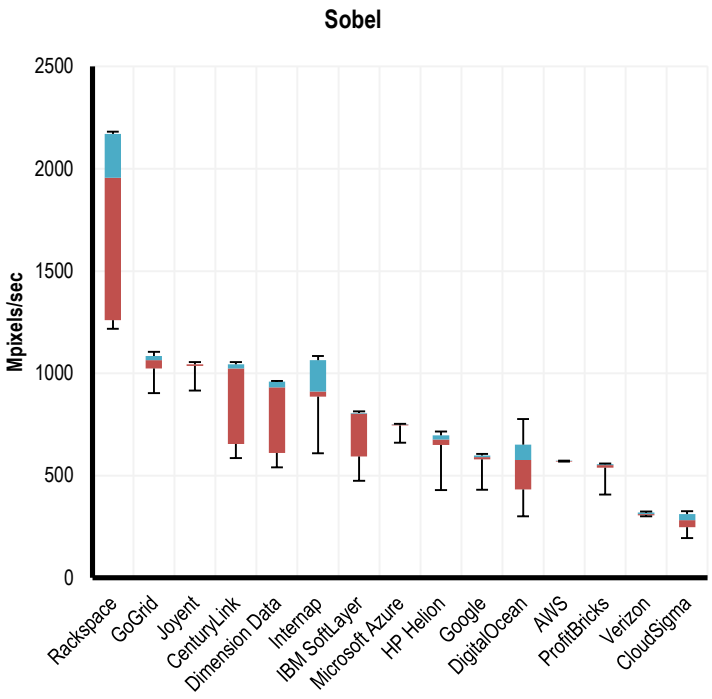
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	10650	11264	11469	11571	11878	86	0.7%
CenturyLink	12186	13210	16179	16486	16589	1043	8.7%
CloudSigma	3400	4549	5325	5795	5970	392	3.3%
DigitalOcean	5396	8392	10854	12083	14029	1190	9.9%
Dimension Data	9851	11674	15258	15872	15872	1375	11.5%
GoGrid	19251	21299	21709	22016	22426	277	2.3%
Google	6687	11571	11878	12083	12288	404	3.4%
HP Helion	6881	10015	10240	10445	10650	200	1.7%
IBM SoftLayer	10199	14438	14643	14643	14746	666	5.6%
Internap	12698	15739	16691	17101	17203	462	3.9%
Joyent	15053	16179	16384	16384	16384	116	1.0%
Microsoft Azure	8049	11878	11981	11981	11981	167	1.4%
ProfitBricks	7721	9144	9380	9491	9595	155	1.3%
Rackspace	23859	25088	32973	34406	34714	3044	25.4%
Verizon	4772	4833	4905	5089	5243	81	0.7%

CPU Integer – PNG Decompression: The PNG workloads also compress and decompress a digital image, but they do so using the PNG format. The workloads use libpng 1.6.2.



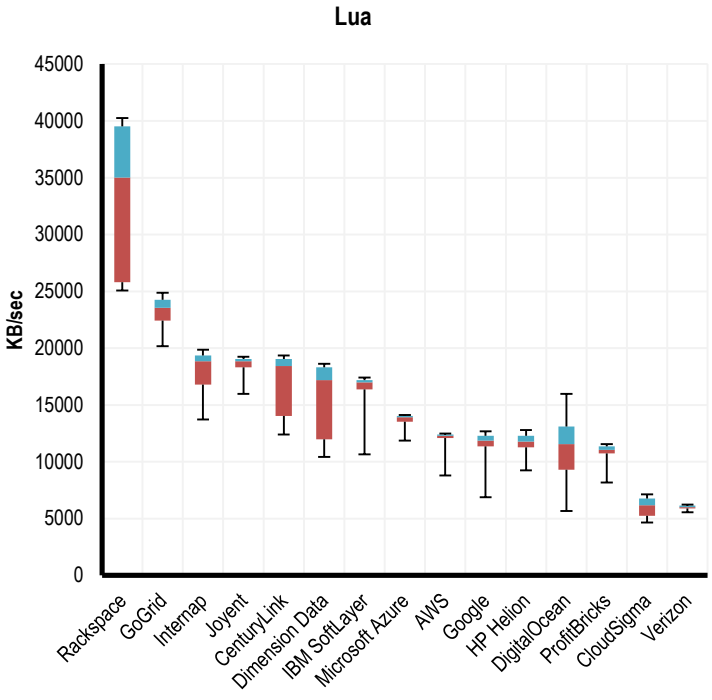
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	116019	165990	167219	168448	170906	1917	1.1%
CenturyLink	172544	182733	253235	257741	259072	25702	14.2%
CloudSigma	56422	74875	87859	96328	101581	6728	3.7%
DigitalOcean	79155	120760	162714	181217	212275	20796	11.5%
Dimension Data	111002	163732	228762	237056	237670	25489	14.1%
GoGrid	262758	288486	295526	299827	308941	4523	2.5%
Google	136090	173824	176845	178893	181658	2716	1.5%
HP Helion	149299	164664	168858	172646	176333	2703	1.5%
IBM SoftLayer	140186	201861	207258	211968	212992	13156	7.3%
Internap	155648	214323	222310	254566	257843	16587	9.1%
Joyent	165786	245146	247194	247808	248422	3231	1.8%
Microsoft Azure	159846	180838	181350	181862	182067	1794	1.0%
ProfitBricks	125235	161495	165888	168243	171930	2891	1.6%
Rackspace	346317	356352	470426	523571	525619	61002	33.6%
Verizon	73728	75469	76493	78131	79974	916	0.5%

CPU Integer – Sobel: The "Sobel operator" is used in image processing for finding edges in images. The Sobel workload uses the same input image as the JPEG and PNG workloads.



