Cloud Vendor Benchmark 2015

Price-Performance Comparison
Among 15 Top IaaS Providers

Part 2.3: Large VMs Linux

May 2015

CLOUD SPECTATOR

Part 2.3: Large VMs Linux

CloudSpectator.com

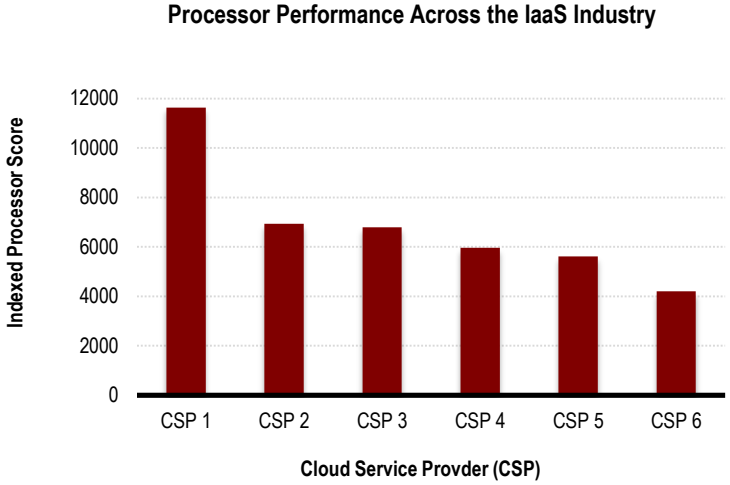
TABLE OF CONTENTS

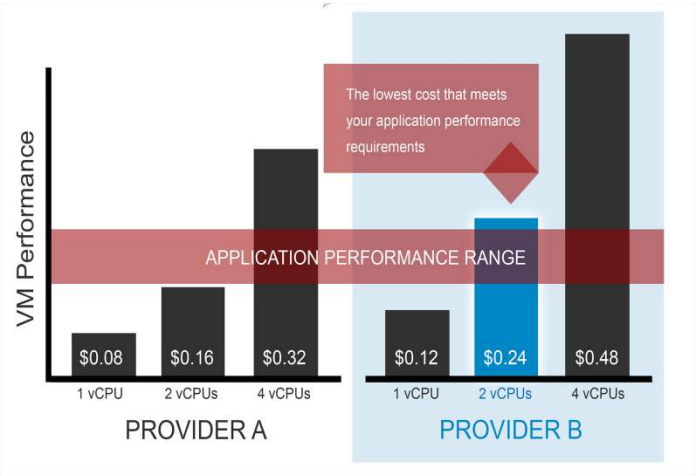
PREFACE

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 LARGE 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 tasks measuring bandwidth. The aggregated CPU & memory test score included 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 large 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 Configurations and Pricing

Provider	Instance	vCPU	RAM	Storage (GB)	Hourly ($)	Monthly ($)	Annual ($)	3-Year ($)
AWS	m3.xlarge	4	15	2 x 40 SSD	0.280	204.40	1503	2746
CenturyLink	customized	4	8	-	0.160	116.80	1402	4205
CloudSigma	customized	4	8	50 SSD	-*	87.72	947	2368
DigitalOcean	standard5	4	8	80 SSD	0.119	80.00	960	2880
Dimension Data	customized	4	8	-	0.306	223.38	2681	8042
GoGrid	Standard X-Large	8	8	400	0.480	262.80	2102	6307
Google	n1-standard-4	4	15	-	0.252	129.21	1551	4652
HP Helion	Standard Large	4	8	130	0.240	175.20	2102	6307
IBM SoftLayer	customized	4	8	25	0.224	153.60	1843	5530
Internap	B-4	4	15	80 SSD	0.320	233.60	2803	8410
Joyent	Standard5	4	15	1467	0.480	350.40	4205	12614
Microsoft Azure	D3	4	14	200 SSD	0.340	248.20	2978	8935
ProfitBricks	customized	4	8	-	0.114	83.51	1002	3006
Rackspace	General1-8	8	8	160 SSD	0.296	216.08	2593	7779
Verizon	7	4	8	-	0.236	172.28	2067	6202

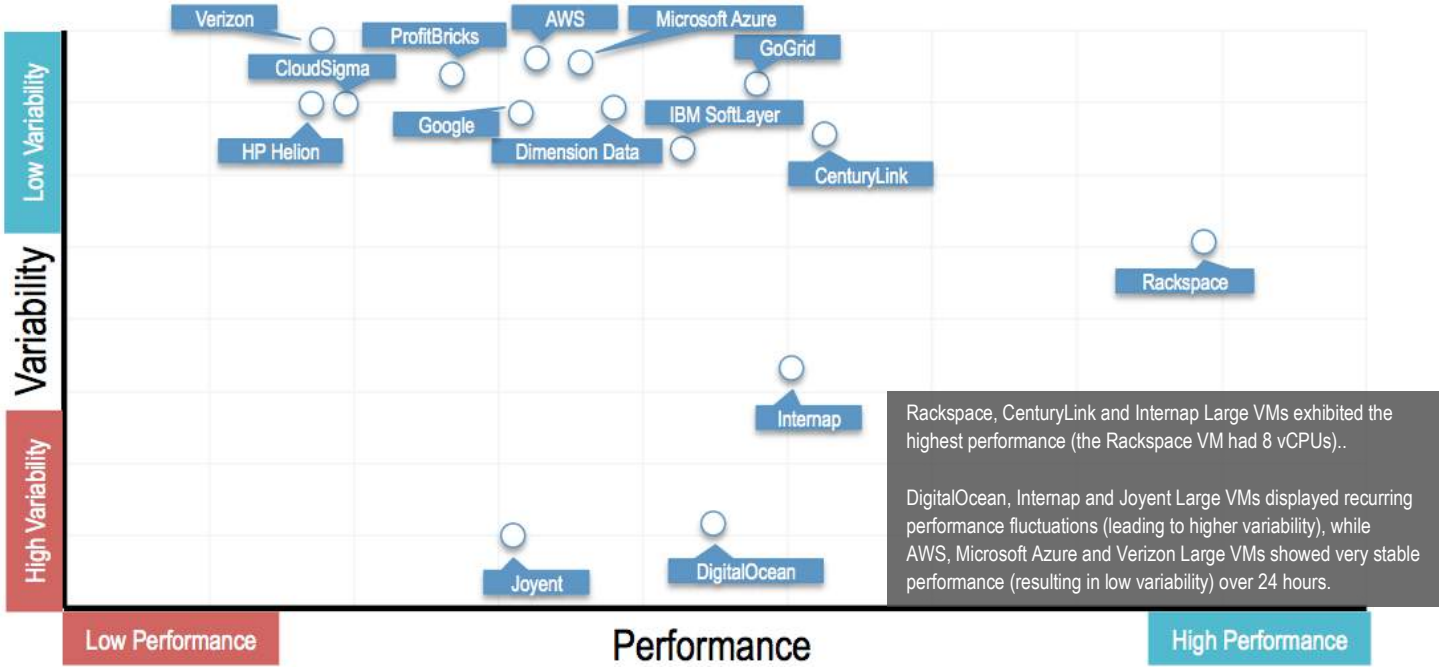
Prices in red longer-term discounted from the hourly pricing.

**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

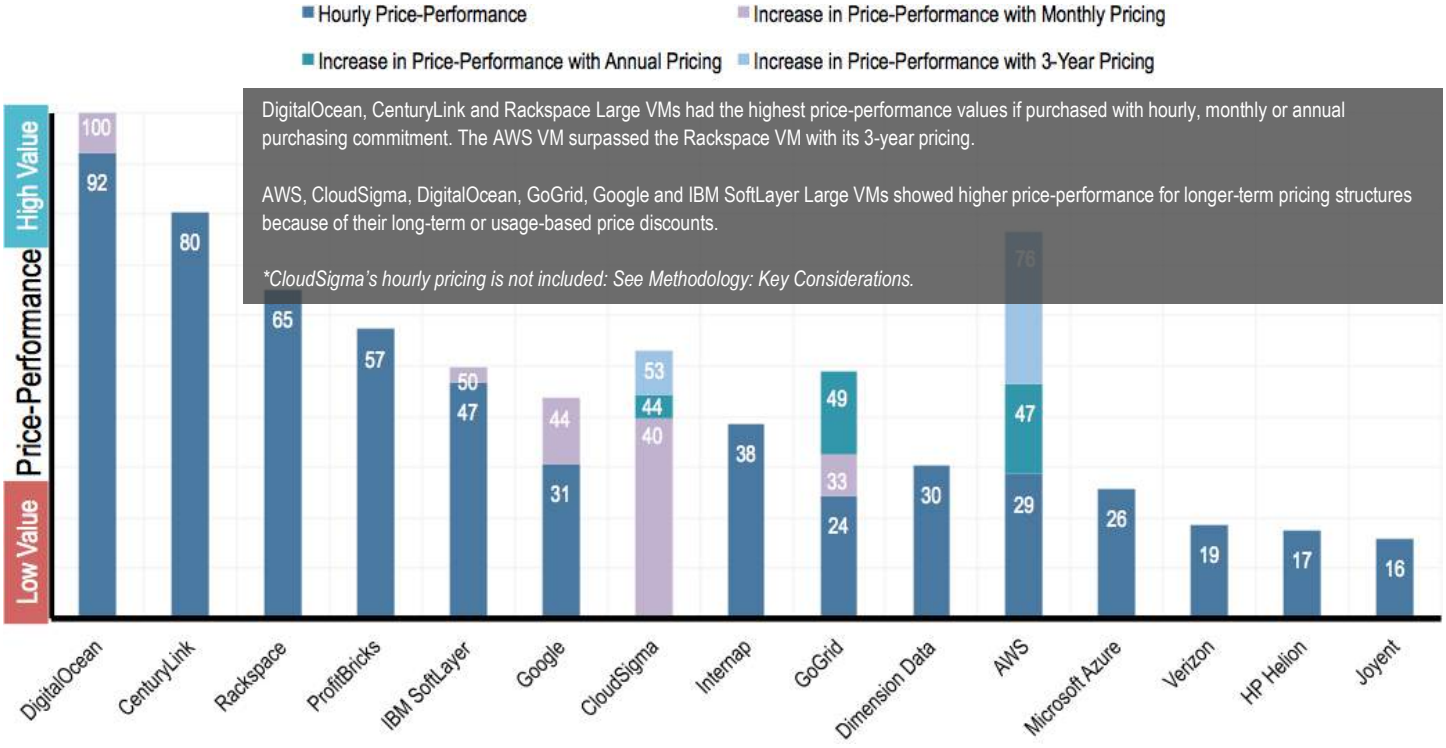
Key Performance Findings

The following graph shows the relationship between the included provider 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.



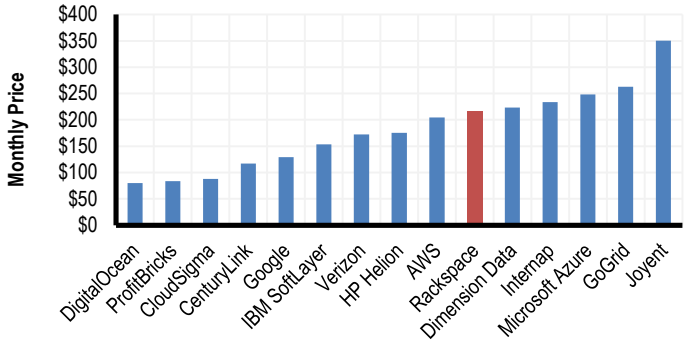
Key Price-Performance Findings

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

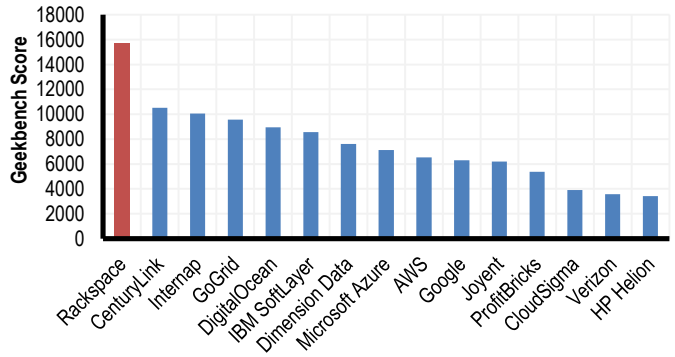


Key Takeaway

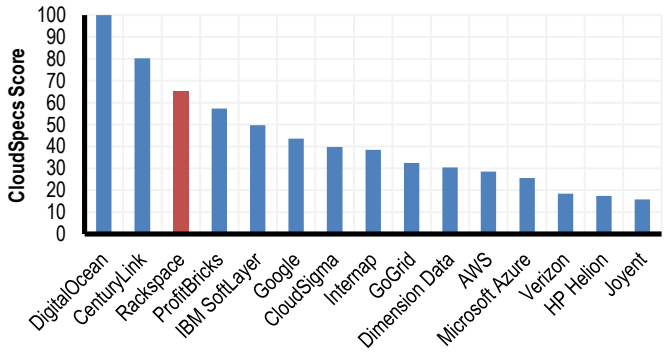
Monthly Pricing Ranking (Low to High) – Large VMs



Median Performance Ranking (High to Low) – Large VMs



Monthly Median Price-Performance Ranking (High to Low) – Large 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 Large VM as an example, while Rackspace ranks 10th 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 Large 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/.

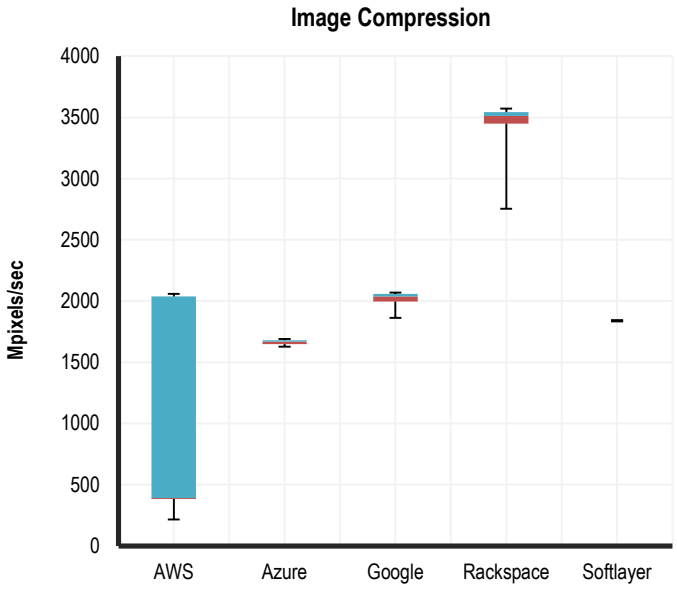
Tests and descriptions related to this report are described in the Table 1.2:

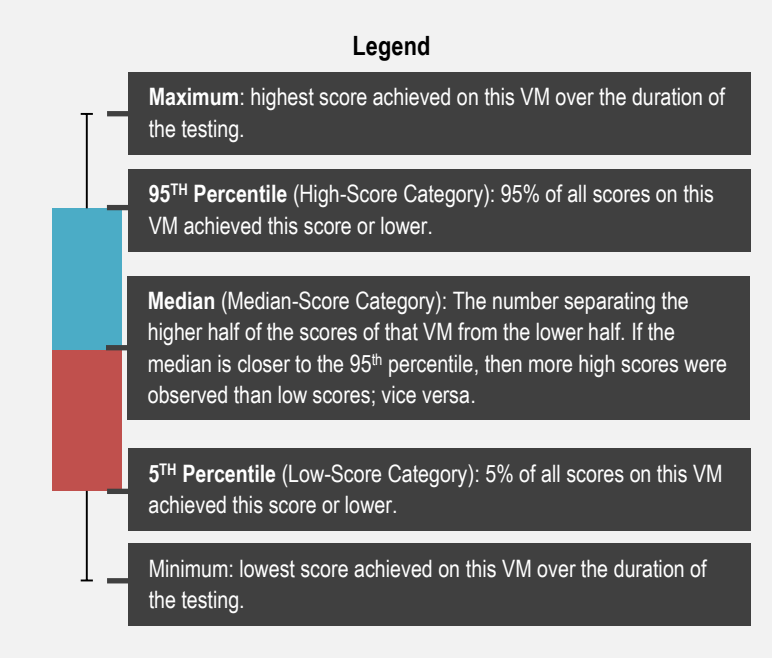
Table 1.2 Performance Tests and Descriptions

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 VMs. 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.

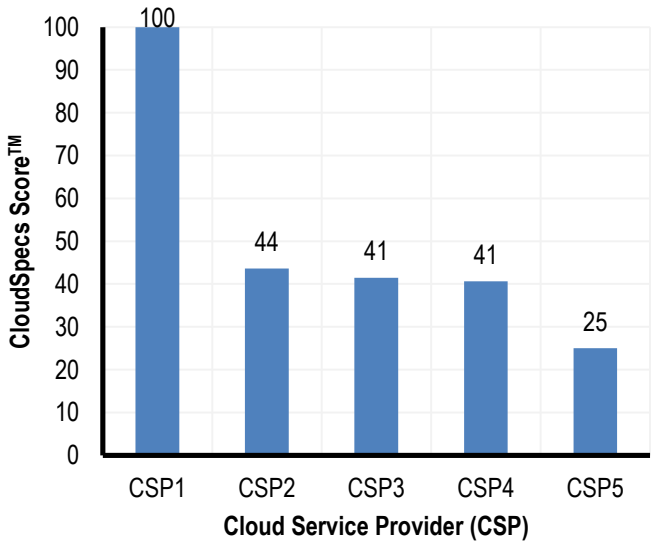
The variability score is designed to reflect the relative fluctuation of a machine in relationship with other VMs included in the same comparison. Therefore, the same variability value of different performance tasks can mean different fluctuation magnitudes. Standard deviation values (Stdev.), alternatively, 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 / best_VM_value*

In this report, Cloud Spectator uses the aggregated performance scores as the [provider 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, 8 vCPU machines were used on GoGrid and Rackspace and 4vCPU machines were used on the remaining providers in order to meet the criteria for selecting Large 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 2.3: Performance and Price Performance (Large 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 – Large VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	5643	7798	2816	4582	4953	8640	4385	2801	5642	7277	3378	5978	4615	12471	3376
5th Per.	6461	10110	3666	6266	7462	9438	6080	3190	8340	8521	3851	7007	5241	14728	3520
Median	**6532**	**10507**	**3904**	**8962**	**7604**	**9573**	**6306**	**3417**	**8553**	**10054**	**6207**	**7134**	**5360**	**15750**	**3571**
95th Per.	6587	10714	4011	9435	7643	9760	6481	3537	8635	10666	6996	7162	5474	16110	3614
Max.	6619	10801	4162	9534	7673	10183	6802	3705	8669	11058	7079	7182	5792	16321	3636

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 and CenturyLink VMs display consistent high rankings in both the High-Score Category and the Low-Score Category, while the rankings of AWS, DigitalOcean and Joyent VMs experience considerable changes in performance values.

