Cloud Vendor Benchmark 2015

Price-Performance Comparison Among 15 Top IaaS Providers

Part 2.1: Small VMs Linux

May 2015

Part 2.1: Small VMs Linux

CloudSpectator.com

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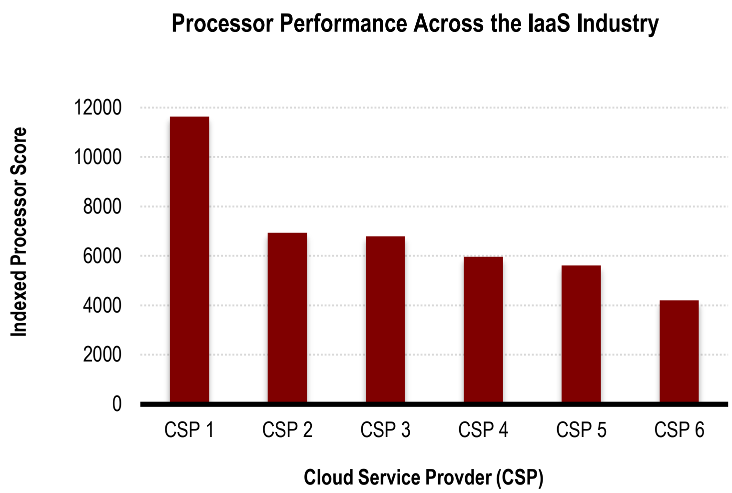
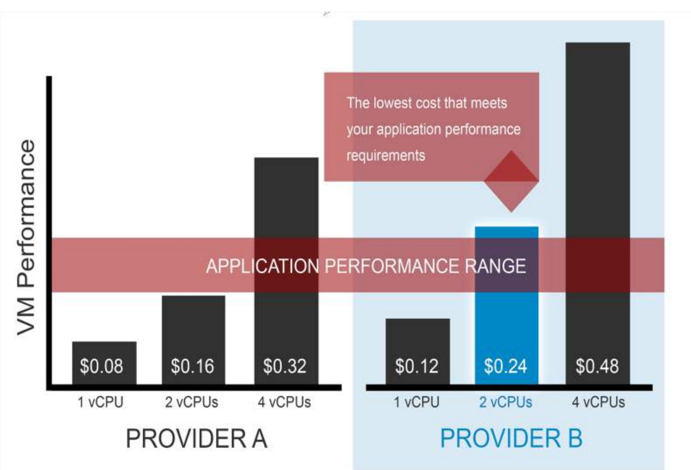
PREFACE

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

Why Does Performance Matter?

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





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

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

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

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

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

THIS REPORT ANALYZES ONLY THE SMALL 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 includes a total of 27 tasks. All 27 tasks were run using the Geekbench 3 Test Suite. Performance results were categorized and analyzed in low, median and high scores. Price-performance was examined using hourly, monthly, annual and 3-year pricing. *The Cloud Vendor Benchmark 2015 Part 2: Performance and Price-Performance* is the largest public-facing performance and price-performance report on the IaaS industry.

Part 2 is divided into 10 separate reports with regard to different VM sizes and operating systems. **This report only examines the Small 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	t2.small	1	2	EBS only	0.026	18.98	151	303
CenturyLink	customized	1	2	-	0.040	29.20	350	1051
CloudSigma	customized	1	2	50 SSD	-*	17.63	190	476
DigitalOcean	standard2	2	2	40 SSD	0.030	20.00	240	720
Dimension Data	customized	1	2	-	0.077	55.85	670	2011
GoGrid	Standard Medium	2	2	100	0.120	65.70	526	1577
Google	n1-standard-1	1	3.75	-	0.063	32.85	394	1183
HP Helion	Standard Small	2	2	10	0.060	43.80	526	1577
IBM SoftLayer	customized	1	2	25	0.059	40.20	482	1447
Internap	B-1	1	4	20 SSD	0.080	58.40	701	2102
Joyent	standard3	1	3.75	123	0.120	87.60	1051	3154
Microsoft Azure	D1	1	3.5	50 SSD	0.085	62.05	745	2234
ProfitBricks	customized	1	2	-	0.029	20.88	251	752
Rackspace	General1-2	2	2	40 SSD	0.074	54.02	648	1945
Verizon	3.5	1	3.5	-	0.074	54.02	648	1945