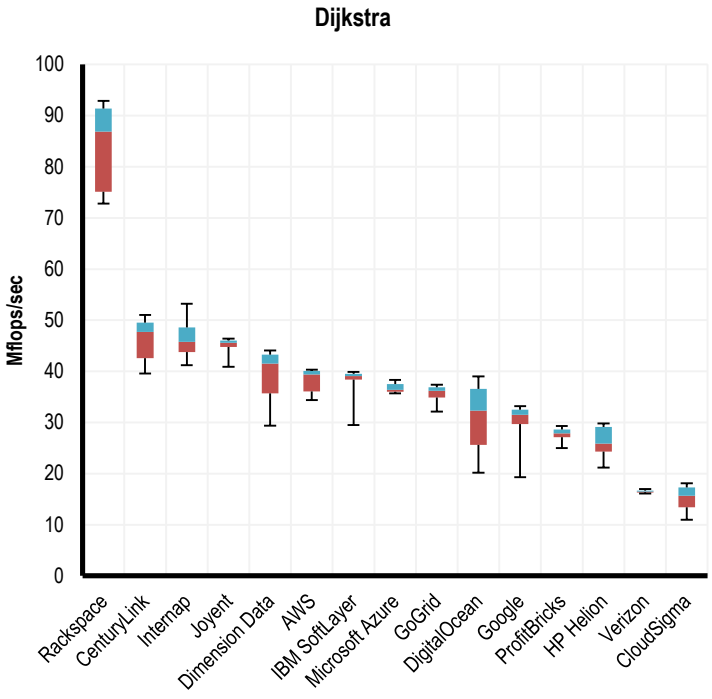
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	568	569	572	573	573	1	0.1%
CenturyLink	586	655	1024	1044	1055	129	17.2%
CloudSigma	195	249	283	312	326	20	2.7%
DigitalOcean	301	432	576	652	776	73	9.7%
Dimension Data	541	610	932	960	962	121	16.1%
GoGrid	903	1024	1065	1085	1106	23	3.1%
Google	430	579	591	598	607	10	1.3%
HP Helion	429	651	677	696	716	24	3.2%
IBM SoftLayer	475	593	804	806	814	71	9.5%
Internap	609	886	911	1065	1085	81	10.8%
Joyent	915	1036	1044	1044	1055	7	0.9%
Microsoft Azure	661	746	750	752	753	6	0.8%
ProfitBricks	408	539	552	556	559	8	1.1%
Rackspace	1219	1260	1956	2171	2181	308	41.1%
Verizon	301	305	312	320	324	4	0.5%

CPU Integer – Lua: Lua is lightweight scripting language. The Lua workload is similar to the code used to display Geekbench results in the Geekbench Browser.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	8806	12083	12288	12390	12493	162	1.2%
CenturyLink	12390	14029	18432	19046	19354	1459	10.5%
CloudSigma	4659	5254	6175	6757	7148	464	3.3%
DigitalOcean	5683	9307	11571	13097	15974	1374	9.9%
Dimension Data	10445	11981	17203	18330	18637	2094	15.0%
GoGrid	20173	22426	23552	24269	24883	619	4.4%
Google	6881	11366	11878	12288	12698	398	2.9%
HP Helion	9236	11264	11776	12288	12800	315	2.3%
IBM SoftLayer	10650	16384	16998	17203	17408	1123	8.1%
Internap	13722	16794	18842	19354	19866	861	6.2%
Joyent	15974	18330	18842	19046	19251	310	2.2%
Microsoft Azure	11878	13517	13926	14029	14131	227	1.6%
ProfitBricks	8192	10752	11059	11366	11571	248	1.8%
Rackspace	25088	25805	35021	39526	40243	4954	35.6%
Verizon	5550	5888	6021	6164	6246	85	0.6%

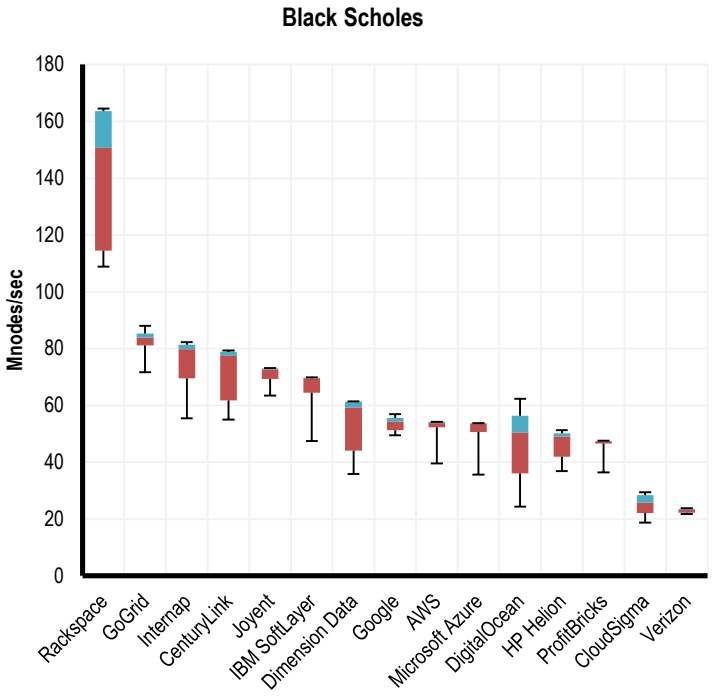
CPU Integer – Dijkstra: The Dijkstra workload computes driving directions between a sequence of destinations. Similar techniques are used by AIs to compute paths in games and by network routers to route computer network traffic.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	34.40	36.09	**39.40**	40.10	40.30	0.78	2.1%
CenturyLink	39.60	42.58	**47.70**	49.50	51.00	1.41	3.9%
CloudSigma	11.00	13.40	**15.70**	17.30	18.10	1.05	2.9%
DigitalOcean	20.20	25.60	**32.30**	36.60	39.00	3.41	9.4%
Dimension Data	29.40	35.70	**41.50**	43.30	44.10	2.00	5.5%
GoGrid	32.10	34.90	**36.20**	36.90	37.40	0.36	1.0%
Google	19.30	29.70	**31.50**	32.50	33.20	0.93	2.6%
HP Helion	21.20	24.30	**25.90**	29.10	29.80	1.30	3.6%
IBM SoftLayer	29.50	38.40	**39.10**	39.50	39.90	1.14	3.1%
Internap	41.20	43.77	**45.80**	48.60	53.20	1.35	3.7%
Joyent	40.90	44.80	**45.60**	46.00	46.40	0.00	0.0%
Microsoft Azure	35.70	36.00	**36.40**	37.50	38.30	0.36	1.0%
ProfitBricks	25.00	27.10	**27.90**	28.60	29.30	0.27	0.7%
Rackspace	72.80	75.10	**86.90**	91.40	92.90	5.10	14.0%
Verizon	16.10	16.30	**16.50**	16.70	17.00	0.00	0.0%

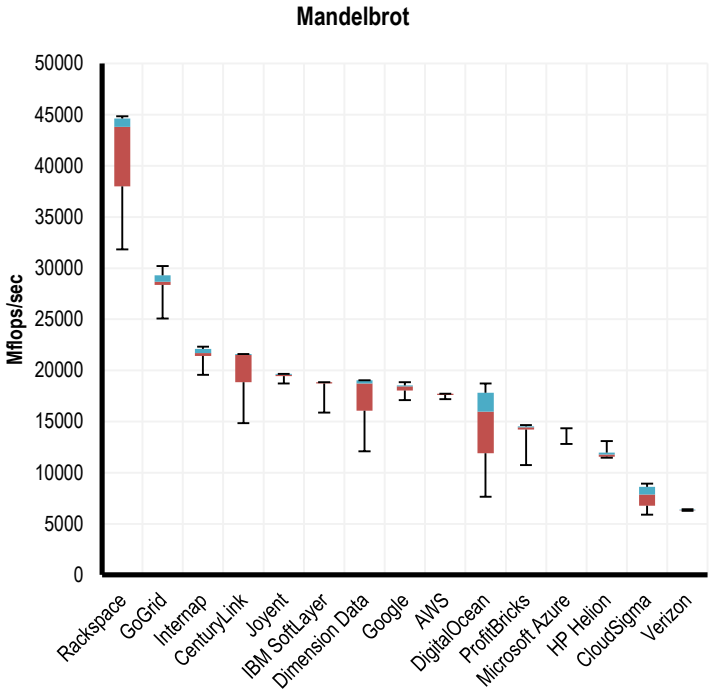
--- End of CPU Integer Results ---

CPU Floating Point – Black Scholes: The Black-Scholes equation is used to model option prices on financial markets. The Black-Scholes workload computes the Black-Scholes formula: a special case solution of the Black-Scholes equation for European call and put options.