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

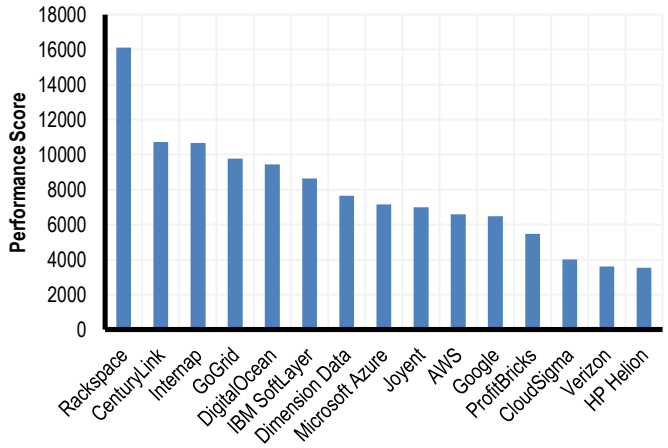
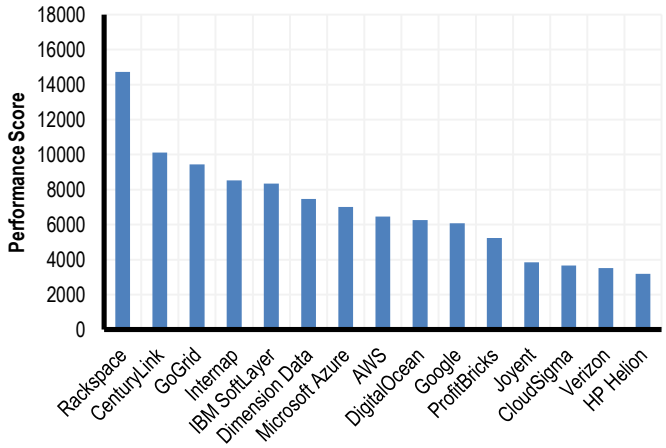


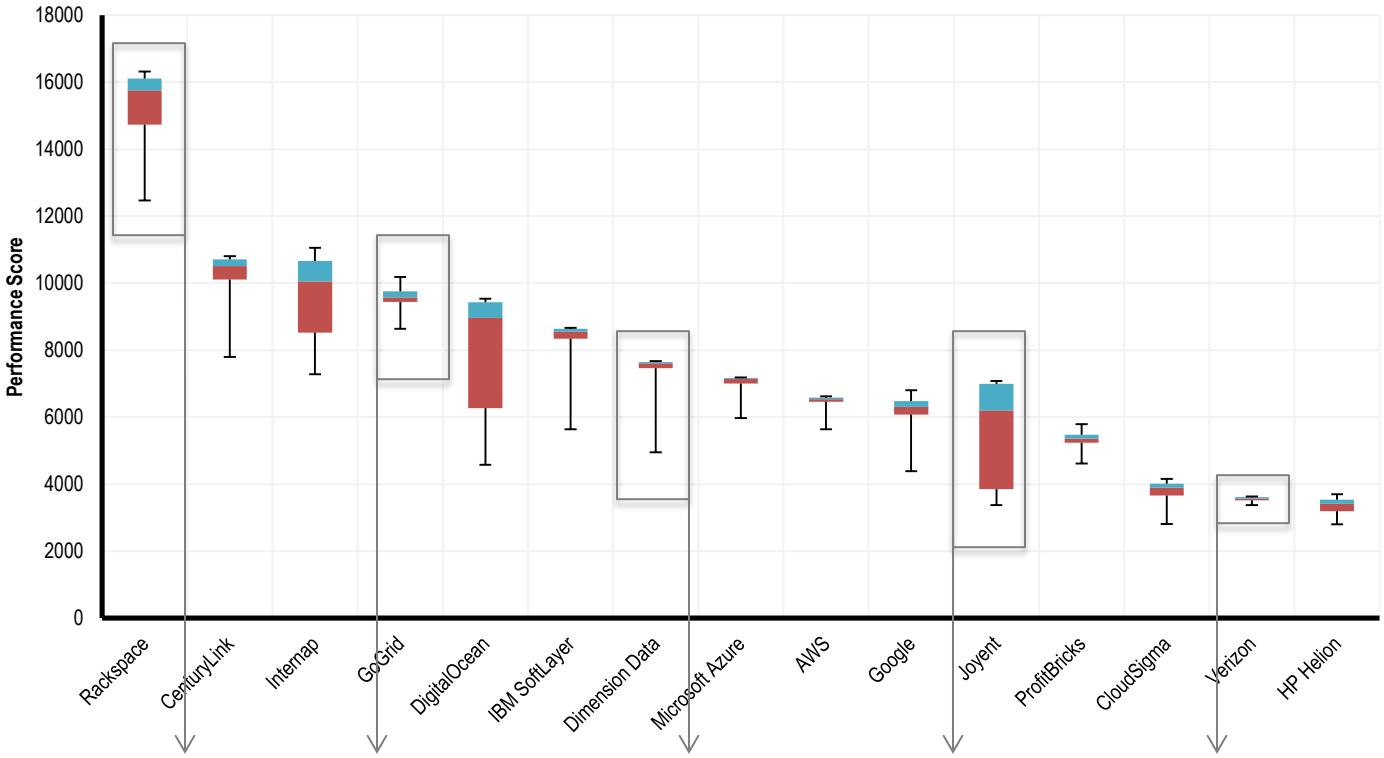
Figure 2.2: CPU & Memory Performance Rank by 5th Percentile (Low-Score Category) – Large VMs



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 below shows that Internap, DigitalOcean and Joyent 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-Score and High-Score Categories. The Rackspace VM also showed some degree of 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 – Large VMs – Ranked by Median



Rackspace's performance graph shows a median line closer to the 95th percentile line than to the 5th percentile line, with the minimum line stretching downwards significantly. This shows a **negative fluctuation**, and one or more points of extremely low scores.

GoGrid's performance graph displays a median line equally diving between the 95th percentile line and the 5th percentile line. Neither the minimum line nor the maximum line stretches out significantly. This indicates a **neutral fluctuation**, and no significant spike was detected.

Dimension Data has its 95th percentile line, median line and 5th percentile line closely compact together, and the minimum line stretches outward significantly. This indicates a relatively stable performance pattern with one or more points of extremely low scores.

Joyent's performance graph shows a median line closer to the 95th percentile line than the 5th percentile line, and the all three lines are distant from each other. This indicates a **negative fluctuation**, with relatively significant performance variation on both high and low scores.

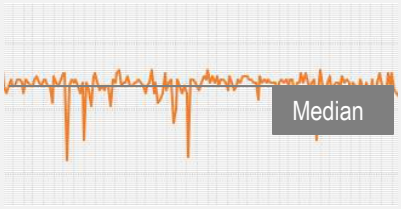
Verizon has its 95th percentile line, median line and 5th percentile line closely compact together, and neither the minimum nor the maximum line stretches outward significantly. This indicates a highly stable performance pattern where **very little fluctuation** was detected.

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 and Joyent VMs exhibited 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.

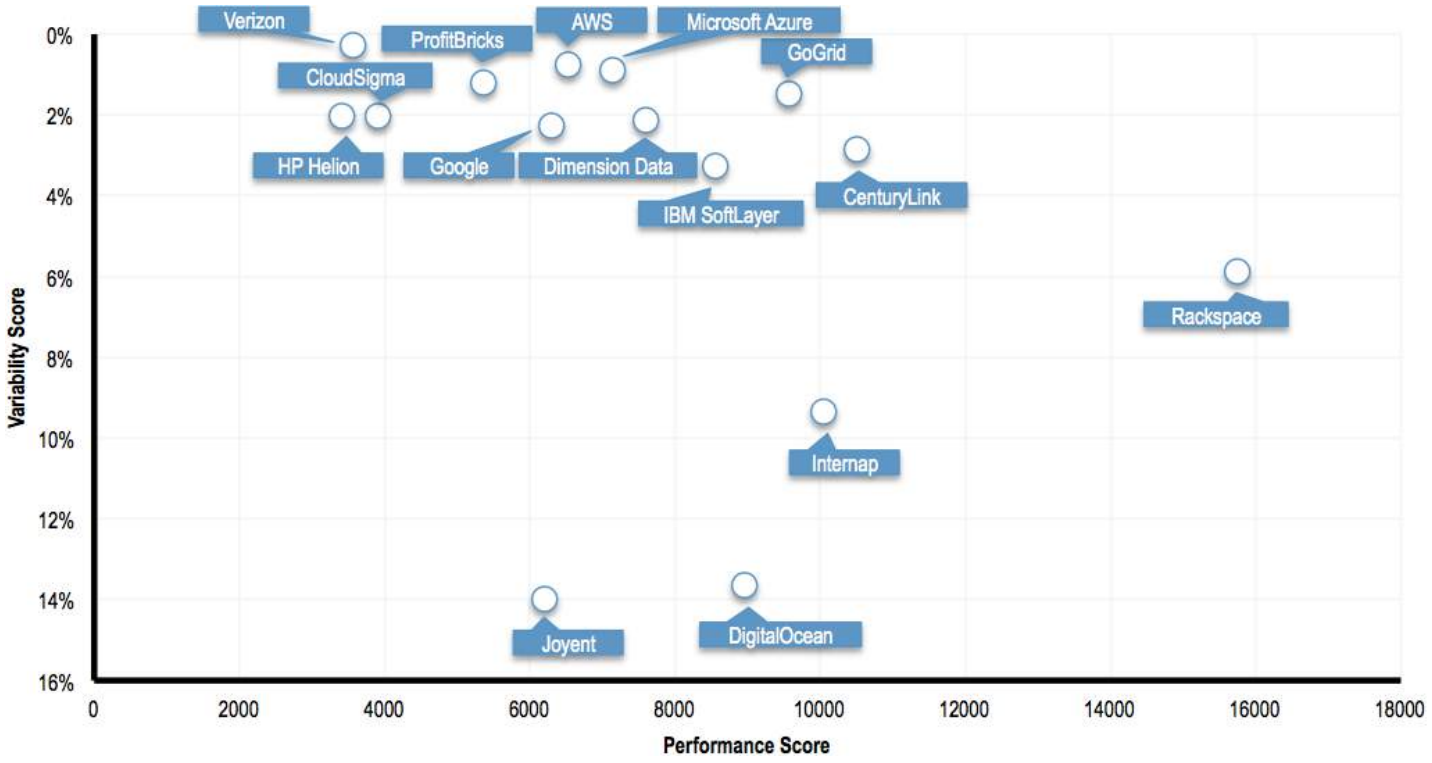
Table 2.2: Aggregated CPU & Memory Performance Variability – Large VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Variability	0.8%	2.9%	2.0%	13.7%	2.1%	1.5%	2.3%	2.0%	3.3%	9.4%	14.0%	0.9%	1.2%	5.9%	0.3%

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 4000 and 10000 with variability lower than 5%.

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

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	6508	8260	3272	4777	5592	10289	4880	3227	6305	7852	3815	6572	5344	13770	3515
5th Per.	7052	10953	4212	6548	8723	11258	6756	3661	9566	9234	4357	7813	6102	16487	3671
Median	**7114**	**11421**	**4491**	**9727**	**8896**	**11418**	**6974**	**3752**	**9820**	**10856**	**7212**	**7938**	**6219**	**17653**	**3725**
95th Per.	7163	11652	4618	10181	8941	11645	7105	3833	9894	11411	8094	7963	6331	18039	3769
Max.	7193	11744	4797	10242	8976	12169	7448	3984	9931	11837	8168	7983	6648	18248	3793
Variability	0.4%	3.1%	2.2%	14.1%	2.5%	1.7%	1.7%	0.9%	3.6%	8.2%	15.2%	0.9%	1.1%	6.1%	0.3%

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. DigitalOcean, and Joyent 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 – Large VMs – Ranked by Median

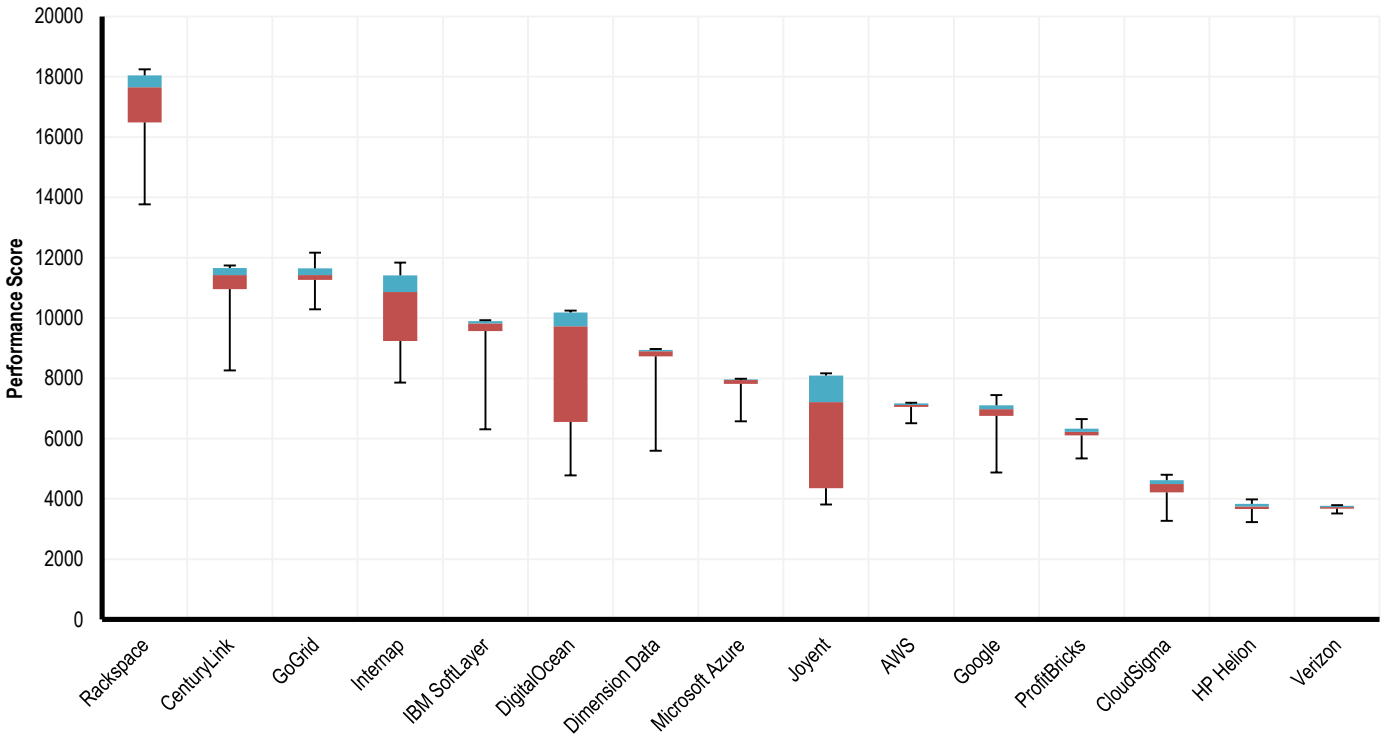
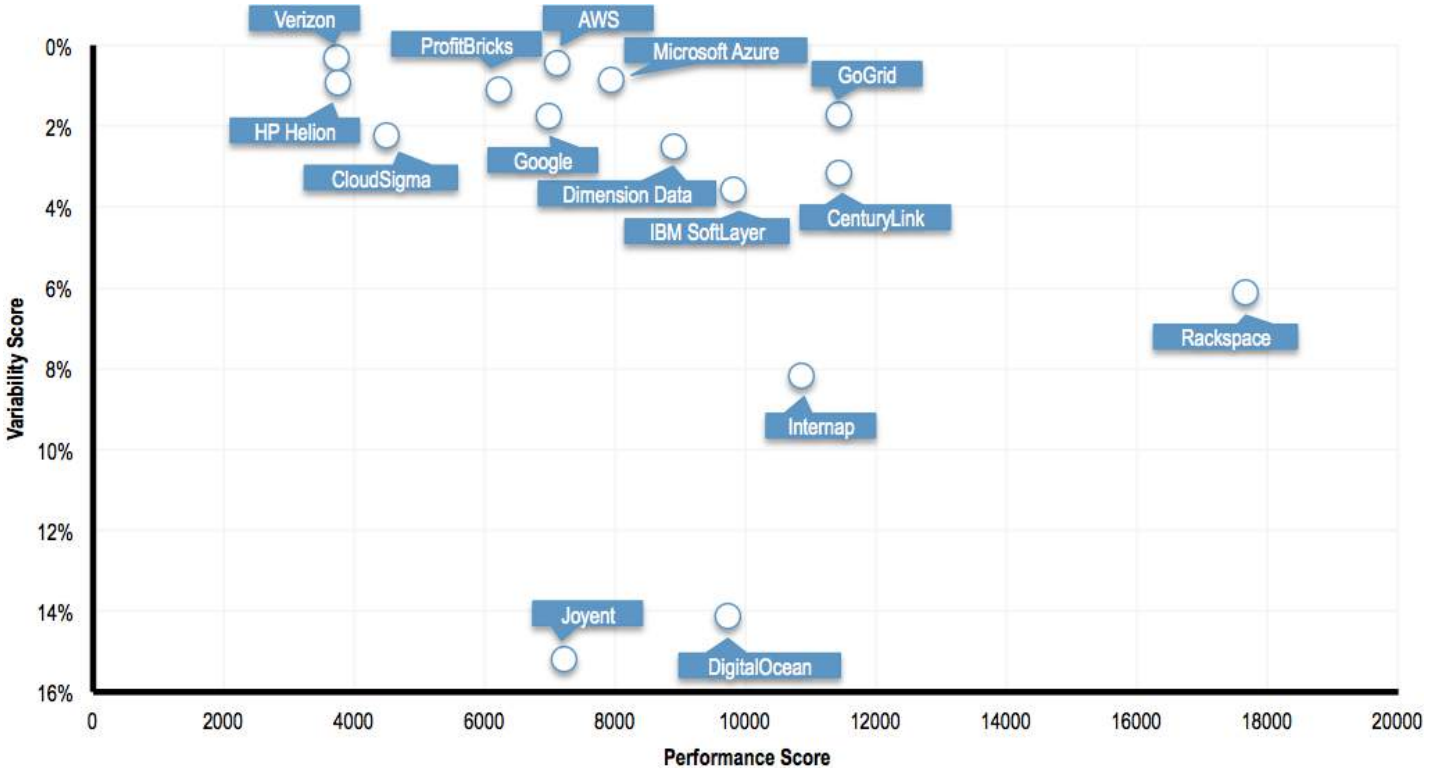


Figure 2.5 shows that Rackspace, CenturyLink and GoGrid are the top three providers for Large VM CPU performance. It is important to keep in mind that the VMs from Rackspace and GoGrid were 8 vCPU machines, while 4 vCPU machines were used on the remaining providers based on Cloud Spectator's selection criteria consistent with that of the *Cloud Vendor Benchmark 2015 Part 1: Pricing* report. For detailed information, see Preface: VM Configurations and Pricing.

DigitalOcean and Joyent VMs displayed high CPU performance variability, while AWS, HP Helion, 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 providers with both high performance and high stability. Most VMs have a performance score between 4000 and 12000 with variability lower than 5%.