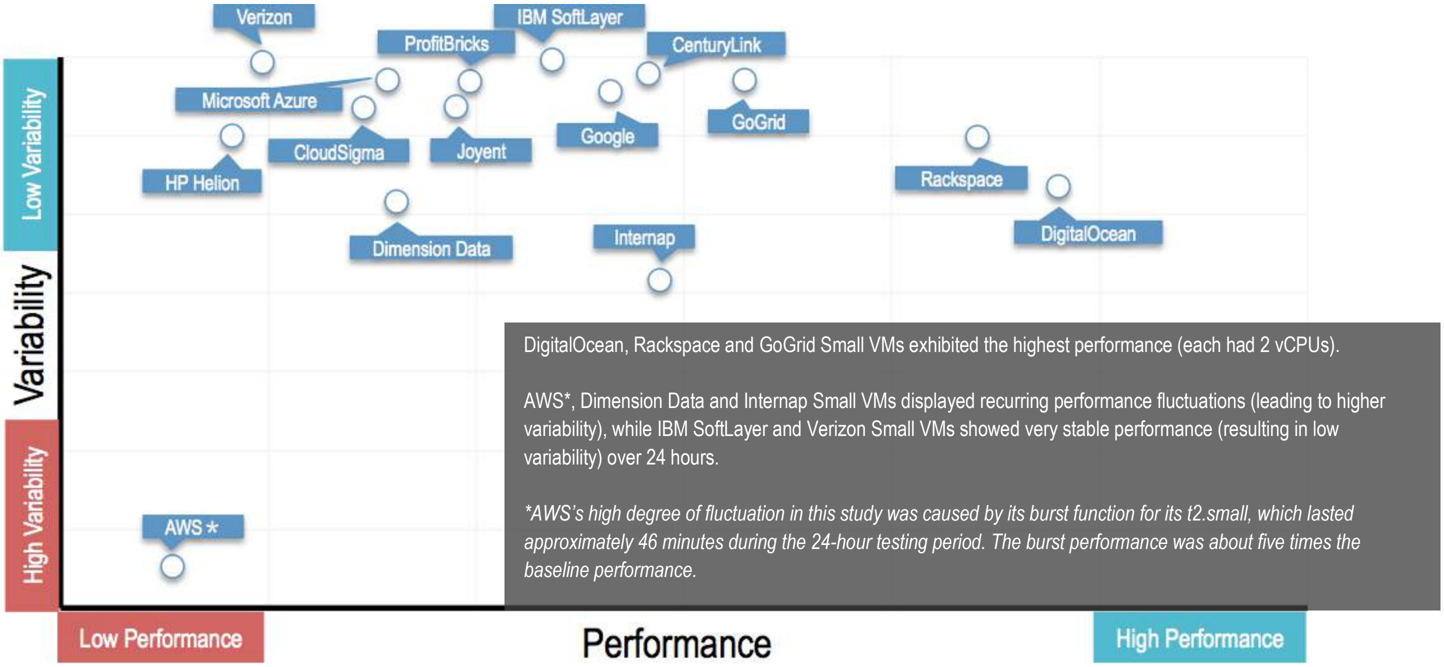
Prices in red are long-term prices discounted from the hourly pricing.