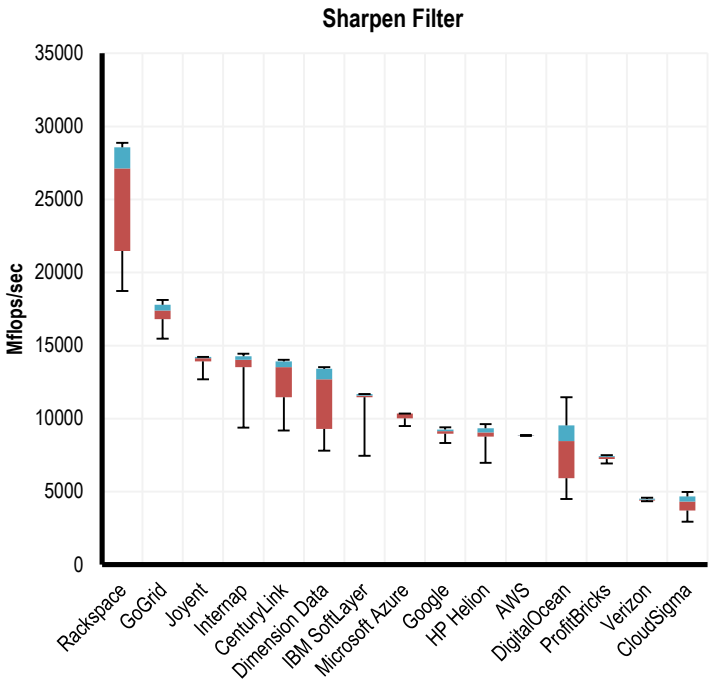
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	39.6	52.3	53.8	54.2	54.2	0.5	1.0%
CenturyLink	55.0	61.8	77.4	78.9	79.4	5.3	9.7%
CloudSigma	18.8	22.1	25.7	28.4	29.5	1.8	3.2%
DigitalOcean	24.4	36.1	50.5	56.4	62.3	5.9	10.8%
Dimension Data	35.9	44.1	59.3	61.3	61.4	5.6	10.3%
GoGrid	71.7	81.1	83.8	85.4	88.0	1.7	3.1%
Google	49.5	51.3	54.3	55.6	56.9	1.1	2.0%
HP Helion	36.9	41.9	49.0	50.2	51.3	1.9	3.5%
IBM SoftLayer	47.5	64.5	69.6	69.8	69.9	3.4	6.3%
Internap	55.5	69.6	79.8	81.3	82.3	3.1	5.7%
Joyent	63.5	69.3	72.7	73.0	73.1	0.7	1.3%
Microsoft Azure	35.7	50.6	53.6	53.8	53.8	1.1	2.0%
ProfitBricks	36.4	46.6	47.4	47.5	47.6	0.5	0.9%
Rackspace	108.9	114.5	150.7	163.6	164.5	17.2	31.6%
Verizon	21.8	22.2	23.3	23.6	23.8	0.2	0.4%

CPU Floating Point – Mandelbrot: The Mandelbrot set is a fractal. It is a useful floating point workload because it has a low memory bandwidth requirement.



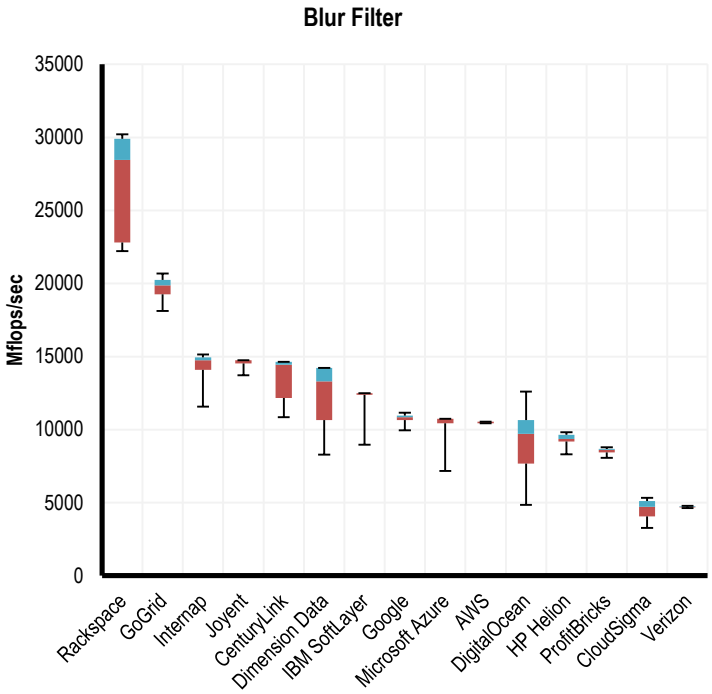
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	17203	17613	17715	17715	17715	39	0.2%
CenturyLink	14848	18842	21504	21606	21606	835	4.5%
CloudSigma	5908	6771	7875	8609	8940	557	3.0%
DigitalOcean	7639	11899	15974	17807	18739	1708	9.3%
Dimension Data	12083	16072	18739	19046	19046	997	5.4%
GoGrid	25088	28365	28672	29286	30208	329	1.8%
Google	17101	18022	18432	18534	18842	199	1.1%
HP Helion	11469	11571	11776	11981	13107	183	1.0%
IBM SoftLayer	15872	18739	18842	18842	18842	226	1.2%
Internap	19558	21402	21709	22118	22323	280	1.5%
Joyent	18739	19456	19558	19661	19661	92	0.5%
Microsoft Azure	12800	14336	14336	14336	14336	109	0.6%
ProfitBricks	10752	14234	14438	14541	14643	172	0.9%
Rackspace	31846	37990	43827	44646	44851	2058	11.2%
Verizon	6257	6297	6339	6390	6431	28	0.2%

CPU Floating Point – Sharpen Filter: The sharpen image workload uses a standard image sharpening technique similar to those found in Photoshop or Gimp.