Figure 2.6: CPU Performance-Variability Matrix – Large 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 – Large VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	2185	5949	993	3800	2396	2043	2404	1100	2989	4978	1630	3599	1700	7275	2819
5th Per.	4097	6739	1480	5136	2417	2159	3376	1308	3436	5670	1829	3784	1799	7691	2914
Median	**4206**	**6852**	**1552**	**5901**	**2437**	**2193**	**3637**	**2076**	**3487**	**6846**	**2184**	**3918**	**1920**	**8136**	**2953**
95th Per.	4285	6964	1583	6449	2452	2217	3985	2353	3600	7689	2605	3958	2048	8392	2991
Max.	4326	7029	1624	6704	2461	2238	4219	2588	3618	7945	2722	3980	2368	8610	3011
Variability	2.6%	1.2%	1.0%	10.9%	0.0%	0.1%	5.3%	8.3%	1.4%	16.2%	7.1%	1.0%	1.8%	4.4%	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. DigitalOcean and Internap 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 – Large VMs – Ranked by Median

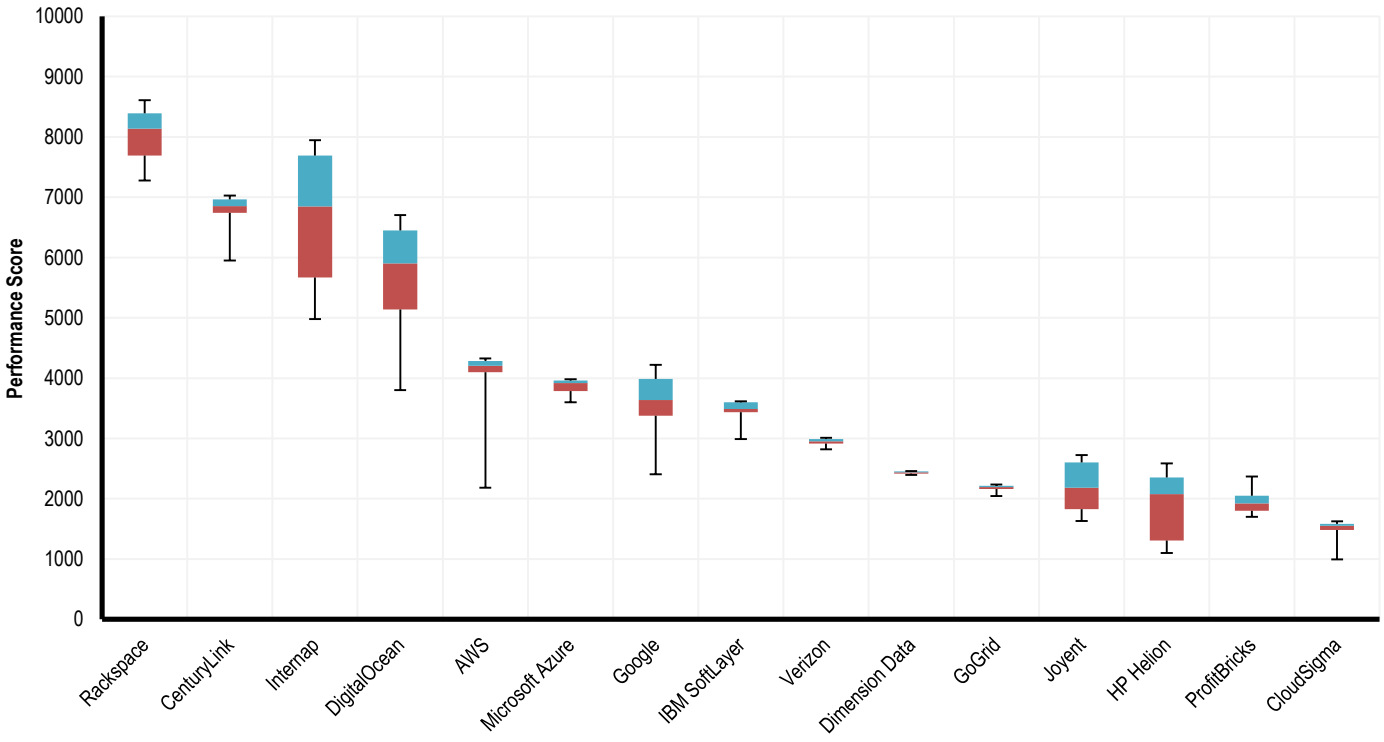
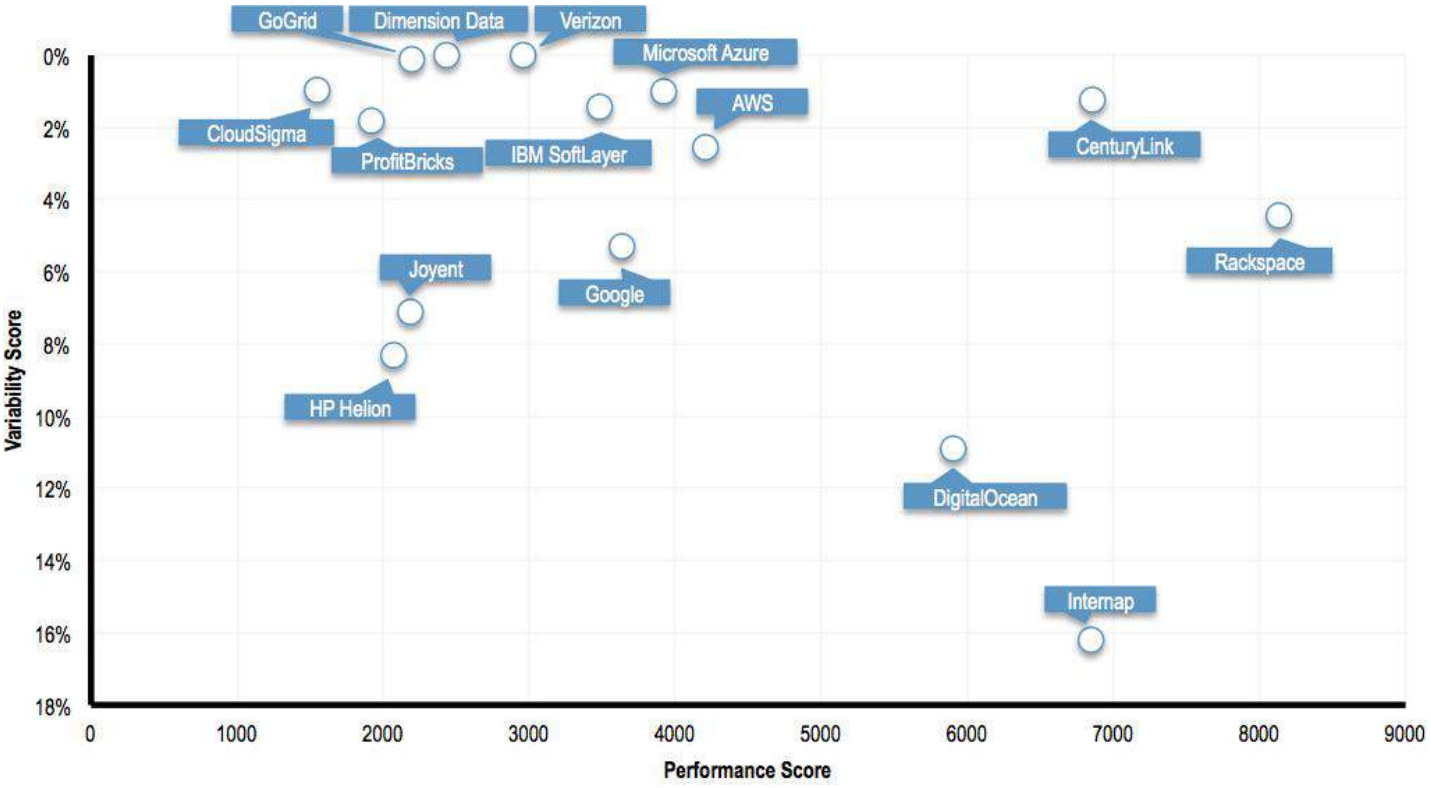


Figure 2.7 shows that Rackspace, CenturyLink and Internap are the top three providers for Large VM memory performance. DigitalOcean and Internap VMs displayed high memory performance variability, while CloudSigma, Dimension Data, GoGrid, Microsoft Azure and Verizon VMs showed high stability with their 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 – Large 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 tables can be found in Appendix: Individual Tasks. In general, the AES, JPEG Decompression, PNG Decompression, Sobel, Lua, SGEMM, Ray Trace 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 26 out of the 27 tasks, and ranked second in the N Body task. GoGrid's VM ranked second in 16 out of 27 tasks.

DigitalOcean, Internap and Joyent VMs displayed recurring fluctuations in all tasks included in the testing. A summary of their performance fluctuation in terms of variability scores is provided in Table 2.5:

Table 2.5: High Variability VM Summary – Large VMs

	High Variability Score*	Low Variability Score*	Average Variability Score	Variability Pattern
DigitalOcean	29.1%	7.6%	13.7%	Mostly negative fluctuations, some positive and neutral
Internap	14.6%	5.1%	9.4%	Mostly negative fluctuations, some positive and neutral
Joyent	17.9%	7.0%	14.0%	Mostly negative fluctuations, some positive and neutral

**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 DigitalOcean VM showed an average variability of 13.7%, with 90% of the variability scores ranging between 7.6% and 29.1%, mostly negative fluctuations; the Internap VM showed an average variability of 9.4%, with 90% of the variability scores ranging between 5.1% and 14.6%, mostly negative fluctuations; and the Joyent VM showed an average variability of 14.0%, with 90% of the variability scores ranging between 7.0% and 17.9%, mostly negative 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 DigitalOcean, Internap and Joyent 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, GoGrid, Microsoft Azure, ProfitBricks and Verizon 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 – Large VMs

	High Variability Score (95%)	Low Variability Score (5%)	Average Variability Score	Variability Pattern
AWS	2.2%	0.0%	0.8%	-
GoGrid	2.4%	0.0%	1.5%	-
Microsoft Azure	1.7%	0.0%	0.9%	-
ProfitBricks	3.1%	0.3%	1.2%	-
Verizon	0.5%	0.0%	0.3%	-

The AWS VM showed an average variability of 0.8%, with 90% of the variability scores ranging between 0.0% and 2.2%; the GoGrid VM showed an average variability of 1.5%, with 90% of the variability scores ranging between 0.0% and 2.4%; the Microsoft Azure VM showed an average variability of 0.9%, with 90% of the variability scores ranging between 0.0% and 1.7%; the ProfitBricks VM showed an average variability of 1.2%, with 90% of the variability scores ranging from 0.3% and 3.1%; and the Verizon VM showed an average variability of 0.3%, with 90% of the variability scores ranging from 0.0% and 0.5%. Variability patterns were unclear since the fluctuations were relatively small. All variability scores can be viewed in the performance analysis tables. The small variability of those provider VMs predicts stable aggregate performance outputs during the 24-hour testing. For variability calculation information, see Methodology: Performance.

CenturyLink, DigitalOcean, Dimension Data, Google, IBM SoftLayer and Rackspace VMs exhibited performance outliers on the lower end for many 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 – Large 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 DigitalOcean VM had the highest price-performance values. CenturyLink, Rackspace and ProfitBricks VMs exhibited high price-performance value for hourly 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.

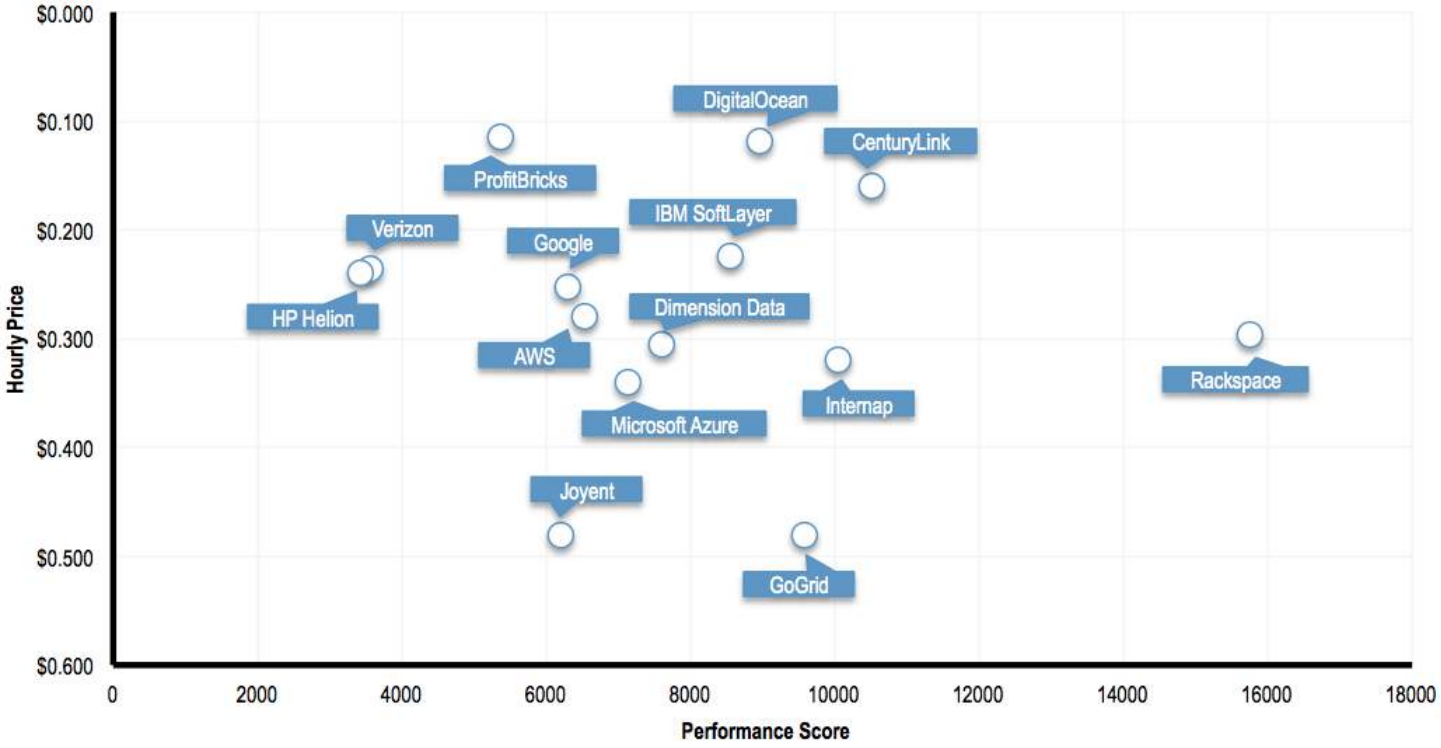
The graphs on the next few pages show the relationship between price and performance for hourly, monthly, annual and 3-year pricing individually, using median performance data, and display the CloudSpecs Score™ price-performance comparison for each pricing model using low scores, median scores and high 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 – Large 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 VMs 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 – Large VMs (Hourly)

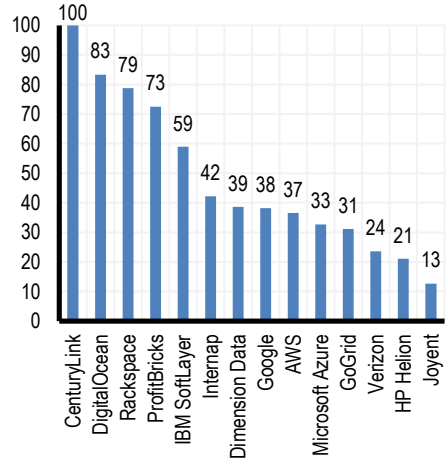


Figure 3.4: Median-Score Category Price-Performance – Large VMs (Hourly)

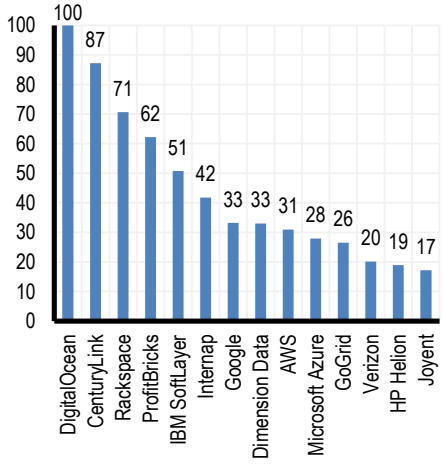
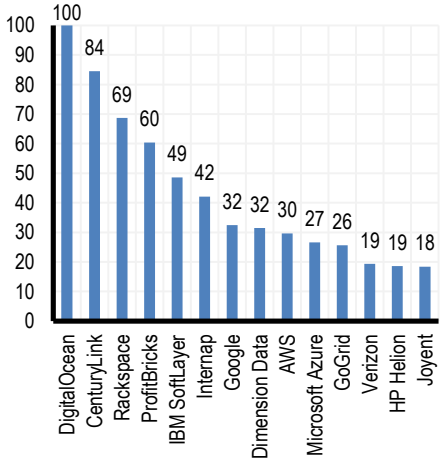


Figure 3.5: High-Score Category Price-Performance – Large VMs (Hourly)



**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.*

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 – Large VMs

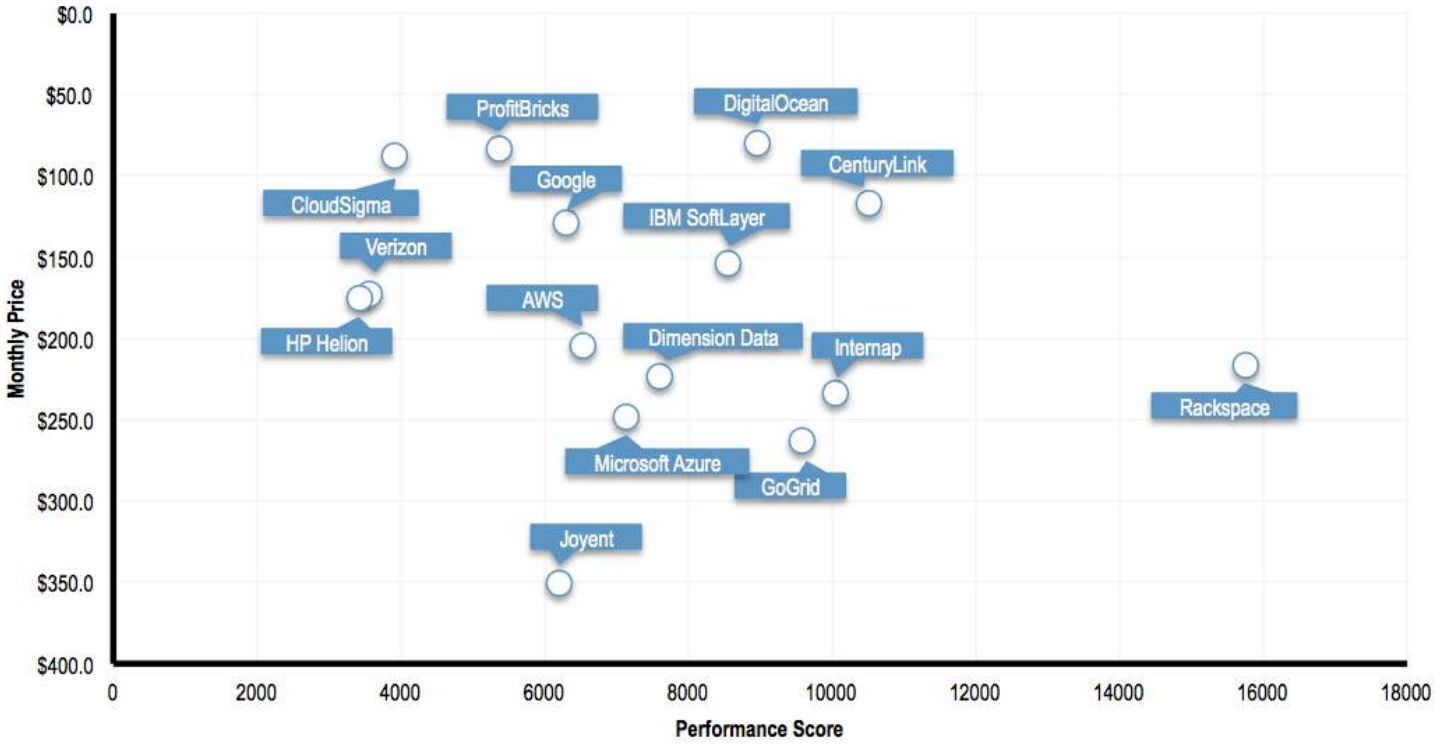


Figure 3.7 – 3.9 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and monthly prices.