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

EXECUTIVE SUMMARY

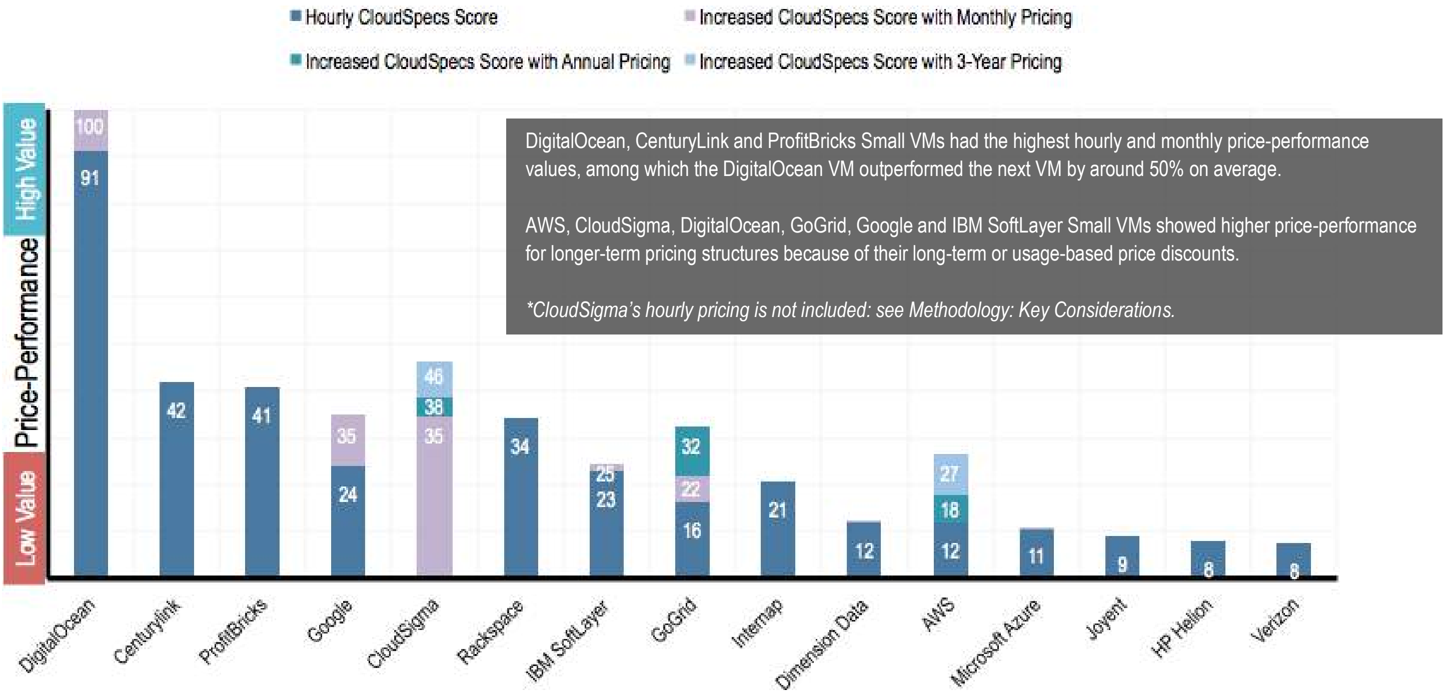
Key Performance Findings

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



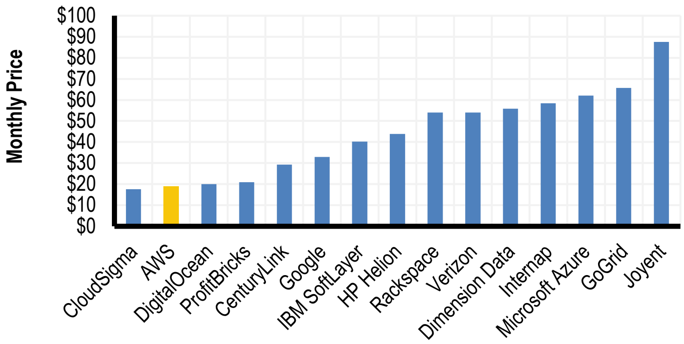
Key Price-Performance Findings

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

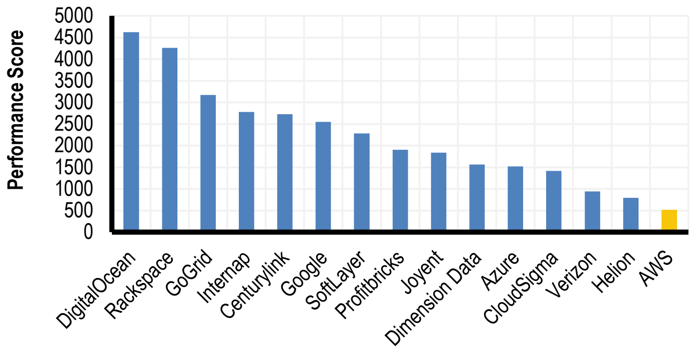


Key Takeaway

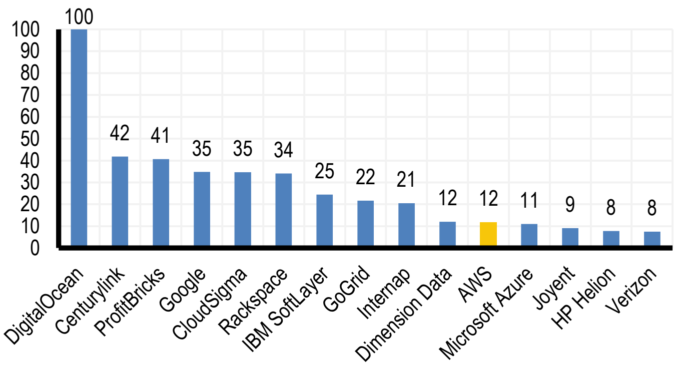
Monthly Pricing Ranking (Low to High) – Small VMs