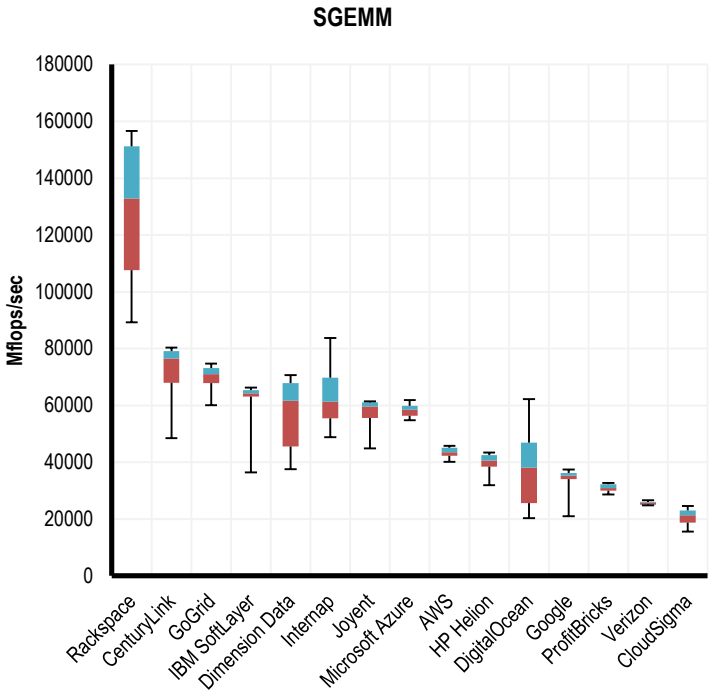
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	8806	8827	8858	8878	8888	12	0.1%
CenturyLink	9196	11469	13517	13926	14029	812	7.9%
CloudSigma	2949	3718	4332	4680	4977	304	2.9%
DigitalOcean	4495	5923	8468	9544	11469	1066	10.3%
Dimension Data	7803	9287	12698	13414	13517	1335	12.9%
GoGrid	15462	16819	17408	17792	18125	302	2.9%
5Google	8335	8960	9144	9257	9400	105	1.0%
HP Helion	6984	8766	9052	9339	9626	249	2.4%
IBM SoftLayer	7465	11469	11571	11674	11674	548	5.3%
Internap	9390	13517	14029	14264	14438	358	3.5%
Joyent	12698	13926	14131	14234	14234	160	1.5%
Microsoft Azure	9492	10025	10342	10342	10342	121	1.2%
ProfitBricks	6932	7240	7373	7434	7496	67	0.6%
Rackspace	18739	21473	27136	28570	28877	2227	21.5%
Verizon	4342	4393	4454	4516	4577	37	0.4%

CPU Floating Point – Blur Filter: Image blurring is also found in tools such as Photoshop. In Geekbench 3, the blur image workload is more computationally demanding than the sharpen workload.



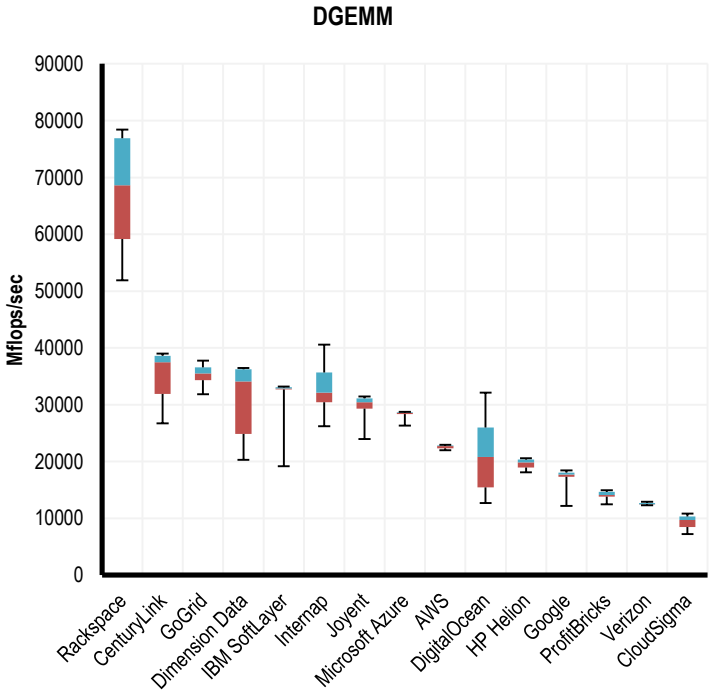
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	10445	10445	10547	10547	10547	30	0.3%
CenturyLink	10854	12160	14438	14643	14643	759	7.0%
CloudSigma	3277	4065	4710	5119	5325	326	3.0%
DigitalOcean	4844	7680	9718	10650	12595	983	9.1%
Dimension Data	8284	10650	13312	14234	14234	1155	10.6%
GoGrid	18125	19251	19866	20250	20685	308	2.8%
Google	9943	10650	10854	10957	11162	116	1.1%
HP Helion	8305	9196	9370	9646	9820	201	1.9%
IBM SoftLayer	8970	12390	12493	12493	12493	542	5.0%
Internap	11571	14100	14746	14950	15155	308	2.8%
Joyent	13722	14541	14746	14746	14746	102	0.9%
Microsoft Azure	7168	10445	10752	10752	10752	170	1.6%
ProfitBricks	8059	8438	8612	8694	8786	85	0.8%
Rackspace	22221	22804	28467	29901	30208	2132	19.6%
Verizon	4628	4669	4710	4762	4792	29	0.3%

CPU Floating Point – SGEMM: GEMM is "general matrix multiplication." Matrix multiplication is a fundamental mathematical operation. It is used in physical simulations, signal processing, graphics processing, and many other areas.