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

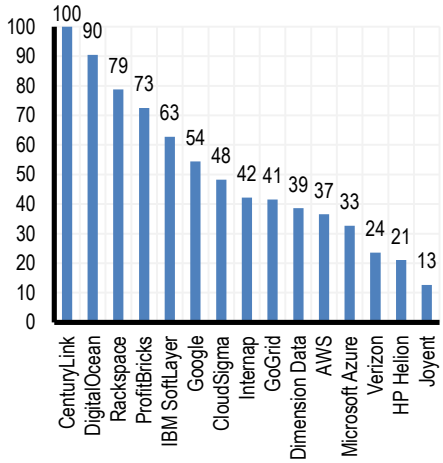


Figure 3.8: Median-Score Category Price-Performance – Large VMs (Monthly)

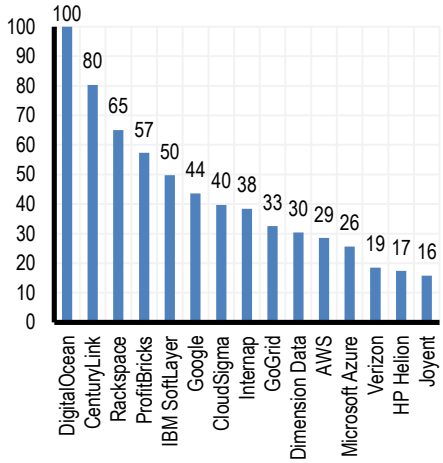
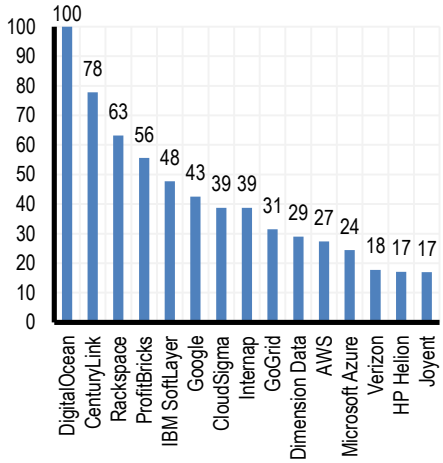


Figure 3.9: High-Score Category Price-Performance – Large VMs (Monthly)



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 – Large VMs

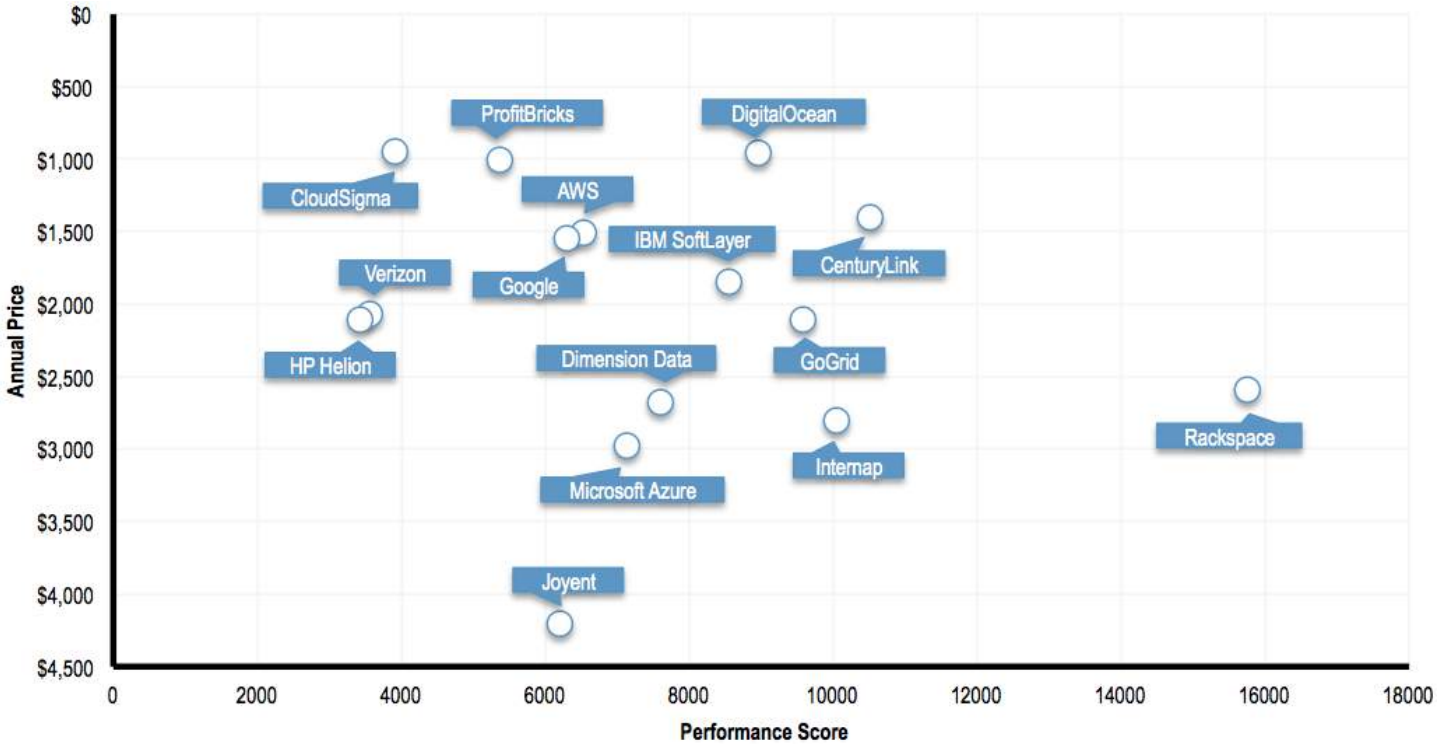


Figure 3.11 – 3.13 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and annual prices.

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

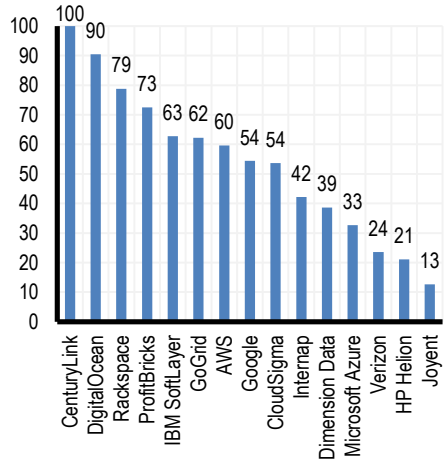


Figure 3.12: Median-Score Category Price-Performance – Large VMs (Annual)

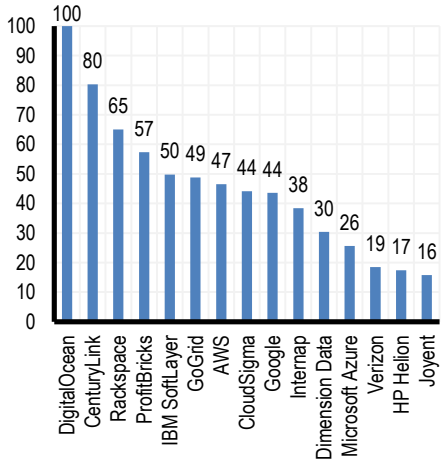
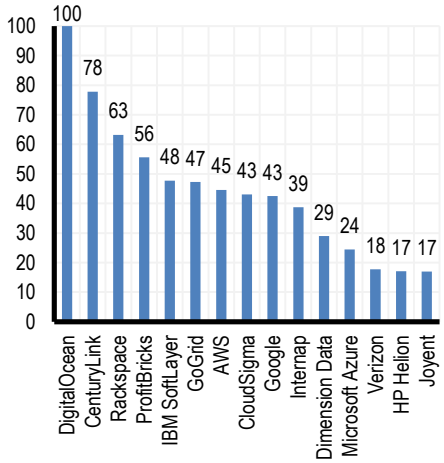


Figure 3.13: High-Score Category Price-Performance – Large VMs (Annual)



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 – Large VMs

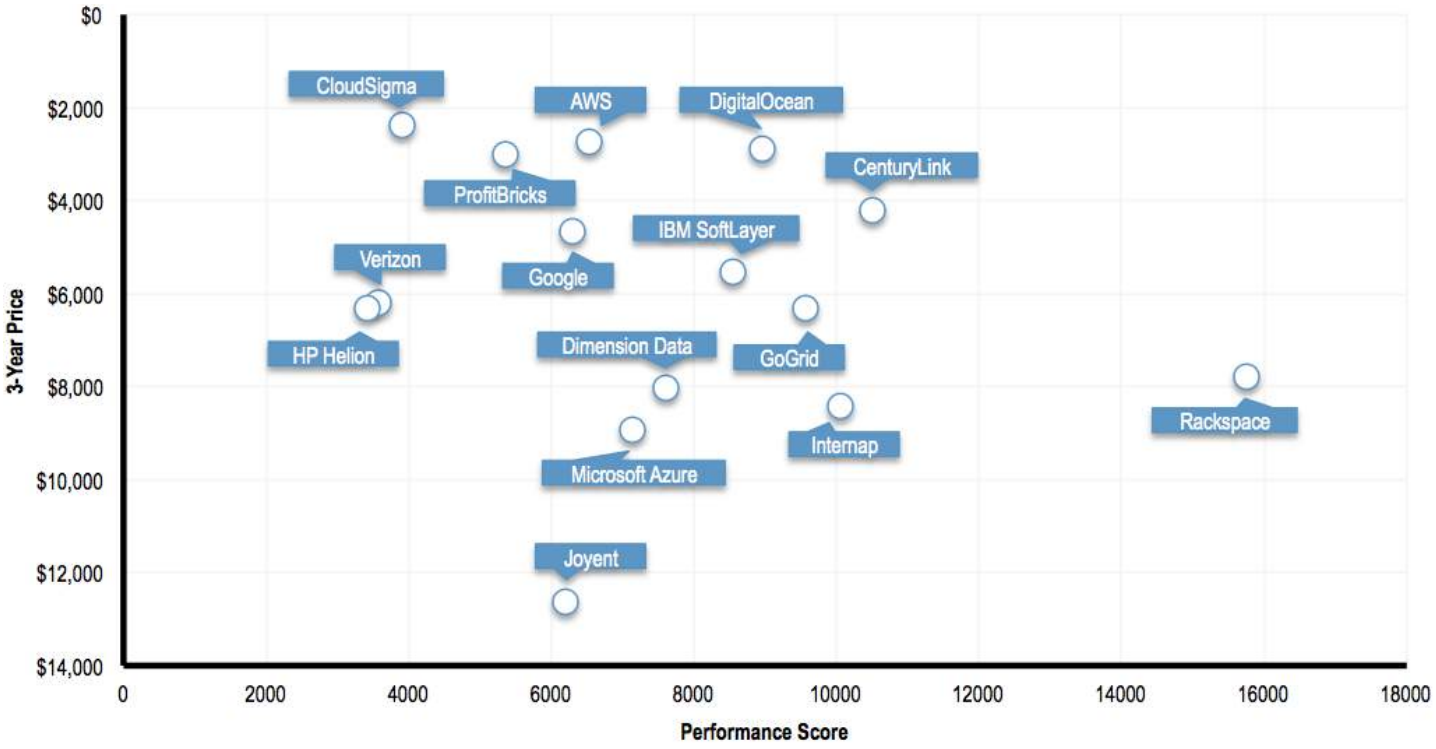


Figure 3.15 – 3.17 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and 3-year prices.

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

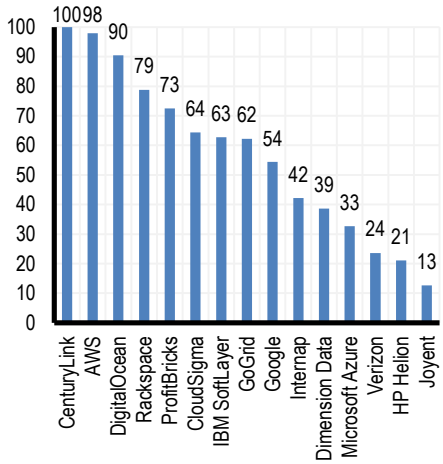


Figure 3.16: Median-Score Category Price-Performance – Large VMs (3-Year)

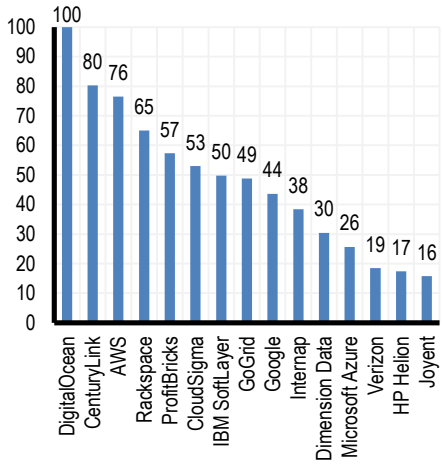
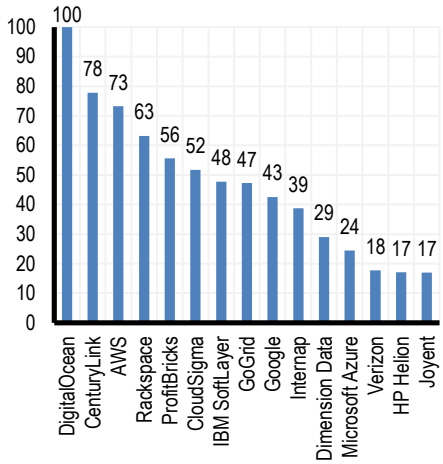


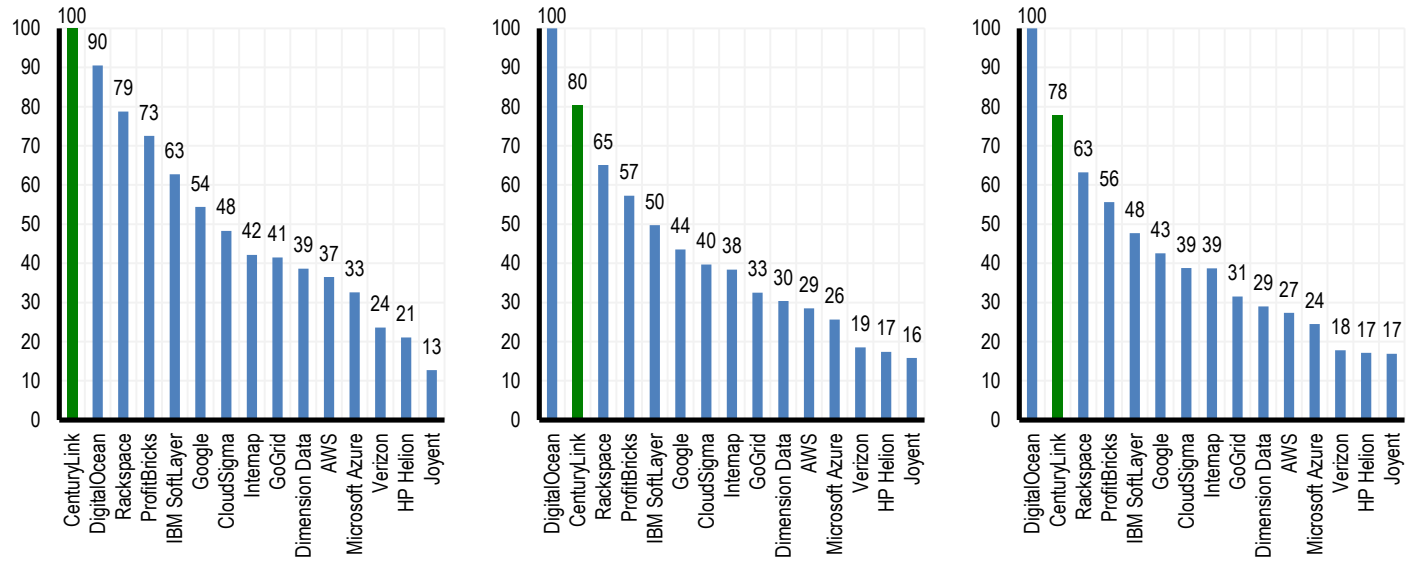
Figure 3.17: High-Score Category Price-Performance – Large VMs (3-Year)



Overall, DigitalOcean, CenturyLink and Rackspace VMs had the highest rankings in low, median and high CloudSpecs scores of all pricing intervals. The DigitalOcean VM led all the Median- and High-Score Categories, and the CenturyLink VM had the top price-performance for all Low-Score Category comparisons. For the 3-year price-performance comparisons, the AWS VM ranked higher than the Rackspace VM with its long-term price discounts.

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 – Large VMs



As illustrated above using the monthly examples, the CenturyLink VM's price-performance ranking in the Low-Score Category is higher than in the Median- and High-Score Categories,

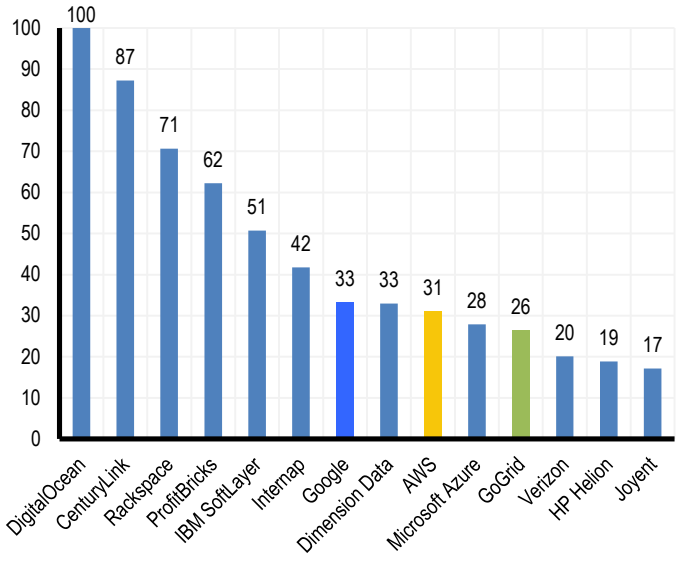
The price-performance value ranges reflected by the three categories are consistent with their performance variations, which are shown in the section titled Performance Comparison.

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:

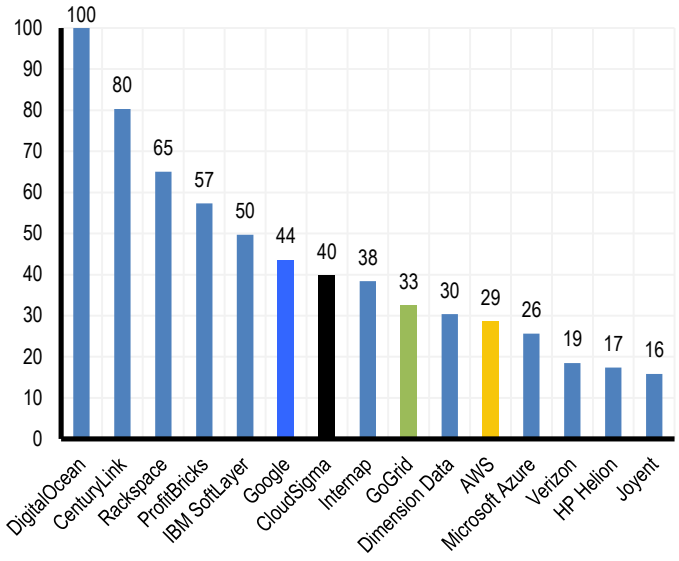
[2] This AWS discount information only applies to the m3.xlarge instance at their Virginia data center assuming full payment upfront. Any changes in conditions may change the discount information for both annual and 3-year pricing.