Median Performance Ranking (High to Low) – Small VMs



Monthly Median Price-Performance Ranking (High to Low) – Small 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 AWS's t2.small VM as an example, while the VM ranks second in the monthly pricing comparison, its median performance output ranks last among the 15 providers, and its price-performance calculated using the data supporting the first two graphs ranks 11th. 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 Small 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/.

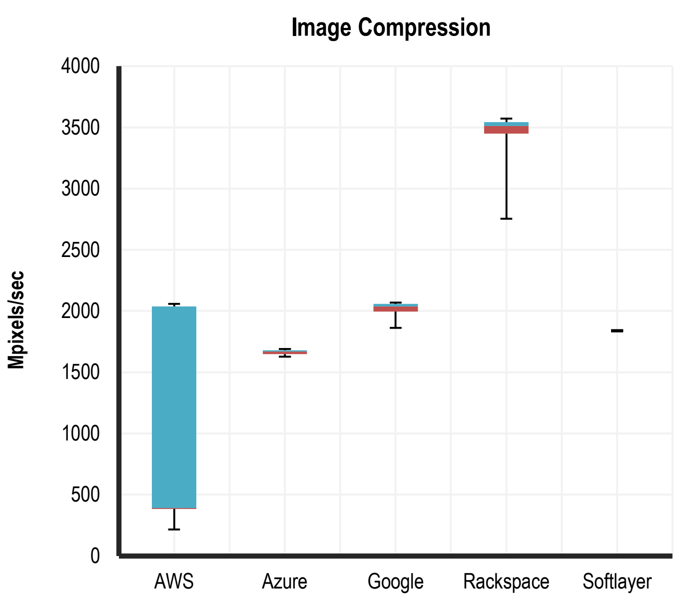
Tests and descriptions related to this report are described in the Table 1.2:

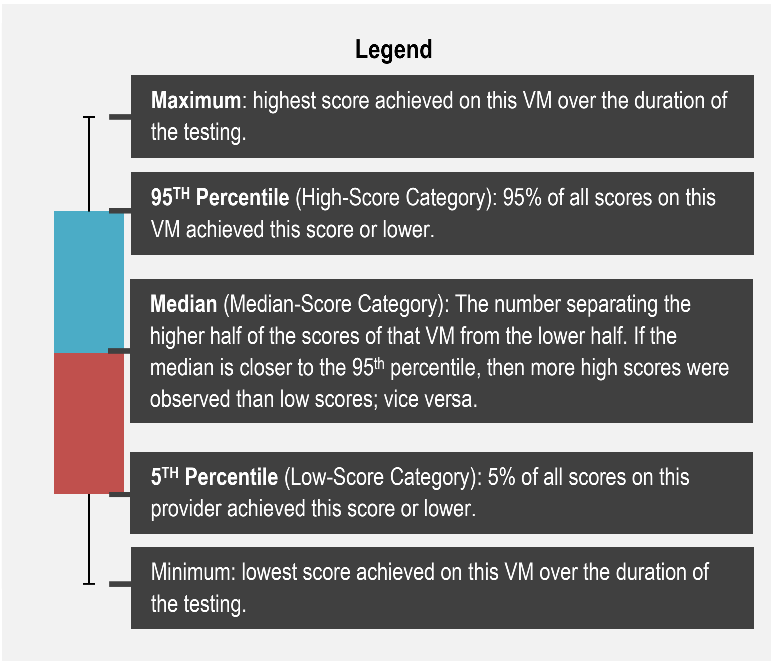
Table 1.2 Performance Tests and Descriptions

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.