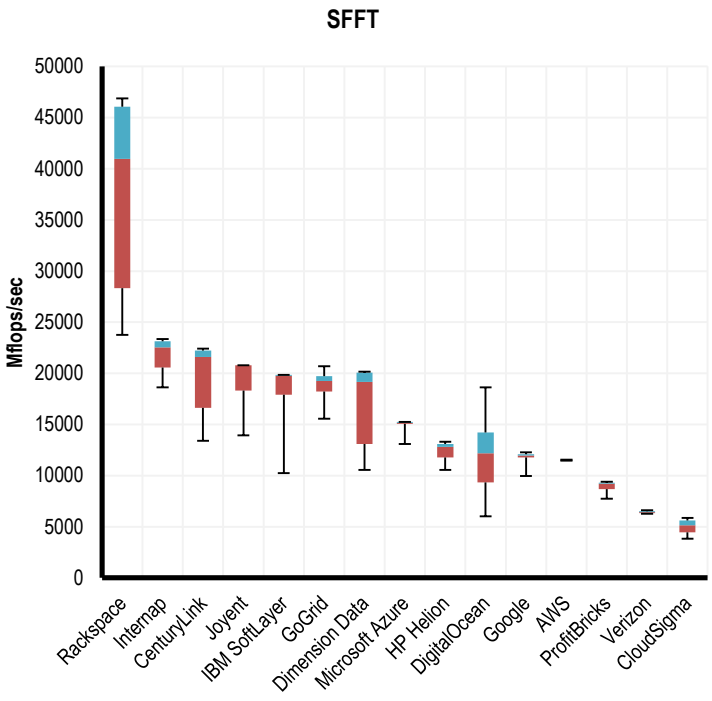
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	40141	42291	43520	45158	45773	919	1.6%
CenturyLink	48538	67968	76493	79155	80384	4289	7.3%
CloudSigma	15565	18739	21299	23040	24576	1411	2.4%
DigitalOcean	20275	25610	38093	46899	62259	6469	11.1%
Dimension Data	37581	45568	61696	67891	70656	7063	12.1%
GoGrid	60109	67891	71066	73114	74752	1750	3.0%
Google	20992	34099	35328	36250	37478	1364	2.3%
HP Helion	31949	38502	40550	42491	43418	1317	2.3%
IBM SoftLayer	36454	63181	64205	65331	66253	2380	4.1%
Internap	48845	55501	61338	69734	83763	4209	7.2%
Joyent	44851	55603	59597	61133	61440	2016	3.4%
Microsoft Azure	54784	56320	58470	59904	61850	1111	1.9%
ProfitBricks	28672	30003	30925	32256	32666	650	1.1%
Rackspace	89293	107663	132813	151173	156570	13902	23.8%
Verizon	24883	25088	25702	26112	26624	317	0.5%

CPU Floating Point – DGEMM: GEMM is "general matrix multiplication." Matrix multiplication is a fundamental mathematical operation. It is used in physical simulations, signal processing, graphics processing, and many other areas.



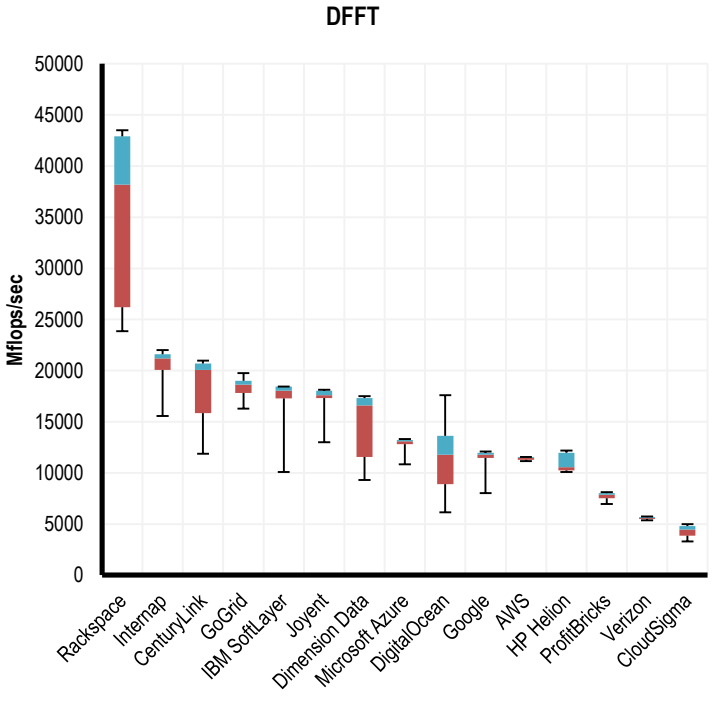
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	22016	22323	22733	22835	22938	189	0.7%
CenturyLink	26726	31898	37478	38605	39014	2159	7.6%
CloudSigma	7219	8482	9718	10342	10854	576	2.0%
DigitalOcean	12698	15473	20787	25999	32154	3148	11.0%
Dimension Data	20275	24878	34099	36250	36454	3719	13.0%
GoGrid	31846	34304	35533	36557	37786	752	2.6%
Google	12186	17306	17715	18022	18432	495	1.7%
HP Helion	18125	18944	19866	20378	20582	444	1.6%
IBM SoftLayer	19149	32666	32870	33075	33178	974	3.4%
Internap	26214	30413	32154	35697	40550	1733	6.1%
Joyent	23962	29286	30413	31130	31437	691	2.4%
Microsoft Azure	26317	28365	28570	28672	28774	206	0.7%
ProfitBricks	12493	13824	14131	14643	14950	296	1.0%
Rackspace	51917	59187	68608	76902	78438	5577	19.5%
Verizon	12288	12390	12493	12698	12902	102	0.4%

CPU Floating Point – SFFT: The fast Fourier transform (FFT) workloads simulate the frequency analysis used to compute the spectrum view in an audio processing application such as Pro Tools.



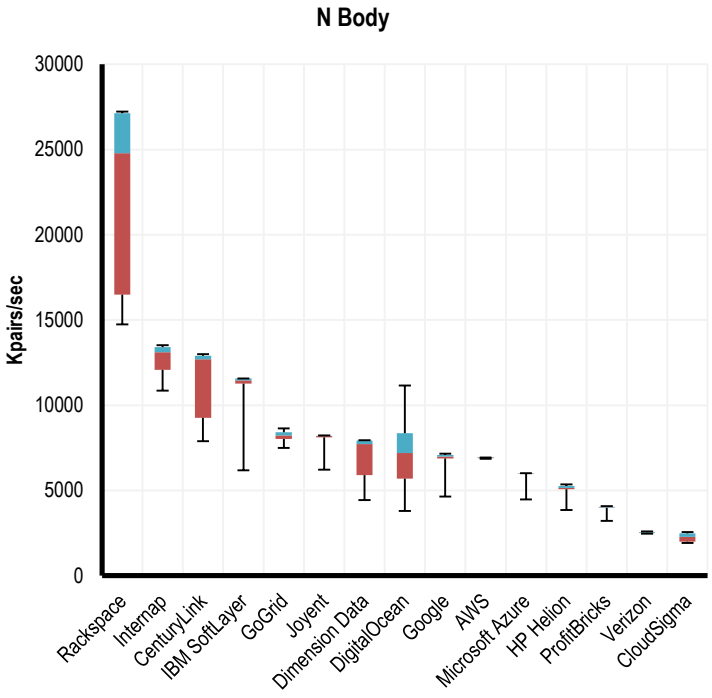
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	11469	11571	11571	11571	11571	20	0.1%
CenturyLink	13414	16640	21606	22221	22426	1687	11.1%
CloudSigma	3820	4444	5151	5601	5878	340	2.2%
DigitalOcean	6011	9341	12186	14223	18637	1632	10.8%
Dimension Data	10547	13107	19149	20070	20173	2332	15.4%
GoGrid	15565	18227	19251	19738	20685	482	3.2%
Google	9964	11776	11981	12083	12288	203	1.3%
HP Helion	10547	11776	12800	13107	13312	438	2.9%
IBM SoftLayer	10240	17920	19763	19866	19866	1570	10.4%
Internap	18637	20582	22528	23142	23347	920	6.1%
Joyent	13926	18330	20787	20787	20787	980	6.5%
Microsoft Azure	13107	15053	15155	15258	15258	119	0.8%
ProfitBricks	7752	8694	9206	9298	9411	216	1.4%
Rackspace	23757	28334	40960	46080	46899	5849	38.6%
Verizon	6267	6328	6420	6533	6615	58	0.4%

CPU Floating Point – DFFT: The fast Fourier transform (FFT) workloads simulate the frequency analysis used to compute the spectrum view in an audio processing application such as Pro Tools.