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

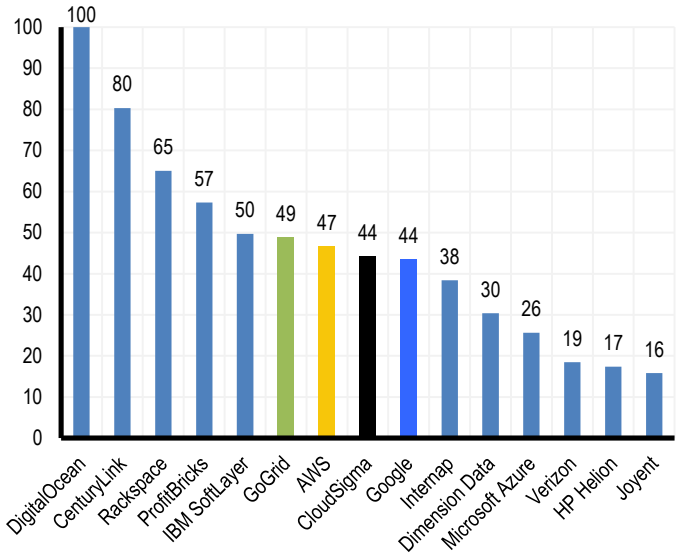
Hourly Price-Performance



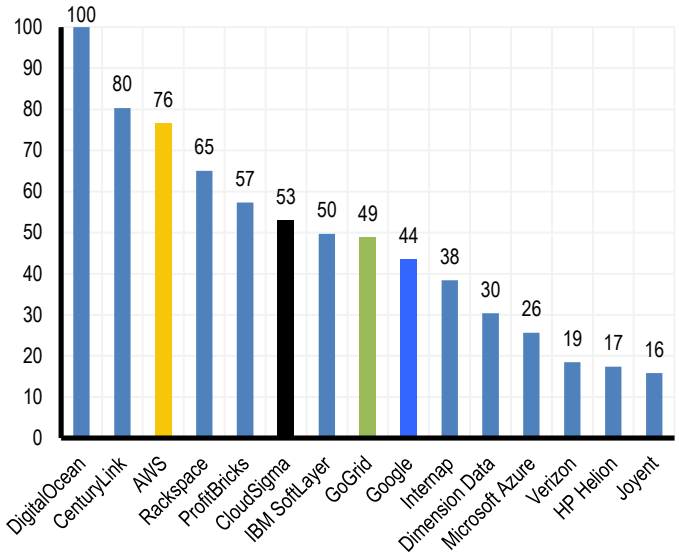
Monthly Price-Performance



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 Large 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 Large VM as an example, while the VM ranks 10th 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. 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 Large VM report are also included in the tables. For price-performance comparisons for Small, Medium, XLarge 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	-	-	-	-

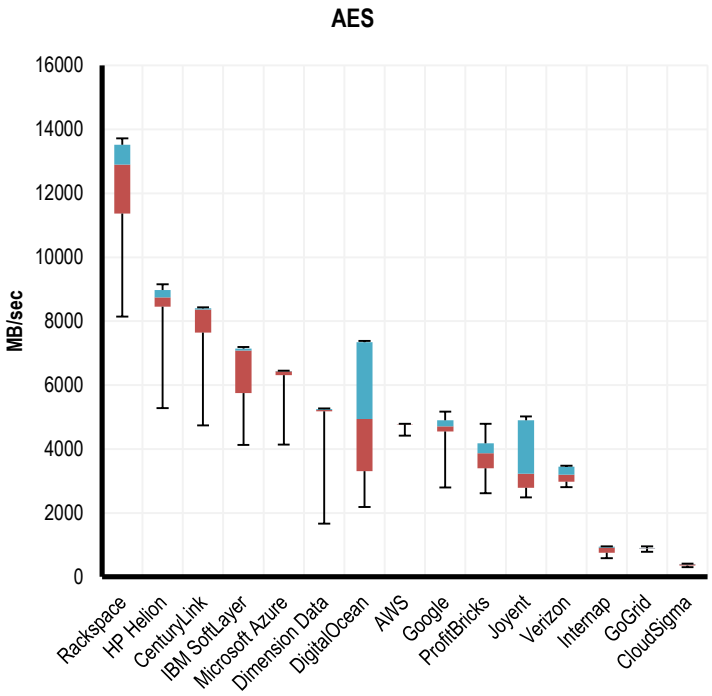
VM Processor Information

Provider	OS	Python Version	Processor (Large)
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

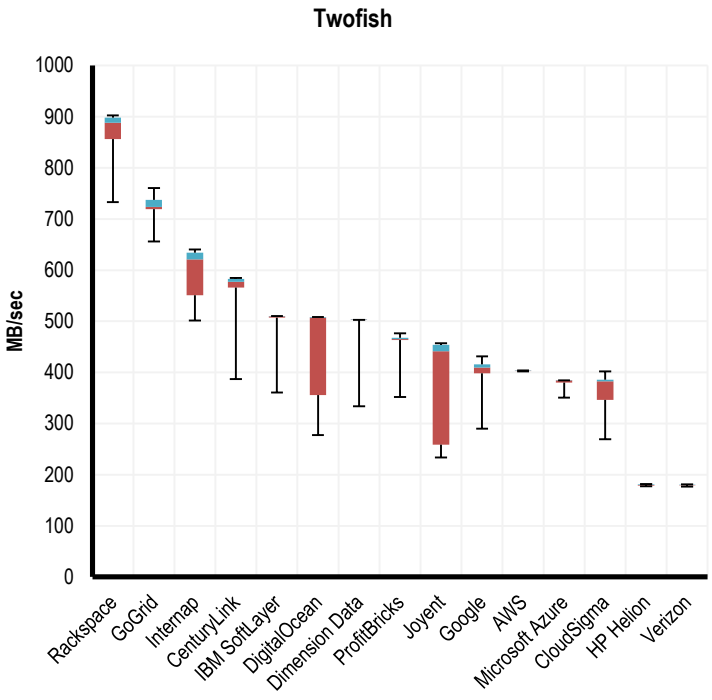
The following tables and graphs describe the performance ranking through each individual task. The rankings are from high to low based on median.

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.



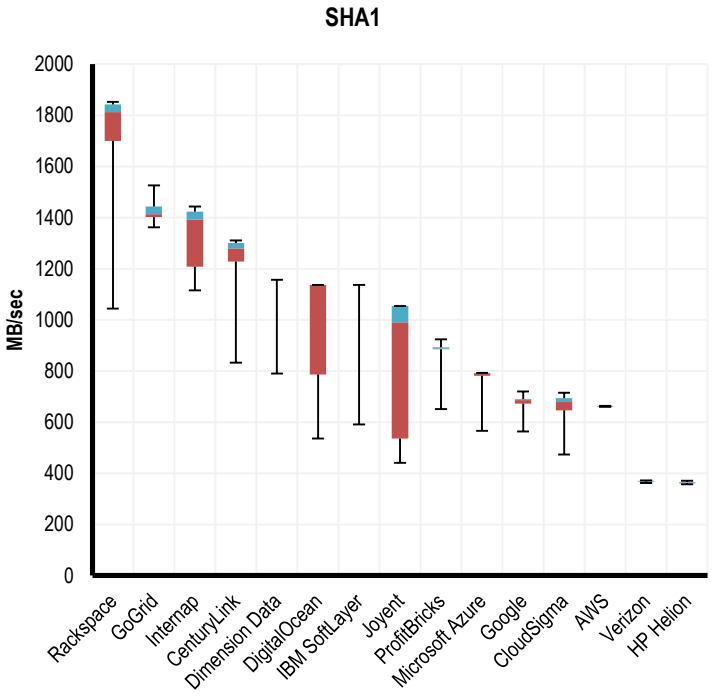
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	4424	4772	4782	4782	4792	13	0.3%
CenturyLink	4741	7649	8366	8407	8438	486	10.2%
CloudSigma	303	353	396	404	413	16	0.3%
DigitalOcean	2191	3308	4941	7342	7383	1749	36.6%
Dimension Data	1669	5186	5222	5249	5274	423	8.8%
GoGrid	785	886	894	909	956	9	0.2%
Google	2796	4547	4710	4905	5171	162	3.4%
HP Helion	5284	8452	8745	8980	9155	270	5.6%
IBM SoftLayer	4127	5755	7086	7148	7188	521	10.9%
Internap	586	759	914	943	959	61	1.3%
Joyent	2488	2785	3226	4905	5018	607	12.7%
Microsoft Azure	4137	6308	6431	6441	6451	132	2.8%
ProfitBricks	2621	3397	3871	4178	4792	238	5.0%
Rackspace	8141	11366	12902	13517	13722	778	16.3%
Verizon	2806	2980	3195	3451	3482	129	2.7%

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.



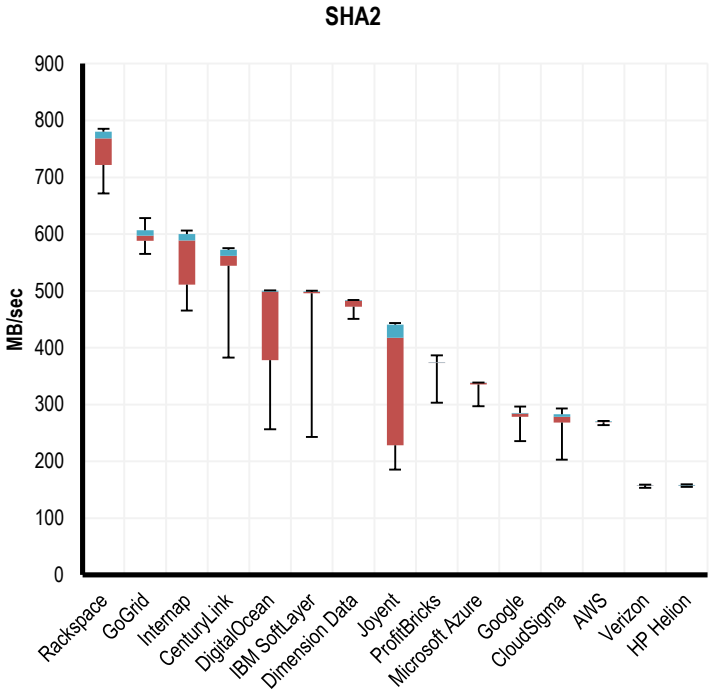
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	402.0	402.7	403.3	403.5	403.6	0.0	0.0%
CenturyLink	386.7	565.8	577.0	582.8	584.6	5.8	1.2%
CloudSigma	269.2	346.5	382.4	386.0	402.3	15.1	3.2%
DigitalOcean	277.6	355.6	507.3	508.4	508.7	43.7	9.4%
Dimension Data	333.7	502.6	502.7	502.9	503.0	5.0	1.1%
GoGrid	656.3	719.6	723.8	737.4	760.9	7.2	1.6%
Google	290.2	398.0	409.5	415.9	431.2	4.1	0.9%
HP Helion	177.6	178.8	179.8	181.2	181.6	0.0	0.0%
IBM SoftLayer	360.8	507.1	509.5	510.0	510.2	15.2	3.3%
Internap	501.4	551.1	620.9	634.2	640.4	24.5	5.3%
Joyent	233.9	258.8	441.6	454.3	456.8	64.6	13.9%
Microsoft Azure	351.0	380.2	384.3	384.7	384.8	2.0	0.4%
ProfitBricks	351.9	463.3	465.3	467.9	476.4	4.7	1.0%
Rackspace	733.1	856.6	888.3	898.0	902.8	8.8	1.9%
Verizon	177.0	179.0	179.7	180.5	181.4	0.0	0.0%

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.



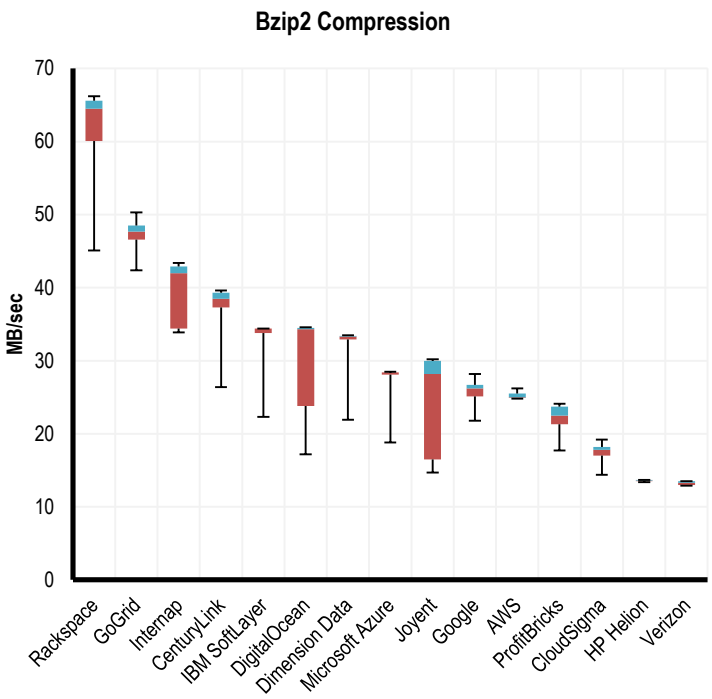
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	660	661	662	663	664	0	0.0%
CenturyLink	833	1229	1280	1300	1311	25	2.6%
CloudSigma	474	647	678	694	715	27	2.7%
DigitalOcean	536	787	1137	1137	1137	109	11.0%
Dimension Data	791	1157	1157	1157	1157	12	1.2%
GoGrid	1362	1403	1413	1444	1526	14	1.4%
Google	564	673	687	691	720	7	0.7%
HP Helion	357	362	363	367	371	1	0.1%
IBM SoftLayer	592	1137	1137	1137	1137	34	3.4%
Internap	1116	1208	1393	1423	1444	55	5.5%
Joyent	441	537	991	1055	1055	171	17.3%
Microsoft Azure	566	782	792	793	793	8	0.8%
ProfitBricks	652	885	887	894	924	9	0.9%
Rackspace	1044	1700	1812	1843	1853	54	5.4%
Verizon	363	368	369	371	372	0	0.0%

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.



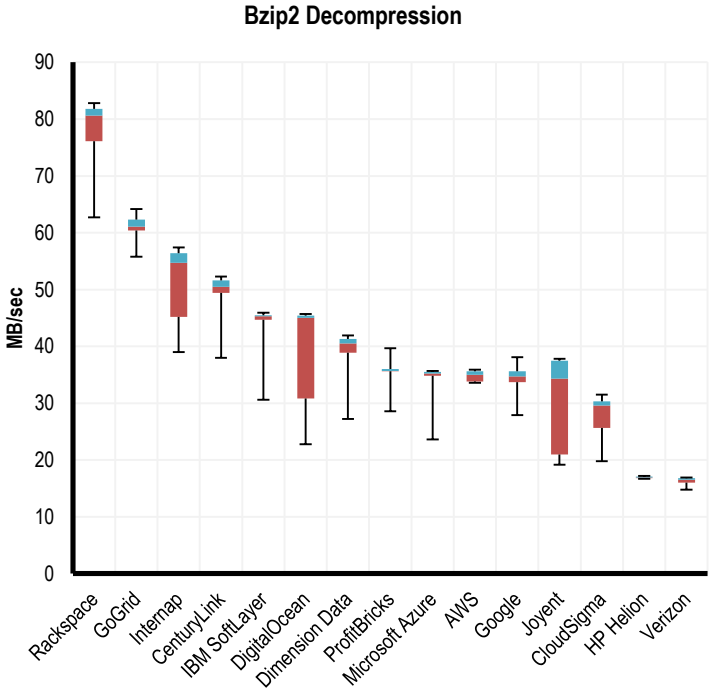
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	264.1	268.9	269.5	270.5	271.2	0.0	0.0%
CenturyLink	382.5	544.4	561.8	572.5	575.1	11.2	2.7%
CloudSigma	202.9	268.2	278.5	282.9	292.9	8.3	2.0%
DigitalOcean	256.4	378.3	498.8	500.6	501.0	38.6	9.3%
Dimension Data	450.6	472.0	483.2	483.9	484.3	3.0	0.7%
GoGrid	565.0	588.4	597.5	606.9	628.3	6.0	1.4%
Google	235.4	278.6	284.0	285.1	296.5	2.8	0.7%
HP Helion	155.0	156.7	157.3	158.7	159.6	0.0	0.0%
IBM SoftLayer	242.9	496.0	498.4	499.3	500.2	14.9	3.6%
Internap	465.7	511.2	588.9	600.0	606.2	23.2	5.6%
Joyent	185.5	228.5	417.4	440.5	443.3	69.1	16.6%
Microsoft Azure	296.9	335.2	338.3	338.5	338.6	2.0	0.5%
ProfitBricks	303.1	373.0	373.6	374.4	386.6	3.0	0.7%
Rackspace	671.5	721.6	768.2	780.4	785.1	15.2	3.7%
Verizon	153.7	156.9	157.5	158.2	159.2	0.0	0.0%

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.



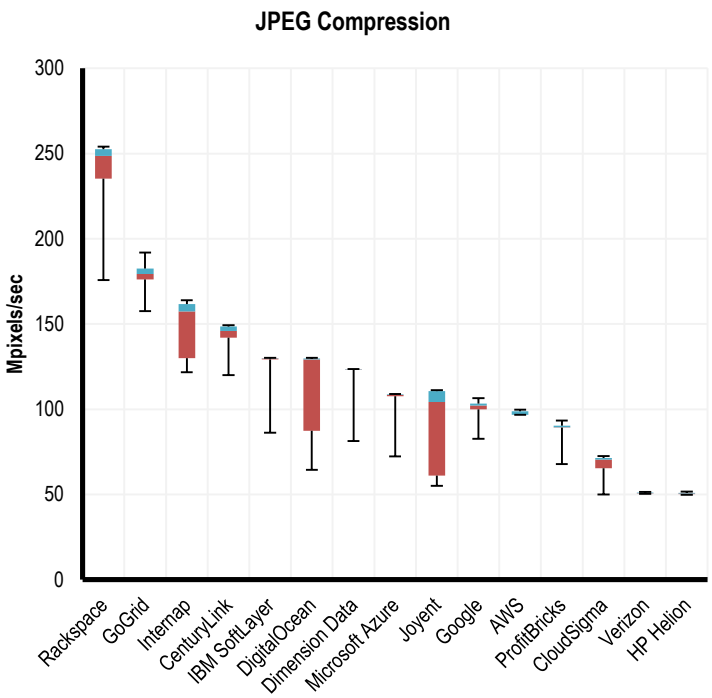
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	24.80	24.90	25.00	25.50	26.20	0.00	0.0%
CenturyLink	26.40	37.30	38.50	39.30	39.60	0.76	2.7%
CloudSigma	14.40	17.00	17.80	18.20	19.20	0.51	1.8%
DigitalOcean	17.20	23.80	34.30	34.50	34.60	3.20	11.3%
Dimension Data	21.90	32.90	33.30	33.40	33.50	0.33	1.2%
GoGrid	42.40	46.60	47.70	48.51	50.30	0.47	1.7%
Google	21.80	25.10	26.20	26.70	28.20	0.52	1.8%
HP Helion	13.40	13.50	13.60	13.70	13.70	0.00	0.0%
IBM SoftLayer	22.30	33.80	34.40	34.40	34.40	1.36	4.8%
Internap	33.90	34.40	42.00	42.90	43.40	2.05	7.2%
Joyent	14.70	16.50	28.20	30.00	30.20	4.50	15.8%
Microsoft Azure	18.80	28.10	28.40	28.40	28.50	0.28	1.0%
ProfitBricks	17.70	21.30	22.50	23.70	24.10	0.88	3.1%
Rackspace	45.10	60.08	64.50	65.60	66.20	1.89	6.7%
Verizon	12.90	13.00	13.30	13.50	13.50	0.13	0.5%

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.