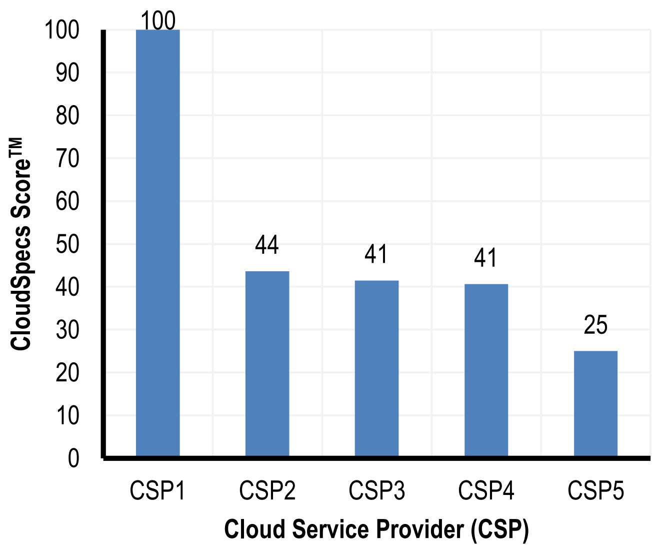
The variability score is designed to reflect the relative fluctuation of a machine in relationship with other VMs included in the same comparison. Therefore, the same variability value of different performance tasks can mean different fluctuation magnitudes. Standard deviation values (Stdev.), alternatively, 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_value / 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, 2 vCPU machines were used on DigitalOcean, GoGrid, HP Helion and Rackspace and 1vCPU machines were used on the remaining providers in order to meet the criteria for selecting Small VMs according to the listed minimum requirements.** AWS's T2 family burst machine was used.
- 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 2.1: Performance and Price-Performance (Small 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 – Small VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	432	2516	846	2756	1201	2527	1934	609	2240	2023	1032	1292	1509	3270	918
5th Per.	509	2661	1261	4372	1314	3144	2476	742	2268	2192	1794	1477	1831	4131	932
Median	**519**	**2730**	**1413**	**4628**	**1562**	**3173**	**2550**	**795**	**2280**	**2779**	**1837**	**1520**	**1903**	**4260**	**940**
95th Per.	2634	2751	1456	4737	1835	3194	2601	891	2287	2862	1849	1569	1936	4381	947
Max.	2680	2761	1477	4810	2045	3213	2622	917	2291	2898	1858	1670	1968	4437	952

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 Low-Score Category respectively. DigitalOcean, Rackspace and GoGrid VMs display consistent high rankings in both the High-Score Category and the Low-Score Category, while the rankings of Internap, AWS and Dimension Data VMs experience considerable changes in performance values.

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

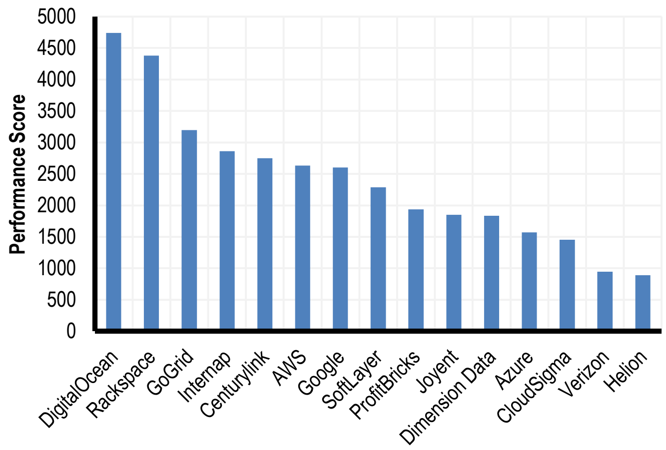
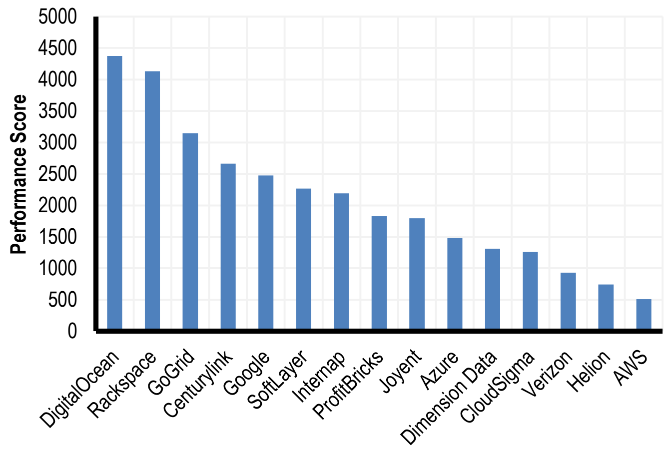