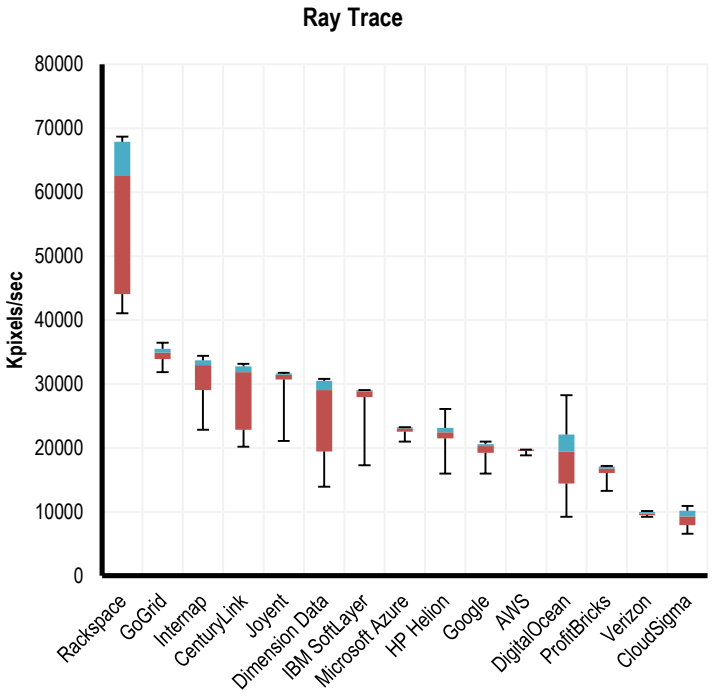
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	11162	11264	11469	11571	11571	117	0.9%
CenturyLink	11878	15846	20070	20685	20992	1494	11.4%
CloudSigma	3308	3872	4444	4802	4997	292	2.2%
DigitalOcean	6154	8895	11776	13619	17613	1531	11.7%
Dimension Data	9318	11571	16589	17306	17510	1900	14.5%
GoGrid	16282	17818	18637	19021	19763	397	3.0%
Google	8038	11469	11776	11981	12083	315	2.4%
HP Helion	10086	10240	10547	11981	12186	684	5.2%
IBM SoftLayer	10076	17275	18022	18432	18432	1440	11.0%
Internap	15565	20070	21197	21606	22016	596	4.5%
Joyent	13005	17306	17613	18022	18125	297	2.3%
Microsoft Azure	10854	12800	13107	13210	13312	155	1.2%
ProfitBricks	6963	7537	7864	8038	8110	174	1.3%
Rackspace	23859	26214	38195	42906	43520	5368	41.0%
Verizon	5376	5478	5571	5663	5755	58	0.4%

CPU Floating Point – N Body: This workload computes a physical simulation similar to that required for a physics game placed in outer space.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	6861	6892	6932	6943	6943	16	0.2%
CenturyLink	7895	9260	12698	12902	13005	972	13.5%
CloudSigma	1915	1997	2284	2478	2570	133	1.8%
DigitalOcean	3799	5694	7199	8365	11162	918	12.8%
Dimension Data	4434	5908	7721	7926	7956	699	9.7%
GoGrid	7496	8031	8223	8428	8643	123	1.7%
Google	4649	6871	6994	7086	7168	203	2.8%
HP Helion	3850	5069	5161	5263	5356	93	1.3%
IBM SoftLayer	6185	11264	11469	11571	11571	936	13.0%
Internap	10854	12083	13107	13414	13517	413	5.7%
Joyent	6216	8120	8192	8212	8223	77	1.1%
Microsoft Azure	4485	5980	6001	6011	6021	65	0.9%
ProfitBricks	3226	3983	4014	4045	4086	30	0.4%
Rackspace	14746	16486	24781	27136	27238	3581	49.7%
Verizon	2468	2499	2529	2560	2591	21	0.3%

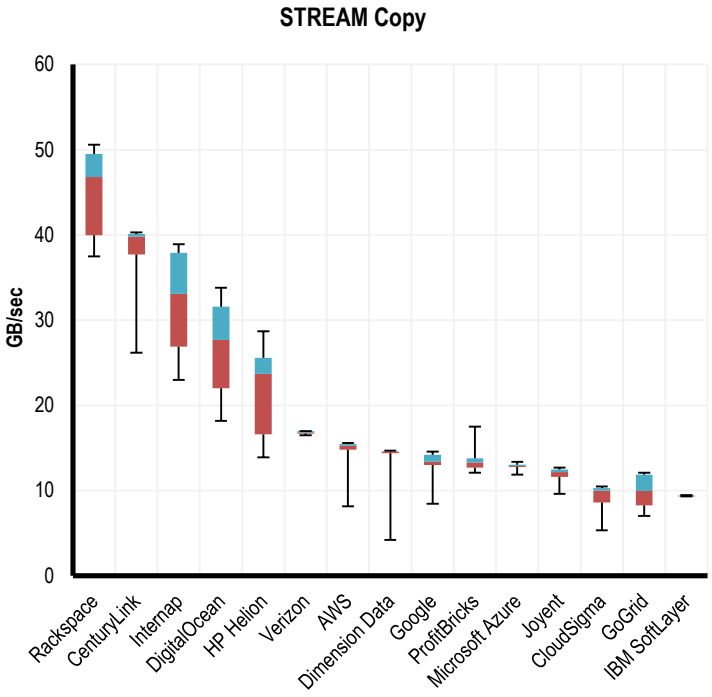
CPU Floating Points – Ray Trace: The ray trace workload renders a 3D scene from a geometric description.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	18842	19558	19763	19763	19763	106	0.5%
CenturyLink	20173	22835	31846	32768	33178	3131	13.6%
CloudSigma	6574	7926	9298	10209	10957	723	3.1%
DigitalOcean	9216	14438	19456	22118	28262	2623	11.4%
Dimension Data	13926	19456	29082	30515	30822	3931	17.1%
GoGrid	31846	33894	34918	35533	36454	565	2.5%
Google	15974	19251	20275	20582	20992	437	1.9%
HP Helion	15974	21509	22426	23142	26112	738	3.2%
IBM SoftLayer	17306	27955	28877	29082	29082	2016	8.8%
Internap	22835	29082	32973	33690	34406	1280	5.6%
Joyent	21094	30720	31437	31642	31744	501	2.2%
Microsoft Azure	20992	22528	23040	23245	23245	287	1.2%
ProfitBricks	13312	16077	16794	17101	17203	353	1.5%
Rackspace	41062	44073	62566	67891	68710	6763	29.4%
Verizon	9257	9462	9748	9964	10127	152	0.7%