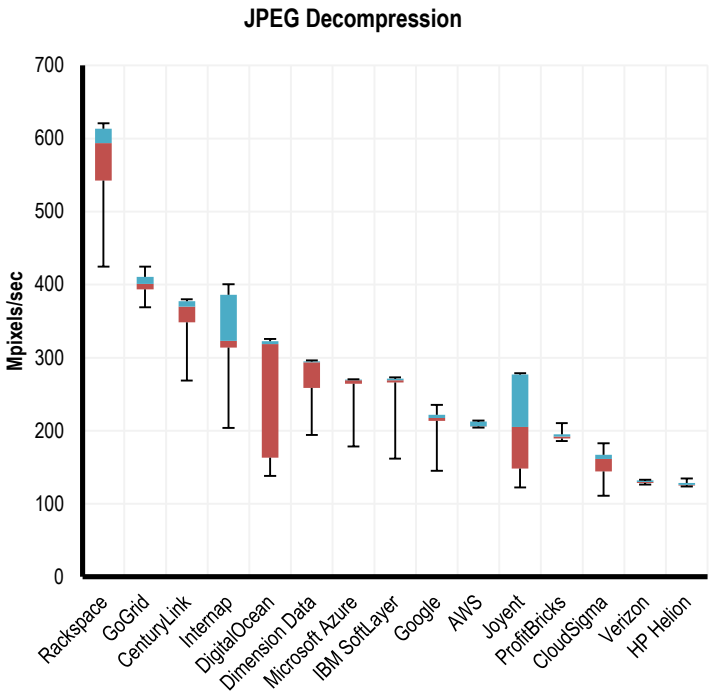
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	33.60	33.80	35.00	35.60	35.90	0.34	1.0%
CenturyLink	38.00	49.40	50.50	51.60	52.30	0.50	1.4%
CloudSigma	19.80	25.66	29.60	30.30	31.50	1.45	4.1%
DigitalOcean	22.80	30.81	45.00	45.40	45.70	4.30	12.0%
Dimension Data	27.20	38.90	40.50	41.30	41.90	0.80	2.2%
GoGrid	55.80	60.40	61.10	62.30	64.20	0.61	1.7%
Google	27.90	33.70	34.70	35.60	38.10	0.68	1.9%
HP Helion	16.70	16.80	16.90	17.10	17.20	0.00	0.0%
IBM SoftLayer	30.60	44.70	45.30	45.50	45.90	0.90	2.5%
Internap	39.00	45.20	54.70	56.40	57.40	3.64	10.2%
Joyent	19.20	21.00	34.35	37.50	37.80	5.58	15.6%
Microsoft Azure	23.60	34.81	35.20	35.50	35.70	0.35	1.0%
ProfitBricks	28.60	35.60	35.70	36.00	39.70	0.35	1.0%
Rackspace	62.70	76.10	80.60	81.80	82.80	1.60	4.5%
Verizon	14.80	16.00	16.50	16.80	16.90	0.16	0.4%

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



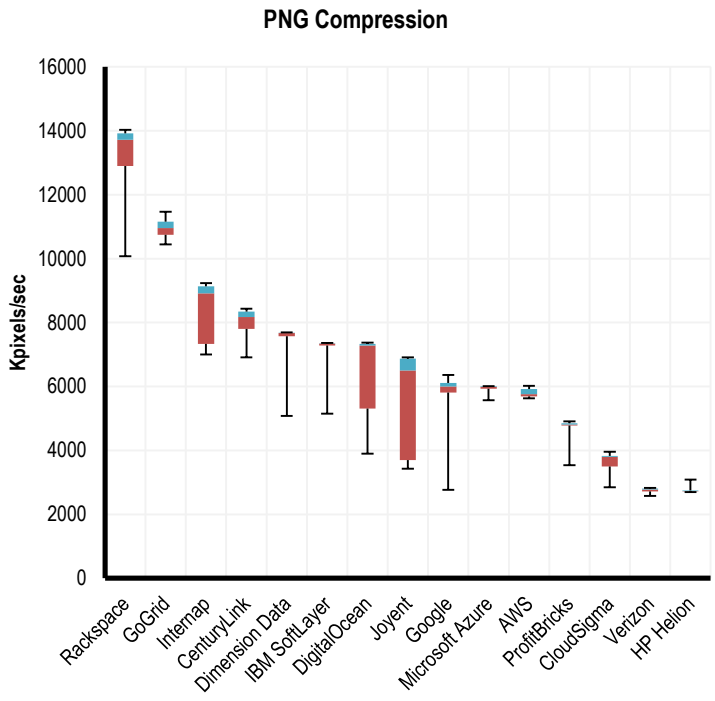
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	96.7	96.8	96.8	98.9	99.8	0.0	0.0%
CenturyLink	120.1	142.0	145.9	148.5	149.3	1.5	1.3%
CloudSigma	50.1	65.5	70.4	71.4	72.6	2.8	2.5%
DigitalOcean	64.5	87.4	129.3	129.8	130.2	12.3	11.3%
Dimension Data	81.3	123.1	123.3	123.5	123.6	1.2	1.1%
GoGrid	157.6	176.2	179.4	182.6	192.0	1.8	1.7%
Google	82.7	99.9	102.3	103.4	106.6	1.0	0.9%
HP Helion	49.8	50.3	50.5	51.0	51.8	0.0	0.0%
IBM SoftLayer	86.2	129.2	129.8	130.0	130.1	1.3	1.2%
Internap	121.7	130.0	157.4	161.8	164.0	9.2	8.5%
Joyent	55.0	61.2	104.3	110.6	111.3	16.9	15.6%
Microsoft Azure	72.4	107.7	108.4	108.8	109.0	1.1	1.0%
ProfitBricks	67.8	89.2	89.5	90.3	93.3	0.9	0.8%
Rackspace	175.8	235.4	248.6	252.5	254.1	4.9	4.6%
Verizon	50.4	50.6	50.8	51.2	51.5	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.



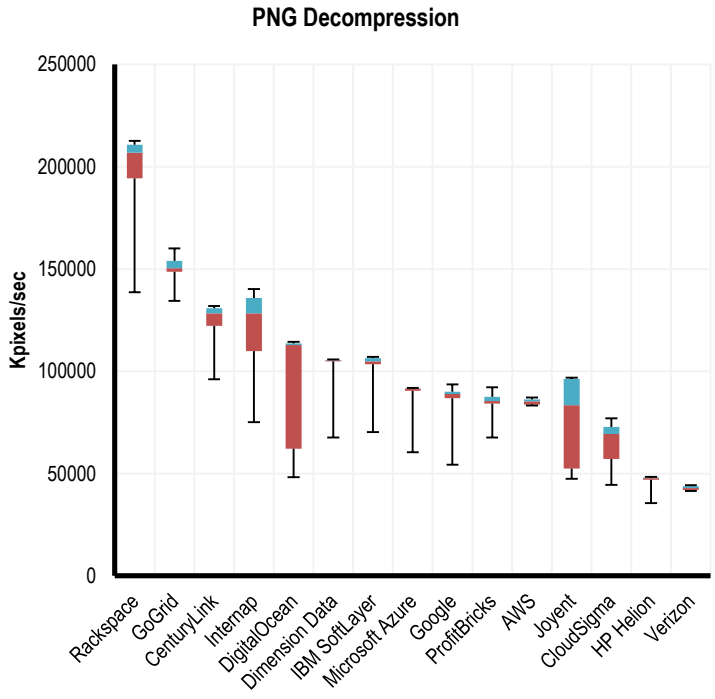
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	204.4	205.6	206.2	212.6	213.8	1.0	0.4%
CenturyLink	268.7	348.3	369.8	377.3	379.9	11.0	4.1%
CloudSigma	110.9	144.3	161.6	167.0	182.8	8.0	3.0%
DigitalOcean	138.0	163.3	318.5	322.7	325.5	52.0	19.3%
Dimension Data	194.4	258.5	293.7	295.0	296.3	14.2	5.3%
GoGrid	368.9	393.6	401.2	410.6	424.7	4.0	1.5%
Google	145.3	213.5	217.6	221.9	235.5	4.3	1.6%
HP Helion	123.9	125.2	126.0	128.4	134.8	1.0	0.4%
IBM SoftLayer	161.8	266.1	269.1	271.4	273.1	8.0	3.0%
Internap	203.8	313.7	323.1	386.3	400.7	27.2	10.1%
Joyent	122.6	148.1	205.4	276.9	278.8	45.2	16.8%
Microsoft Azure	178.5	264.3	269.2	269.9	270.3	2.7	1.0%
ProfitBricks	186.1	189.6	192.3	195.0	210.3	1.9	0.7%
Rackspace	424.7	542.7	593.7	613.6	620.7	17.6	6.6%
Verizon	126.5	128.4	129.9	132.0	132.8	1.0	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.



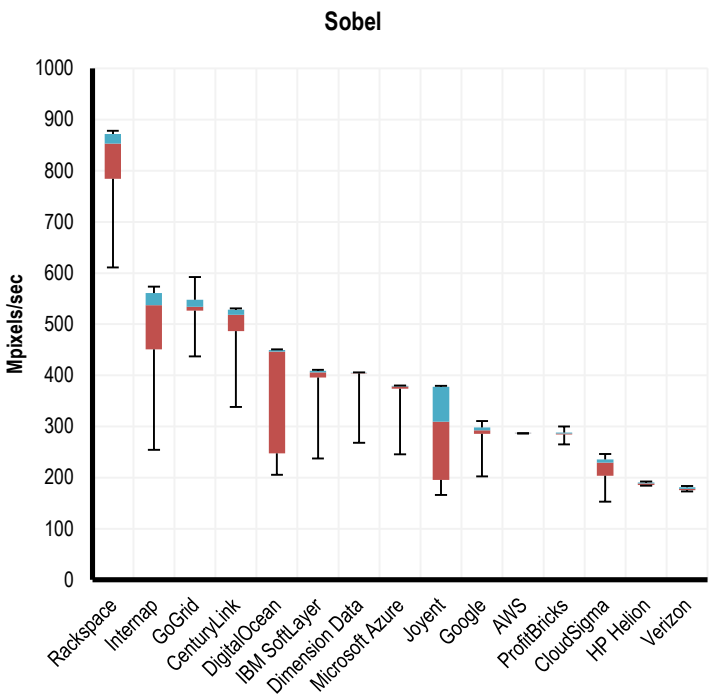
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	5632	5693	5765	5919	6021	51	0.8%
CenturyLink	6912	7802	8172	8346	8438	143	2.2%
CloudSigma	2847	3500	3799	3830	3963	141	2.2%
DigitalOcean	3901	5315	7281	7332	7373	553	8.5%
Dimension Data	5079	7578	7670	7680	7690	144	2.2%
GoGrid	10445	10752	10957	11162	11469	116	1.8%
Google	2765	5816	6001	6113	6359	154	2.4%
HP Helion	2693	2714	2724	2744	3092	20	0.3%
IBM SoftLayer	5151	7281	7342	7352	7363	143	2.2%
Internap	7004	7332	8919	9134	9236	492	7.6%
Joyent	3430	3699	6502	6871	6912	922	14.2%
Microsoft Azure	5571	5929	5990	6011	6011	0	0.0%
ProfitBricks	3543	4782	4813	4854	4915	41	0.6%
Rackspace	10076	12902	13722	13926	14029	266	4.1%
Verizon	2580	2714	2775	2806	2826	20	0.3%

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.



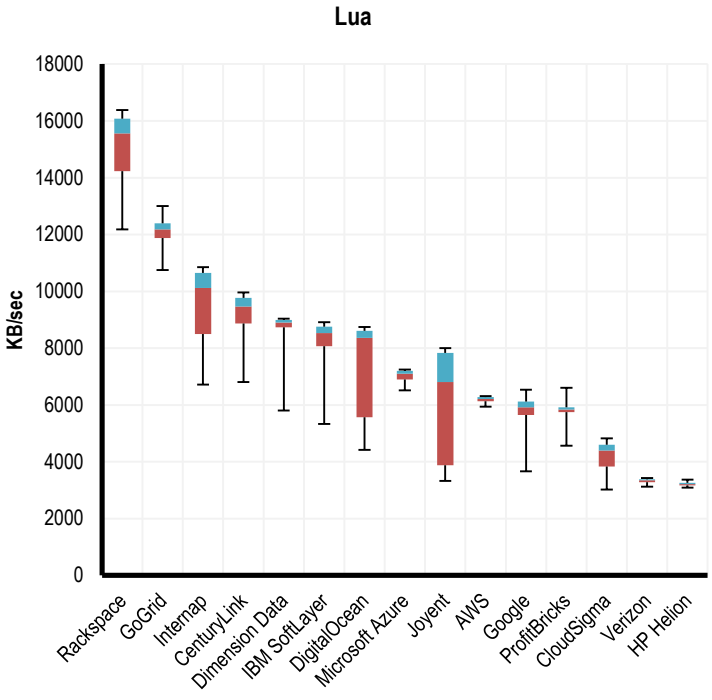
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	83354	83763	85299	86323	87245	850	0.9%
CenturyLink	96154	122255	128307	130867	131891	2540	2.8%
CloudSigma	44442	57221	69325	72745	77107	4055	4.4%
DigitalOcean	48230	62111	112845	113664	114381	16548	18.1%
Dimension Data	67584	104960	105370	105574	105779	1458	1.6%
GoGrid	134451	148685	150426	153938	160051	2058	2.2%
Google	54374	86938	88883	90010	93696	1761	1.9%
HP Helion	35635	47002	47718	48128	48435	471	0.5%
IBM SoftLayer	70246	103424	104960	106496	107008	3133	3.4%
Internap	75162	109957	128307	135885	140186	9912	10.8%
Joyent	47411	52480	83456	96358	96870	16343	17.9%
Microsoft Azure	60518	90522	91546	91750	91853	911	1.0%
ProfitBricks	67584	84275	85504	87450	92262	850	0.9%
Rackspace	138650	194335	206950	210842	212685	6144	6.7%
Verizon	41472	41984	43008	43873	44339	420	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.



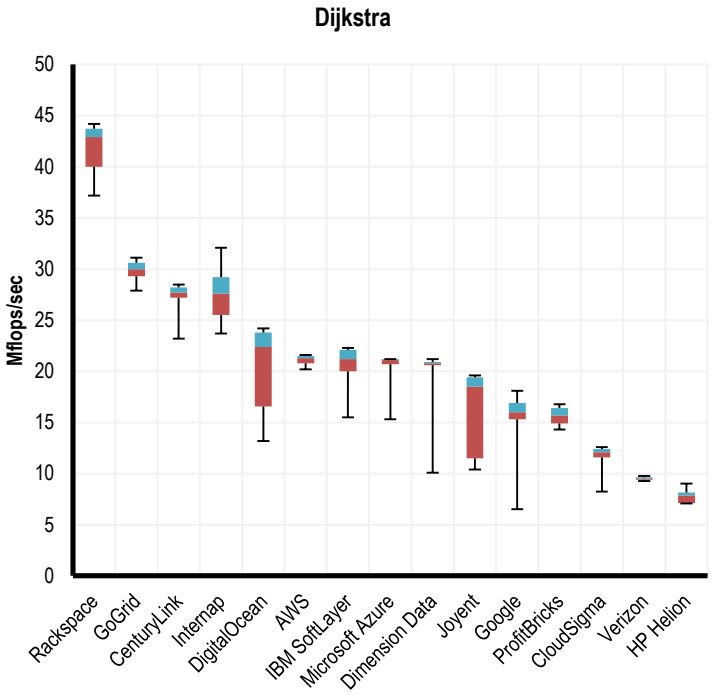
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	286.3	286.6	286.8	286.9	286.9	0.0	0.0%
CenturyLink	338.0	486.2	518.4	528.3	531.1	18.0	4.8%
CloudSigma	153.2	203.8	229.5	235.5	246.4	13.0	3.4%
DigitalOcean	205.7	247.7	446.4	449.6	450.8	64.0	16.9%
Dimension Data	268.3	403.8	404.5	405.2	405.5	6.0	1.6%
GoGrid	437.2	526.4	534.2	548.1	592.5	9.0	2.4%
Google	202.2	285.4	292.3	298.0	310.4	6.0	1.6%
HP Helion	184.3	185.2	188.7	190.8	192.4	1.0	0.3%
IBM SoftLayer	237.6	395.9	405.8	408.8	410.5	20.0	5.3%
Internap	254.3	451.1	537.1	560.7	573.7	45.0	11.9%
Joyent	165.8	195.4	309.5	377.9	379.5	67.0	17.7%
Microsoft Azure	245.7	373.7	378.5	379.5	379.9	5.0	1.3%
ProfitBricks	265.2	284.4	286.1	288.3	299.8	1.0	0.3%
Rackspace	611.2	784.1	853.5	872.2	878.2	33.0	8.7%
Verizon	173.0	175.2	177.9	181.1	183.8	1.0	0.3%

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	5939	6134	6216	6277	6318	48	0.7%
CenturyLink	6810	8868	9462	9769	9964	315	4.4%
CloudSigma	3021	3838	4403	4598	4823	239	3.4%
DigitalOcean	4424	5572	8366	8612	8745	927	13.0%
Dimension Data	5806	8735	8899	8991	9042	182	2.6%
GoGrid	10752	11878	12186	12390	13005	197	2.8%
Google	3666	5651	5919	6124	6543	177	2.5%
HP Helion	3092	3174	3215	3256	3369	28	0.4%
IBM SoftLayer	5335	8069	8530	8755	8919	458	6.4%
Internap	6717	8499	10117	10650	10854	712	10.0%
Joyent	3328	3881	6810	7834	8008	1331	18.7%
Microsoft Azure	6513	6902	7107	7199	7250	104	1.5%
ProfitBricks	4567	5745	5837	5919	6605	95	1.3%
Rackspace	12186	14234	15565	16077	16384	570	8.0%
Verizon	3123	3287	3348	3389	3430	33	0.5%