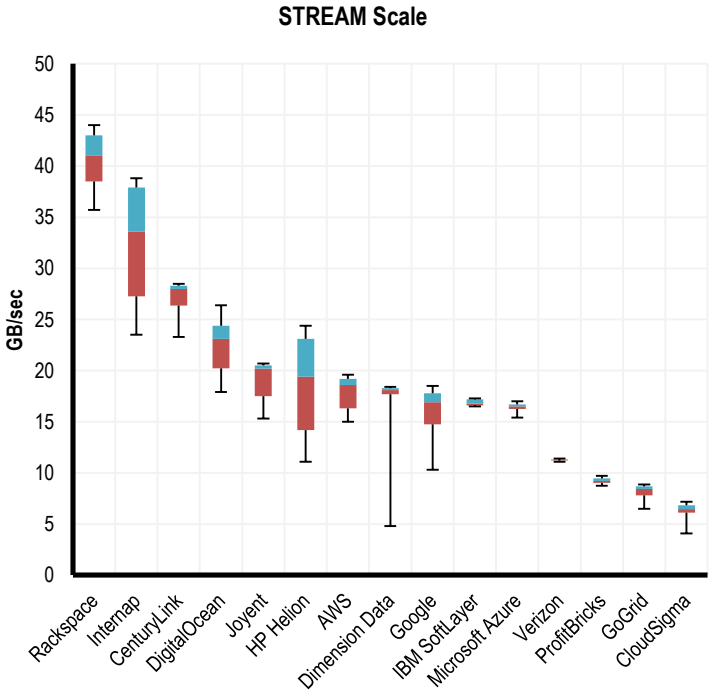
--- End of Floating Point Results ---

Memory – STREAM Copy: The stream copy workload tests how fast your computer can copy large amounts of data in memory. It executes a value-by-value copy of a large list of floating point numbers.



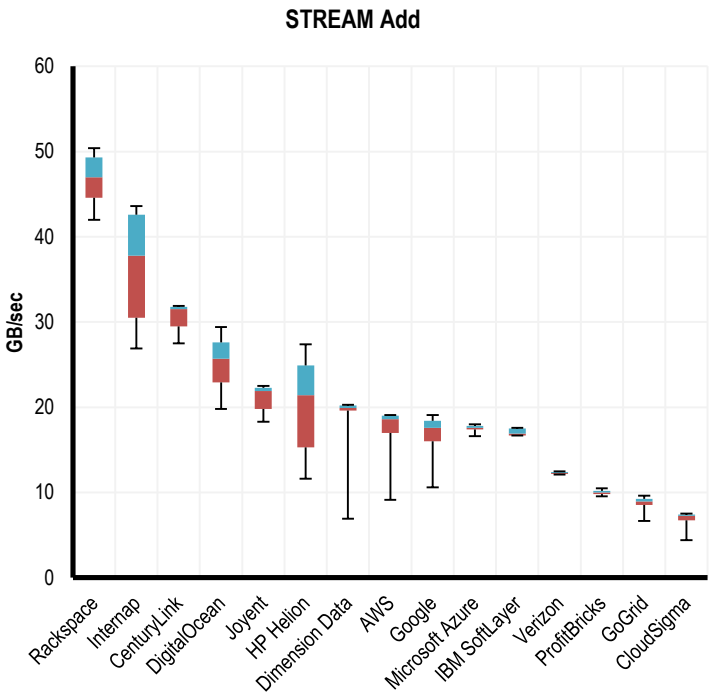
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	8.16	14.80	15.30	15.50	15.60	0.30	2.1%
CenturyLink	26.20	37.70	39.80	40.10	40.30	1.17	8.0%
CloudSigma	5.33	8.60	10.00	10.30	10.50	0.54	3.7%
DigitalOcean	18.20	22.01	27.70	31.59	33.80	2.70	18.5%
Dimension Data	4.24	14.40	14.60	14.61	14.70	0.42	2.9%
GoGrid	7.05	8.26	9.96	11.90	12.10	1.10	7.5%
Google	8.46	13.00	13.40	14.20	14.60	0.39	2.7%
HP Helion	13.90	16.61	23.70	25.60	28.70	2.64	18.1%
IBM SoftLayer	9.31	9.34	9.39	9.44	9.49	0.00	0.0%
Internap	23.00	26.90	33.10	37.90	38.90	3.20	21.9%
Joyent	9.64	11.60	12.20	12.49	12.70	0.36	2.5%
Microsoft Azure	11.90	12.80	12.90	13.05	13.40	0.00	0.0%
ProfitBricks	12.10	12.70	13.30	13.80	17.50	0.26	1.8%
Rackspace	37.50	39.97	46.80	49.50	50.60	2.76	18.9%
Verizon	16.50	16.70	16.80	17.00	17.00	0.00	0.0%

Memory – STREAM Scale: This workload is similar to stream copy, but each value is multiplied by a constant during the copy.



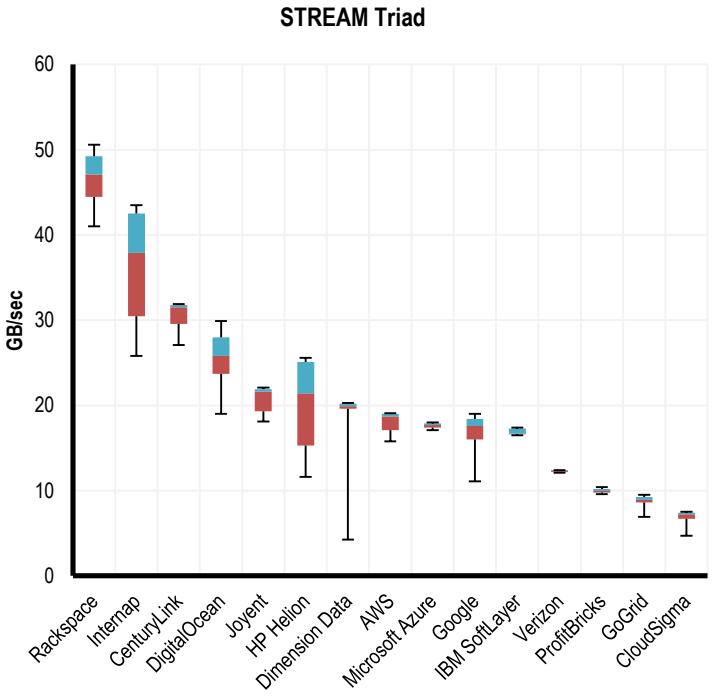
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	15.00	16.30	18.60	19.20	19.60	0.72	4.0%
CenturyLink	23.30	26.38	28.00	28.30	28.50	0.54	3.0%
CloudSigma	4.08	6.10	6.46	6.83	7.19	0.30	1.7%
DigitalOcean	17.90	20.22	23.10	24.40	26.40	1.10	6.1%
Dimension Data	4.80	17.70	18.10	18.30	18.40	0.54	3.0%
GoGrid	6.49	7.81	8.44	8.67	8.87	0.24	1.3%
Google	10.30	14.75	16.90	17.80	18.50	0.64	3.5%
HP Helion	11.10	14.20	19.40	23.10	24.40	2.34	12.9%
IBM SoftLayer	16.50	16.60	16.80	17.20	17.30	0.16	0.9%
Internap	23.50	27.27	33.60	37.90	38.80	3.30	18.2%
Joyent	15.30	17.50	20.20	20.50	20.70	0.76	4.2%
Microsoft Azure	15.40	16.25	16.50	16.70	17.00	0.00	0.0%
ProfitBricks	8.73	9.01	9.22	9.45	9.70	0.09	0.5%
Rackspace	35.70	38.50	41.00	43.00	44.00	1.20	6.6%
Verizon	11.10	11.20	11.30	11.30	11.40	0.00	0.0%

Memory – STREAM Add: The stream add workload reads two large lists of floating point numbers value-by-value, adds corresponding values, and stores the result in a third list.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	9.14	17.00	18.60	19.00	19.10	0.54	2.9%
CenturyLink	27.50	29.50	31.50	31.80	31.90	0.62	3.3%
CloudSigma	4.40	6.73	7.25	7.42	7.52	0.35	1.9%
DigitalOcean	19.80	22.91	25.70	27.60	29.40	0.75	4.0%
Dimension Data	6.94	19.60	19.90	20.20	20.30	0.57	3.1%
GoGrid	6.67	8.55	8.97	9.27	9.63	0.24	1.3%
Google	10.60	16.00	17.60	18.40	19.10	0.68	3.7%
HP Helion	11.60	15.31	21.40	24.90	27.40	2.60	14.0%
IBM SoftLayer	16.70	16.70	16.90	17.50	17.60	0.17	0.9%
Internap	26.90	30.50	37.80	42.60	43.60	3.70	19.9%
Joyent	18.30	19.80	21.90	22.29	22.50	0.63	3.4%
Microsoft Azure	16.60	17.40	17.60	17.80	18.00	0.00	0.0%
ProfitBricks	9.56	9.80	9.99	10.20	10.50	0.09	0.5%
Rackspace	42.00	44.57	47.00	49.30	50.40	1.41	7.6%
Verizon	12.10	12.20	12.30	12.40	12.50	0.00	0.0%

Memory – STREAM Triad: This workload combines stream add and stream scale. It reads two lists of floating point numbers value-by-value, multiplies one of the numbers by a constant, adds the result to the other number, and writes that result to a third list.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	15.80	17.10	18.70	19.00	19.10	0.54	2.9%
CenturyLink	27.10	29.58	31.50	31.80	31.90	0.62	3.3%
CloudSigma	4.70	6.68	7.22	7.41	7.53	0.28	1.5%
DigitalOcean	19.00	23.70	25.80	27.99	29.90	1.25	6.7%
Dimension Data	4.26	19.60	19.90	20.20	20.30	0.57	3.0%
GoGrid	6.92	8.62	8.92	9.27	9.51	0.24	1.3%
Google	11.10	16.00	17.60	18.40	19.00	0.68	3.6%
HP Helion	11.60	15.31	21.40	25.10	25.60	2.73	14.6%
IBM SoftLayer	16.50	16.60	16.70	17.30	17.40	0.16	0.9%
Internap	25.80	30.47	37.90	42.53	43.50	3.70	19.8%
Joyent	18.10	19.32	21.60	21.90	22.10	0.63	3.4%
Microsoft Azure	17.10	17.40	17.70	17.90	18.00	0.00	0.0%
ProfitBricks	9.60	9.78	9.96	10.20	10.40	0.09	0.5%
Rackspace	41.00	44.47	47.10	49.23	50.60	1.38	7.4%
Verizon	12.10	12.20	12.30	12.40	12.40	0.00	0.0%

--- End of Memory Results ---

Score Aggregation

The performance output of each individual task was converted into Geekbench performance scores using the conversion rates and formulas below. The below conversion rates are consistent with Geekbench's methodology. Information on how specific aggregate scores were calculated appears in the equations below the table.

Category	Task	Conversion Rate
Integer	AES (MB/sec)	1.14
	Twofish (MB/sec)	17.82
	SHA1 (MB/sec)	9.21
	SHA2 (MB/sec)	23.11
	BZip2 Compression (MB/sec)	246.02
	BZip2 Decompression (MB/sec)	184.51
	JPEG Compression (Mpixels/sec)	75.27
	JPEG Decompression (Mpixels/sec)	42.42
	PNG Compression (Kpixels/sec)	1.28
	PNG Decompression (Kpixels/sec)	0.09
	Sobel (Mpixels/sec)	28.82
	Lua (KB/sec)	1.09
	Dijkstra (Mflops/sec)	292.20
Floating Point	BlackScholes (Mnodes/sec)	235.64
	Mandelbrot (Mflops/sec)	1.02
	Sharpen Filter (Mflops/sec)	1.41
	Blur Filter (Mflops/sec)	1.10
	SGEMM (Mflops/sec)	0.37
	DGEMM (Mflops/sec)	0.71
	SFFT (Mflops/sec)	0.99
	DFFT (Mflops/sec)	1.15
	N-Body (Kpairs/sec)	2.76
	Ray Trace (Kpixels/sec)	0.87
Memory	STREAM Copy (GB/sec)	250.66
	STREAM Scale (GB/sec)	250.48
	STREAM Add (GB/sec)	221.14
	STREAM Triad (GB/sec)	227.55

*Task_Performance_Score = Test_Score * Conversion_Rate*

Integer_Performance_Score = Geometric mean {Integer_Task_Performance_Scores}

Floating_Point_Performance_Score = Geometric mean {Floating_Point_Task_Performance_Scores}

CPU_Performance_Score = Average {Integer_Performance_Score, Floating_Point_Performance_Score}

Memory_Performance_Score = Geometric mean {Memory_Test_Performance_Scores}

CPU_&_Memory_Performance_Score = (4 CPU_Performance_Score + Memory_Performance_Score)/5*

About Cloud Spectator

Cloud Spectator is a cloud analyst agency focused on cloud Infrastructure-as-a-Service (IaaS) performance. The company actively monitors several of the largest IaaS providers in the world, comparing VM performance (i.e., CPU, RAM, disk, internal network, and workloads) and pricing to achieve transparency in the cloud market. The company helps cloud providers understand their market position and helps business make intelligent decisions in selecting cloud providers and lowering total cost of ownership. The firm was founded in early 2011 and is located in Boston, MA.

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