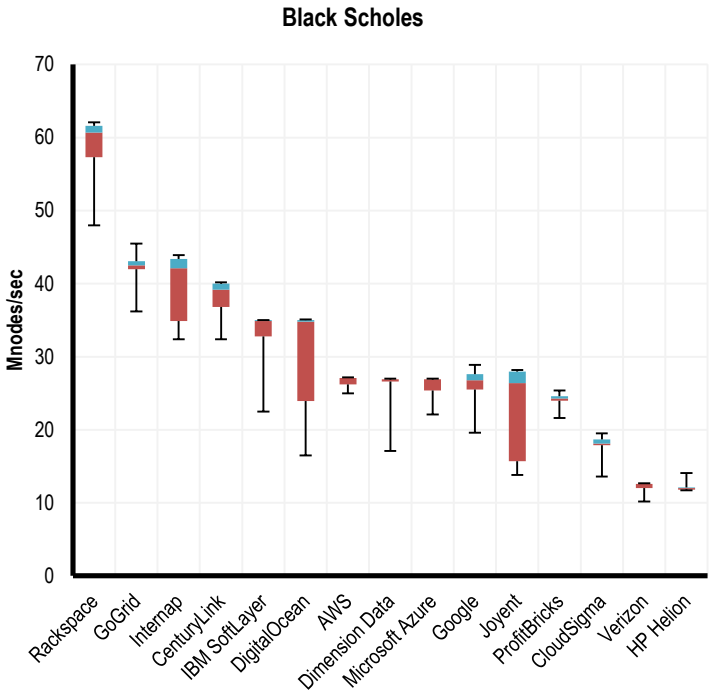
CPU Integer – Dijkstra: The Dijkstra workload computes driving directions between a sequence of destinations. Similar techniques are used by AIs to compute paths in games and by network routers to route computer network traffic.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	20.20	20.80	**21.30**	21.50	21.60	0.21	1.0%
CenturyLink	23.20	27.20	**27.70**	28.20	28.50	0.27	1.3%
CloudSigma	8.23	11.60	**12.10**	12.40	12.60	0.36	1.7%
DigitalOcean	13.20	16.56	**22.40**	23.80	24.20	2.10	10.0%
Dimension Data	10.10	20.60	**20.80**	20.90	21.20	0.40	1.9%
GoGrid	27.90	29.30	**30.00**	30.60	31.10	0.30	1.4%
Google	6.53	15.30	**16.00**	16.92	18.10	0.64	3.0%
HP Helion	7.07	7.13	**7.87**	8.15	9.03	0.35	1.7%
IBM SoftLayer	15.50	20.00	**21.20**	22.10	22.30	0.63	3.0%
Internap	23.70	25.50	**27.60**	29.20	32.10	1.08	5.1%
Joyent	10.40	11.50	**18.50**	19.40	19.60	2.38	11.3%
Microsoft Azure	15.30	20.70	**21.10**	21.20	21.20	0.20	0.9%
ProfitBricks	14.30	14.90	**15.70**	16.40	16.80	0.45	2.1%
Rackspace	37.20	40.00	**42.90**	43.72	44.20	0.84	4.0%
Verizon	9.26	9.40	**9.52**	9.65	9.78	0.00	0.0%

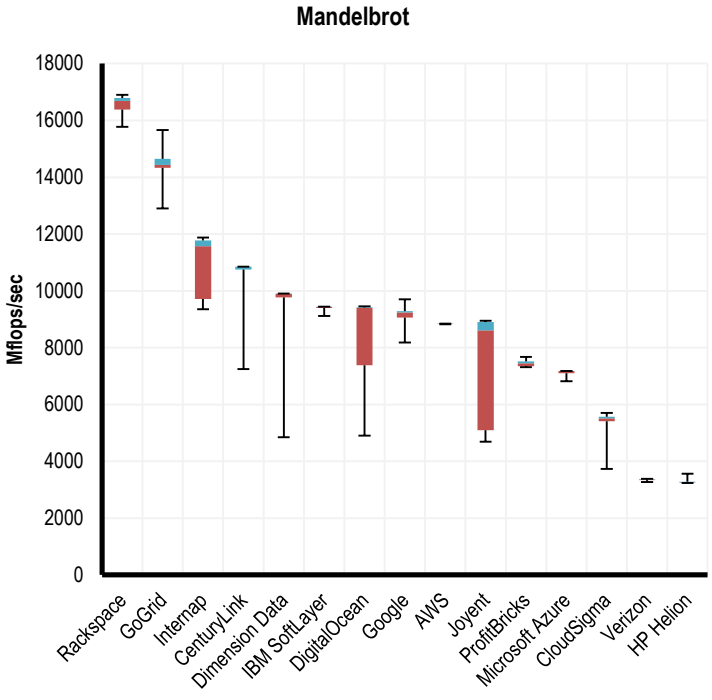
--- End of CPU Integer Results ---

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.



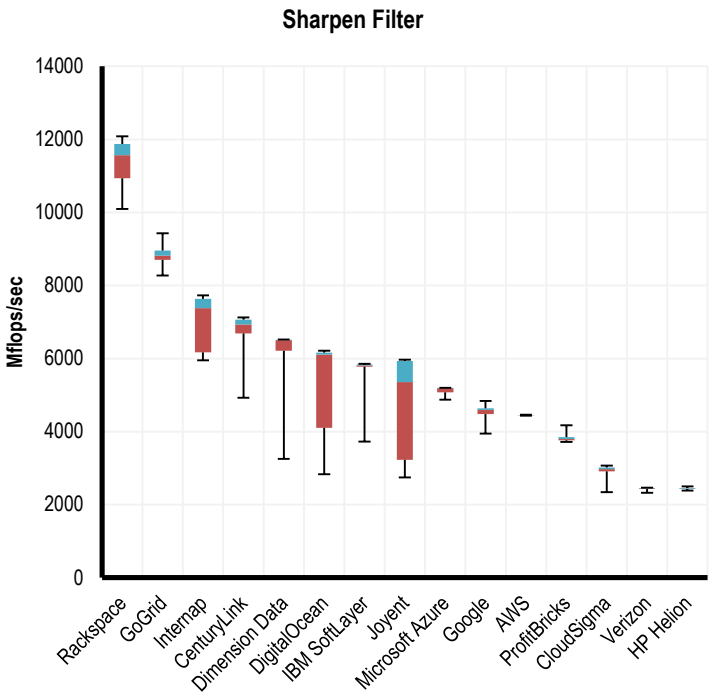
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	25.00	26.20	27.10	27.10	27.20	0.26	1.0%
CenturyLink	32.40	36.80	39.20	40.00	40.20	0.78	2.9%
CloudSigma	13.60	17.90	18.10	18.70	19.50	0.36	1.3%
DigitalOcean	16.50	23.96	34.80	35.00	35.10	3.30	12.3%
Dimension Data	17.10	26.60	26.90	26.90	27.00	0.52	1.9%
GoGrid	36.20	42.00	42.50	43.10	45.50	0.42	1.6%
Google	19.60	25.50	26.80	27.60	28.90	0.52	1.9%
HP Helion	11.70	11.80	12.00	12.10	14.10	0.24	0.9%
IBM SoftLayer	22.50	32.80	34.90	35.00	35.00	1.02	3.8%
Internap	32.40	34.90	42.10	43.40	43.90	2.40	8.9%
Joyent	13.80	15.70	26.40	27.98	28.20	4.08	15.2%
Microsoft Azure	22.10	25.40	26.90	26.90	27.00	0.26	1.0%
ProfitBricks	21.60	24.00	24.30	24.60	25.40	0.24	0.9%
Rackspace	48.00	57.30	60.70	61.60	62.10	1.20	4.5%
Verizon	10.20	12.00	12.60	12.60	12.70	0.12	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.



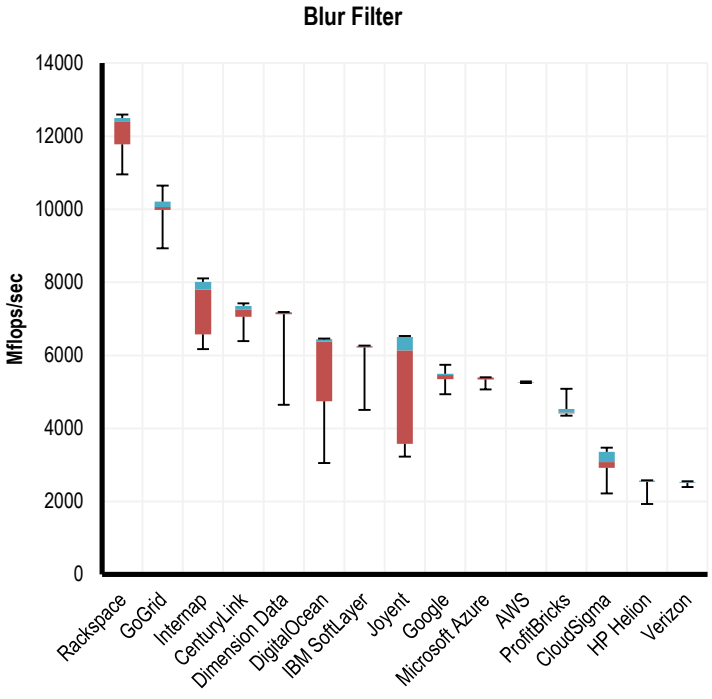
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	8827	8837	8847	8847	8847	2	0.0%
CenturyLink	7250	10752	10752	10854	10854	119	1.3%
CloudSigma	3738	5417	5509	5571	5704	154	1.7%
DigitalOcean	4905	7384	9400	9421	9452	703	7.6%
Dimension Data	4844	9769	9892	9902	9902	320	3.5%
GoGrid	12902	14336	14438	14643	15667	140	1.5%
Google	8182	9062	9247	9288	9708	104	1.1%
HP Helion	3236	3246	3256	3287	3564	42	0.5%
IBM SoftLayer	9114	9400	9431	9441	9441	17	0.2%
Internap	9359	9712	11571	11776	11878	637	6.9%
Joyent	4690	5097	8612	8906	8950	1317	14.2%
Microsoft Azure	6820	7107	7178	7178	7178	38	0.4%
ProfitBricks	7311	7352	7455	7516	7680	50	0.5%
Rackspace	15770	16384	16691	16794	16896	153	1.7%
Verizon	3267	3338	3359	3369	3379	10	0.1%

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



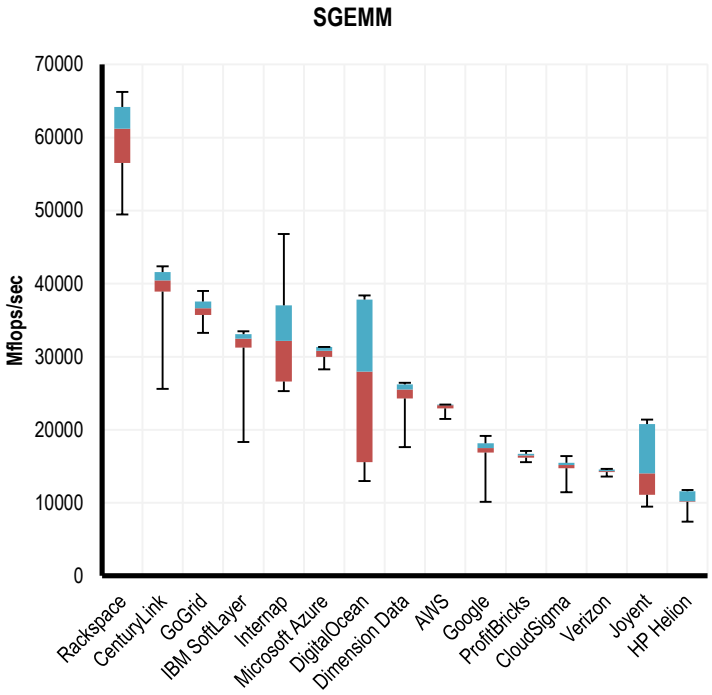
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	4434	4434	4444	4444	4465	4	0.1%
CenturyLink	4925	6687	6932	7066	7127	152	2.8%
CloudSigma	2345	2908	2970	3021	3072	63	1.2%
DigitalOcean	2836	4104	6113	6164	6216	639	11.9%
Dimension Data	3256	6216	6502	6513	6523	217	4.1%
GoGrid	8274	8704	8817	8961	9431	97	1.8%
5Google	3942	4485	4598	4639	4844	59	1.1%
HP Helion	2386	2427	2437	2458	2499	11	0.2%
IBM SoftLayer	3727	5775	5816	5837	5857	122	2.3%
Internap	5949	6175	7383	7639	7731	427	8.0%
Joyent	2744	3226	5356	5937	5970	957	17.9%
Microsoft Azure	4874	5080	5192	5202	5202	41	0.8%
ProfitBricks	3717	3758	3799	3850	4178	40	0.7%
Rackspace	10097	10936	11571	11878	12083	303	5.7%
Verizon	2324	2427	2447	2458	2468	11	0.2%

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.



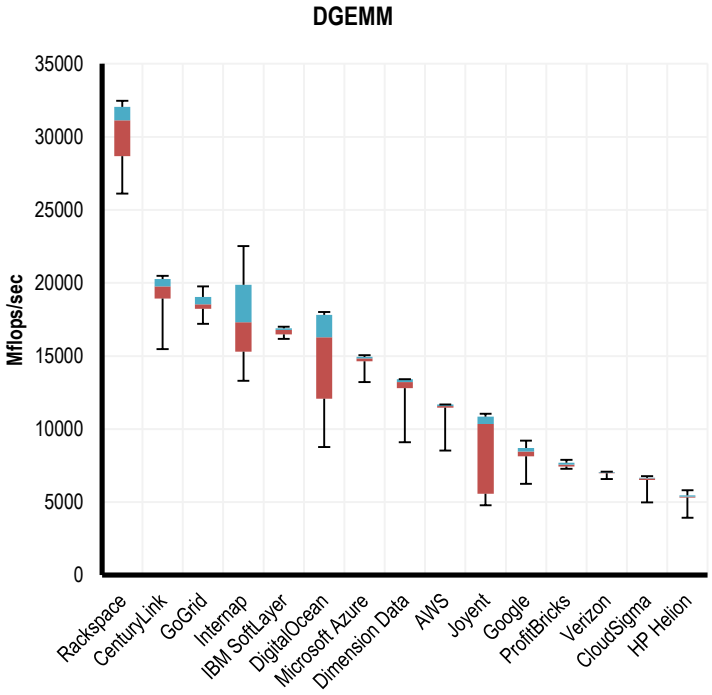
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	5243	5253	5263	5274	5284	5	0.1%
CenturyLink	6390	7055	7260	7352	7424	97	1.6%
CloudSigma	2222	2918	3082	3359	3471	187	3.0%
DigitalOcean	3052	4747	6380	6441	6461	559	9.1%
Dimension Data	4649	7127	7178	7188	7188	168	2.7%
GoGrid	8929	9983	10066	10209	10650	108	1.8%
Google	4936	5345	5458	5499	5745	62	1.0%
HP Helion	1935	2540	2550	2570	2580	36	0.6%
IBM SoftLayer	4506	6216	6246	6257	6267	134	2.2%
Internap	6175	6574	7803	8008	8110	435	7.1%
Joyent	3226	3576	6134	6502	6533	1029	16.8%
Microsoft Azure	5069	5335	5386	5396	5396	30	0.5%
ProfitBricks	4352	4413	4434	4529	5089	63	1.0%
Rackspace	10957	11776	12390	12493	12595	242	3.9%
Verizon	2396	2509	2519	2540	2550	10	0.2%

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.



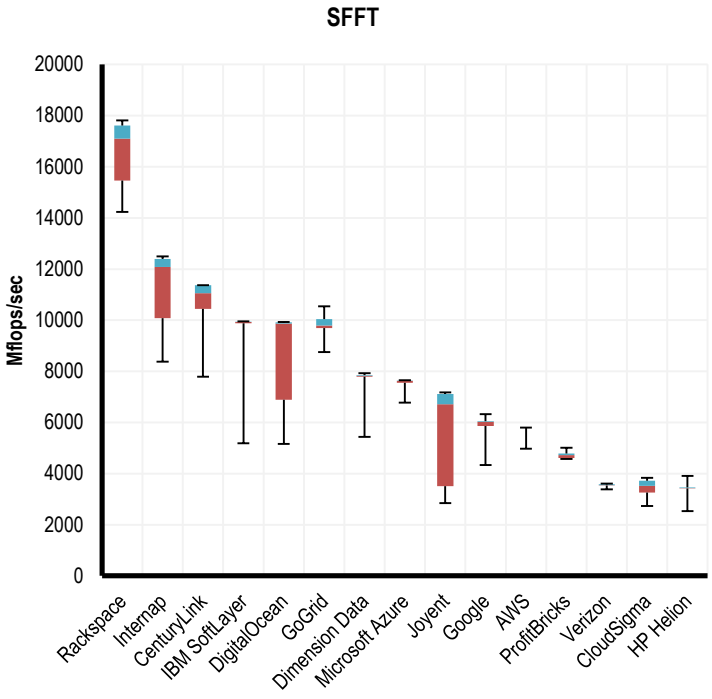
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	21504	22938	23347	23450	23450	296	1.2%
CenturyLink	25600	38912	40448	41574	42394	1098	4.3%
CloudSigma	11469	14746	15155	15498	16384	412	1.6%
DigitalOcean	13005	15565	27955	37832	38400	7409	29.1%
Dimension Data	17613	24269	25498	26214	26419	1178	4.6%
GoGrid	33280	35738	36659	37581	39014	613	2.4%
Google	10117	16896	17510	18140	19149	587	2.3%
HP Helion	7424	10127	10220	11571	11776	575	2.3%
IBM SoftLayer	18330	31232	32461	33075	33485	788	3.1%
Internap	25293	26624	32154	37028	46797	3080	12.1%
Joyent	9492	11085	14029	20787	21402	2971	11.7%
Microsoft Azure	28262	30003	30822	31334	31334	441	1.7%
ProfitBricks	15565	16179	16486	16691	17101	181	0.7%
Rackspace	49459	56525	61235	64205	66253	2329	9.1%
Verizon	13619	14234	14336	14541	14643	97	0.4%

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.



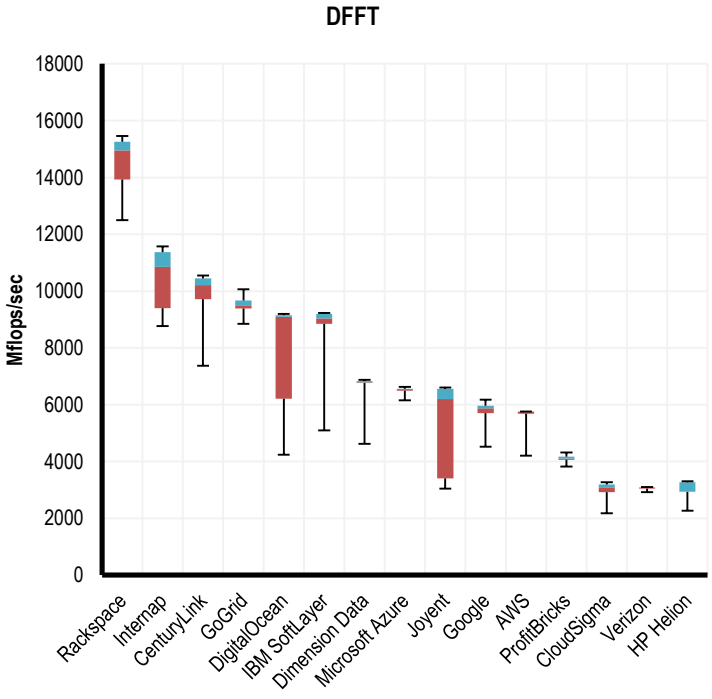
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	8520	11469	11571	11674	11674	122	0.9%
CenturyLink	15462	18944	19763	20275	20480	448	3.4%
CloudSigma	4977	6513	6615	6676	6779	168	1.3%
DigitalOcean	8765	12083	16282	17818	18022	1986	15.0%
Dimension Data	9103	12800	13210	13414	13414	407	3.1%
GoGrid	17203	18227	18534	19046	19763	260	2.0%
Google	6257	8141	8463	8714	9216	225	1.7%
HP Helion	3932	5315	5376	5458	5816	114	0.9%
IBM SoftLayer	16179	16486	16794	16896	16998	139	1.1%
Internap	13312	15299	17306	19866	22528	1291	9.8%
Joyent	4782	5565	10342	10854	11059	1620	12.3%
Microsoft Azure	13210	14643	14848	14950	15053	131	1.0%
ProfitBricks	7291	7434	7557	7690	7905	82	0.6%
Rackspace	26112	28672	31130	32051	32461	1080	8.2%
Verizon	6584	6984	7025	7055	7076	27	0.2%

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.



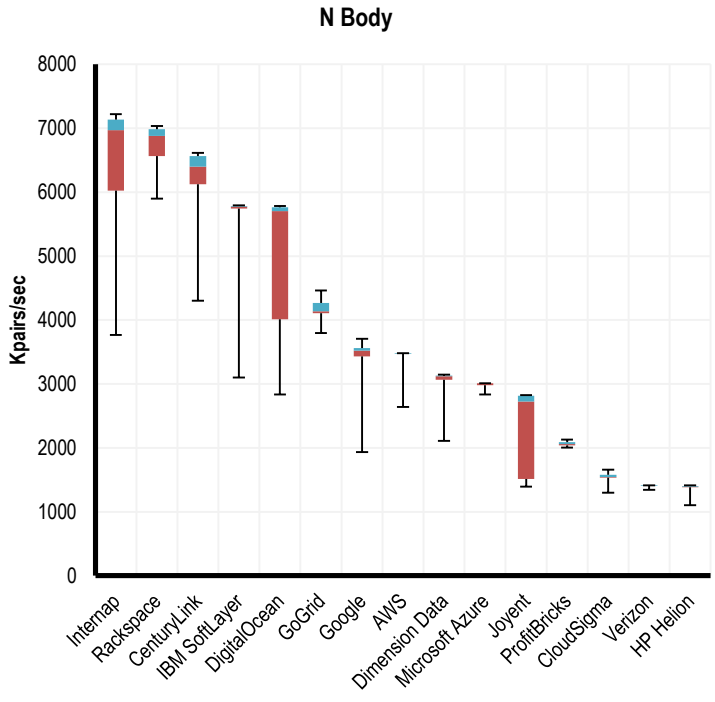
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	4977	5796	5796	5796	5796	28	0.4%
CenturyLink	7793	10445	11059	11366	11366	313	4.1%
CloudSigma	2734	3256	3523	3727	3840	159	2.1%
DigitalOcean	5161	6895	9871	9912	9933	972	12.7%
Dimension Data	5437	7793	7834	7854	7926	94	1.2%
GoGrid	8755	9687	9789	10046	10547	128	1.7%
Google	4332	5868	6021	6052	6328	106	1.4%
HP Helion	2529	3420	3441	3461	3912	88	1.2%
IBM SoftLayer	5181	9882	9933	9943	9953	318	4.2%
Internap	8376	10076	12083	12390	12493	684	9.0%
Joyent	2847	3515	6717	7117	7178	1169	15.3%
Microsoft Azure	6779	7557	7629	7639	7649	59	0.8%
ProfitBricks	4577	4617	4721	4792	5018	60	0.8%
Rackspace	14234	15462	17101	17613	17818	748	9.8%
Verizon	3379	3533	3553	3584	3604	15	0.2%

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.



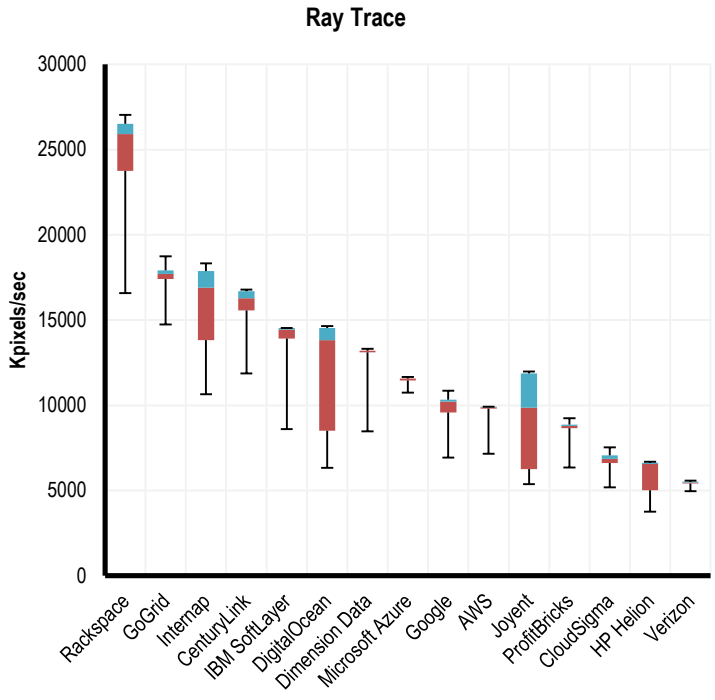
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	4209	5683	5745	5755	5765	57	0.9%
CenturyLink	7373	9717	10209	10445	10547	276	4.2%
CloudSigma	2181	2918	3092	3195	3267	105	1.6%
DigitalOcean	4239	6206	9093	9155	9196	893	13.6%
Dimension Data	4628	6758	6789	6830	6871	87	1.3%
GoGrid	8847	9390	9482	9668	10066	100	1.5%
Google	4526	5704	5873	5961	6175	130	2.0%
HP Helion	2273	2939	2949	3269	3308	91	1.4%
IBM SoftLayer	5100	8847	9042	9196	9226	327	5.0%
Internap	8765	9402	10854	11366	11571	540	8.2%
Joyent	3052	3402	6205	6564	6605	1016	15.5%
Microsoft Azure	6154	6492	6554	6564	6625	36	0.5%
ProfitBricks	3820	4055	4106	4178	4321	46	0.7%
Rackspace	12493	13926	14950	15258	15462	427	6.5%
Verizon	2918	3052	3072	3092	3103	13	0.2%

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	2642	3471	3471	3482	3482	0	0.0%
CenturyLink	4301	6124	6400	6564	6615	123	3.5%
CloudSigma	1300	1536	1546	1577	1659	25	0.7%
DigitalOcean	2836	4014	5704	5765	5786	461	13.3%
Dimension Data	2109	3066	3123	3133	3144	45	1.3%
GoGrid	3799	4106	4137	4270	4465	54	1.6%
Google	1935	3430	3523	3564	3707	61	1.8%
HP Helion	1106	1382	1393	1403	1413	10	0.3%
IBM SoftLayer	3103	5745	5775	5786	5796	102	2.9%
Internap	3768	6025	6973	7137	7219	307	8.8%
Joyent	1393	1516	2724	2816	2826	307	8.8%
Microsoft Azure	2836	2980	3011	3011	3011	0	0.0%
ProfitBricks	2007	2038	2058	2089	2130	0	0.0%
Rackspace	5898	6564	6881	6984	7035	123	3.5%
Verizon	1341	1403	1403	1413	1413	0	0.0%

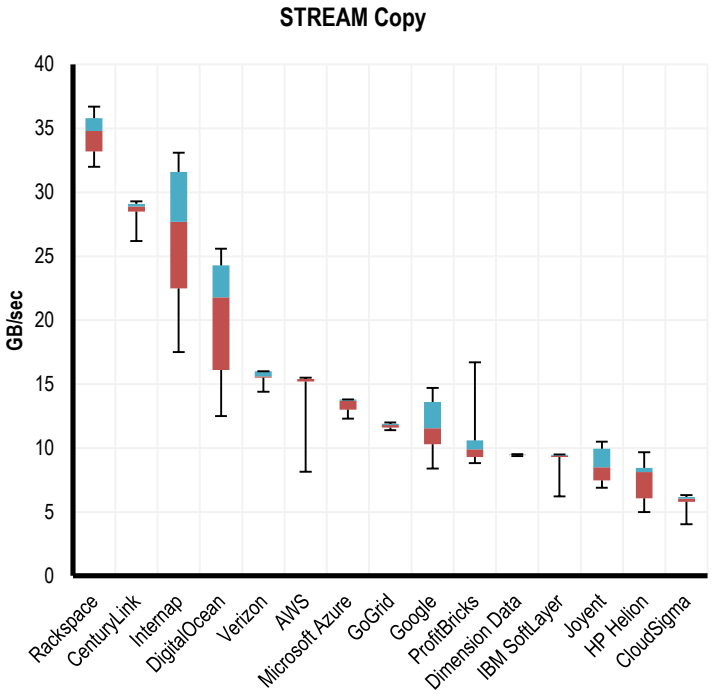
CPU Floating Points – Ray Trace: The ray trace workload renders a 3D scene from a geometric description.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	7158	9810	9892	9912	9912	92	0.8%
CenturyLink	11878	15565	16282	16691	16794	307	2.7%
CloudSigma	5192	6611	6861	7076	7537	214	1.8%
DigitalOcean	6328	8522	13824	14541	14643	1597	13.8%
Dimension Data	8468	13107	13210	13210	13312	319	2.8%
GoGrid	14746	17408	17715	17920	18739	256	2.2%
Google	6932	9592	10220	10342	10854	276	2.4%
HP Helion	3768	5028	6564	6629	6697	492	4.2%
IBM SoftLayer	8602	13926	14438	14541	14541	532	4.6%
Internap	10650	13824	16896	17879	18330	1147	9.9%
Joyent	5376	6254	9861	11878	11981	2028	17.5%
Microsoft Azure	10752	11469	11571	11571	11674	0	0.0%
ProfitBricks	6349	8663	8786	8868	9247	82	0.7%
Rackspace	16589	23757	25907	26522	27034	768	6.6%
Verizon	4966	5407	5468	5530	5591	0	0.0%

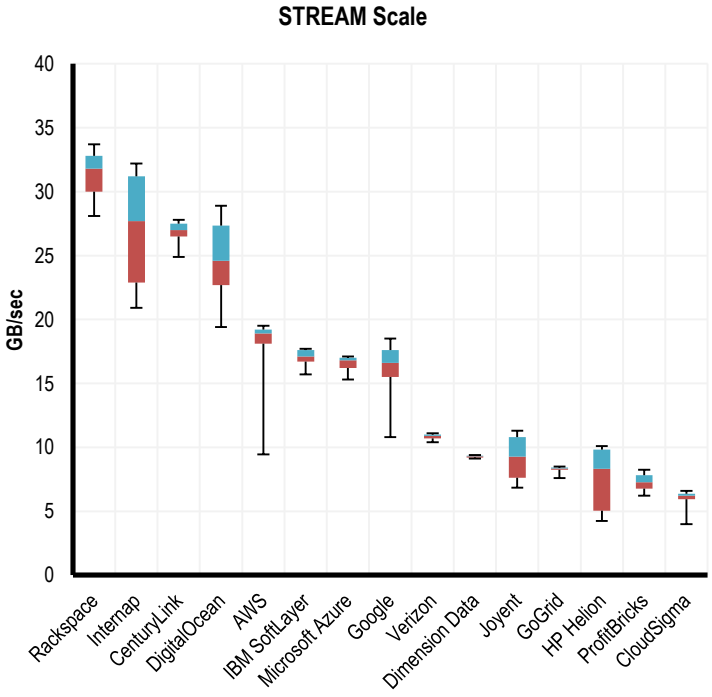
--- End of Floating Point Results ---

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.



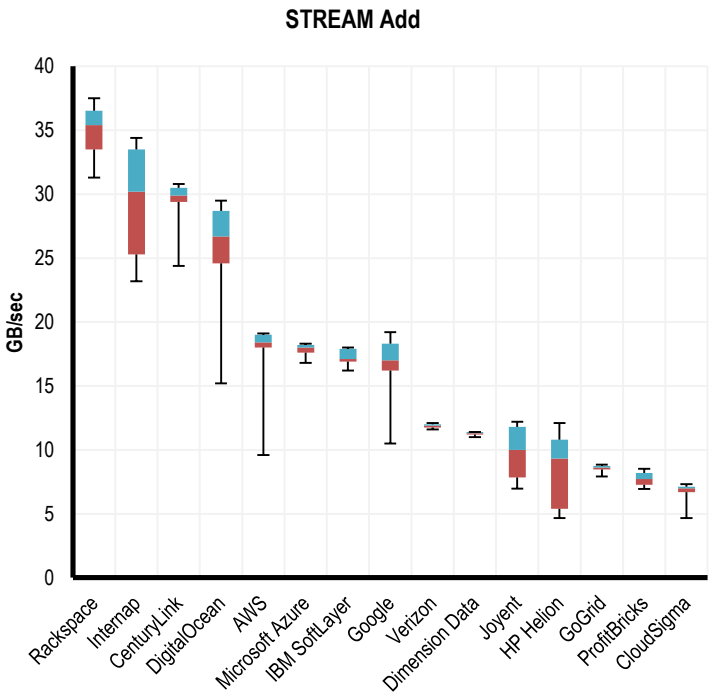
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	8.15	15.20	15.40	15.40	15.50	0.45	3.8%
CenturyLink	26.20	28.50	28.90	29.10	29.30	0.00	0.0%
CloudSigma	4.03	5.80	6.05	6.16	6.32	0.12	1.0%
DigitalOcean	12.50	16.10	21.80	24.30	25.60	2.31	19.6%
Dimension Data	9.38	9.44	9.48	9.50	9.52	0.00	0.0%
GoGrid	11.40	11.60	11.80	11.90	12.00	0.00	0.0%
Google	8.40	10.30	11.55	13.62	14.70	1.10	9.3%
HP Helion	5.00	6.07	8.11	8.45	9.68	0.77	6.5%
IBM SoftLayer	6.21	9.30	9.41	9.48	9.51	0.09	0.8%
Internap	17.50	22.50	27.70	31.60	33.10	2.70	22.9%
Joyent	6.90	7.46	8.51	9.94	10.50	0.72	6.1%
Microsoft Azure	12.30	13.00	13.70	13.80	13.80	0.13	1.1%
ProfitBricks	8.81	9.29	9.90	10.60	16.70	0.36	3.1%
Rackspace	32.00	33.20	34.80	35.80	36.70	0.68	5.8%
Verizon	14.40	15.50	15.60	16.00	16.00	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.



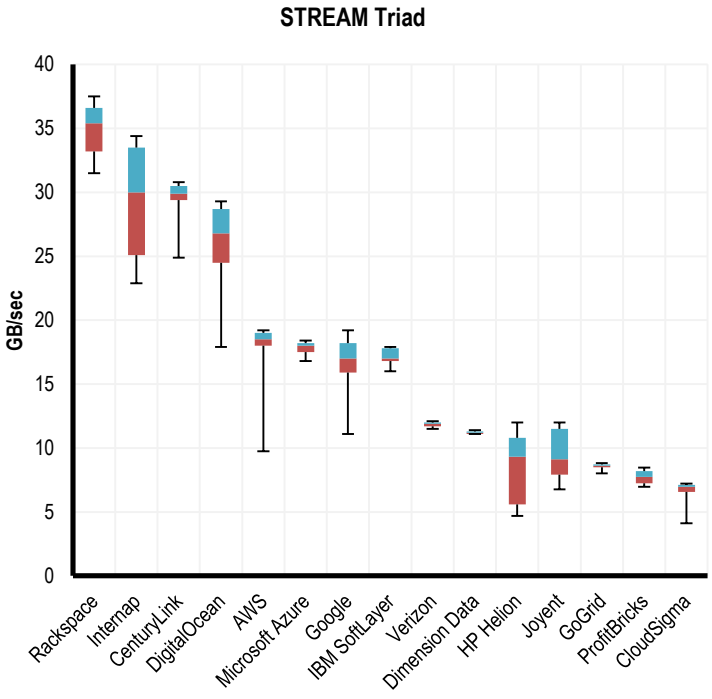
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	9.45	18.10	18.90	19.20	19.50	0.36	2.2%
CenturyLink	24.90	26.50	27.00	27.50	27.80	0.26	1.6%
CloudSigma	3.99	5.94	6.22	6.36	6.59	0.12	0.7%
DigitalOcean	19.40	22.70	24.60	27.35	28.90	1.44	8.7%
Dimension Data	9.11	9.20	9.30	9.35	9.39	0.00	0.0%
GoGrid	7.60	8.24	8.35	8.43	8.50	0.00	0.0%
Google	10.80	15.50	16.60	17.60	18.50	0.64	3.9%
HP Helion	4.23	5.04	8.33	9.83	10.10	1.44	8.7%
IBM SoftLayer	15.70	16.70	17.10	17.60	17.70	0.17	1.0%
Internap	20.90	22.90	27.70	31.20	32.20	2.43	14.6%
Joyent	6.85	7.62	9.29	10.80	11.30	1.17	7.0%
Microsoft Azure	15.30	16.20	16.80	17.00	17.10	0.16	1.0%
ProfitBricks	6.21	6.76	7.26	7.81	8.24	0.28	1.7%
Rackspace	28.10	30.00	31.80	32.80	33.70	0.62	3.7%
Verizon	10.40	10.70	10.90	11.00	11.10	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	9.61	18.00	18.40	19.00	19.10	0.36	2.1%
CenturyLink	24.40	29.40	29.90	30.50	30.80	0.29	1.7%
CloudSigma	4.66	6.71	7.00	7.13	7.32	0.18	1.1%
DigitalOcean	15.20	24.60	26.70	28.70	29.50	1.30	7.6%
Dimension Data	11.00	11.20	11.30	11.40	11.40	0.00	0.0%
GoGrid	7.93	8.48	8.62	8.74	8.84	0.08	0.5%
Google	10.50	16.20	17.00	18.30	19.20	0.68	4.0%
HP Helion	4.66	5.40	9.33	10.80	12.10	1.62	9.5%
IBM SoftLayer	16.20	16.90	17.10	17.90	18.00	0.34	2.0%
Internap	23.20	25.30	30.20	33.50	34.40	2.32	13.6%
Joyent	6.98	7.85	10.00	11.80	12.20	1.35	7.9%
Microsoft Azure	16.80	17.60	18.00	18.20	18.30	0.17	1.0%
ProfitBricks	6.94	7.28	7.73	8.20	8.53	0.21	1.2%
Rackspace	31.30	33.50	35.40	36.52	37.50	0.70	4.1%
Verizon	11.60	11.76	11.90	12.00	12.10	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	9.75	18.00	18.50	19.00	19.20	0.36	2.1%
CenturyLink	24.90	29.40	29.90	30.50	30.80	0.29	1.7%
CloudSigma	4.11	6.58	6.98	7.11	7.22	0.18	1.1%
DigitalOcean	17.90	24.50	26.80	28.70	29.30	1.30	7.6%
Dimension Data	11.10	11.10	11.20	11.30	11.40	0.00	0.0%
GoGrid	8.02	8.49	8.62	8.72	8.81	0.00	0.0%
Google	11.10	15.90	17.00	18.20	19.20	0.68	4.0%
HP Helion	4.70	5.60	9.32	10.80	12.00	1.44	8.5%
IBM SoftLayer	16.00	16.80	17.00	17.80	17.90	0.34	2.0%
Internap	22.90	25.10	30.00	33.50	34.40	2.32	13.6%
Joyent	6.78	7.93	9.13	11.50	12.00	1.26	7.4%
Microsoft Azure	16.80	17.50	18.00	18.20	18.40	0.17	1.0%
ProfitBricks	6.97	7.25	7.75	8.20	8.48	0.21	1.2%
Rackspace	31.50	33.20	35.40	36.60	37.50	0.70	4.1%
Verizon	11.50	11.70	11.90	12.00	12.10	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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