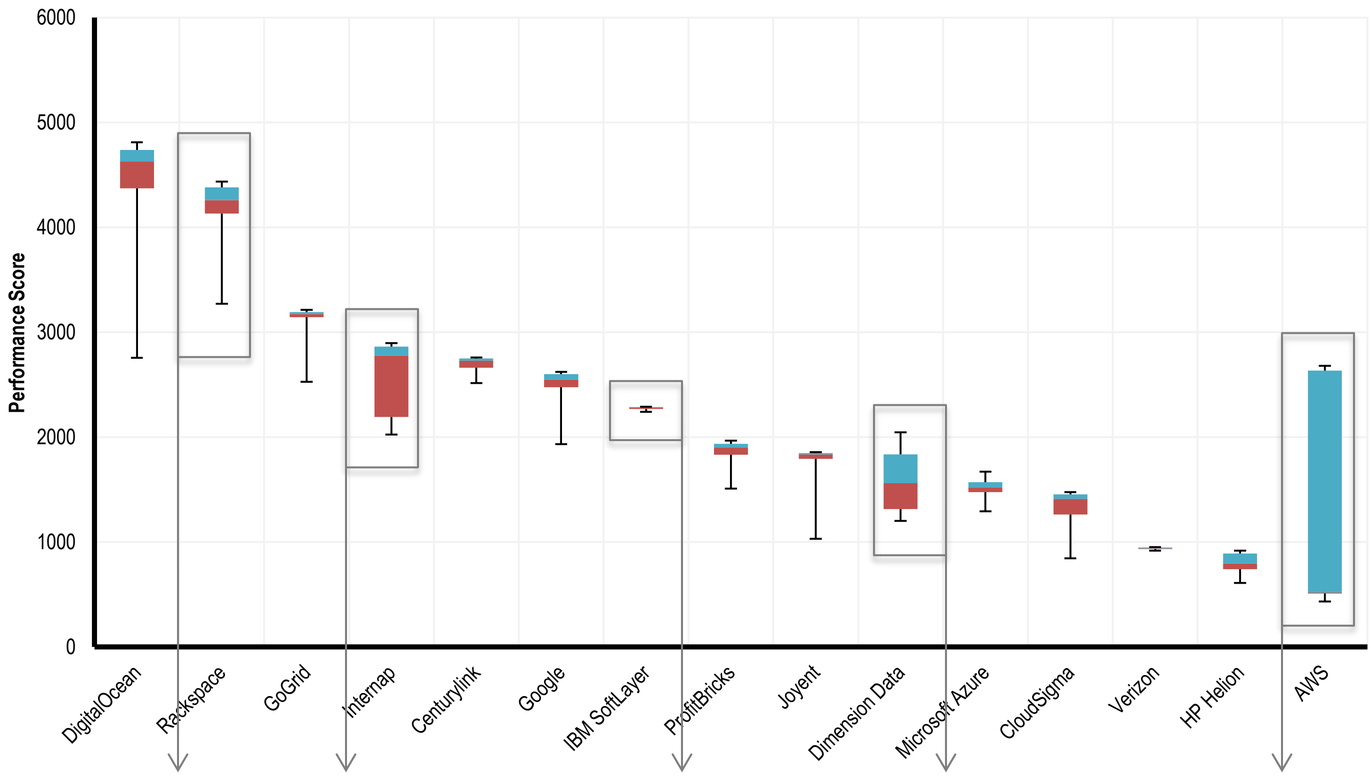
Figure 2.2: CPU & Memory Performance Rank by 5th Percentile (Low-Score Category) – Small VMs



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

The graph indicates that although DigitalOcean maintained high rankings in both the High-Score Category and the Low-Score Category, it experienced relatively large performance variation with some extremely low scores during the testing period. Internap, Dimension Data and AWS VMs had wide ranges of performance levels that covered the performance ranges of their neighboring VMs, which caused their performance rankings to shift in different categories. 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 – Small VMs – Ranked by Median



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

Internap's performance graph displays a median line closer to the 95th percentile line than the 5th percentile line. Neither the minimum line nor the maximum line stretches out significantly. This indicates a **negative fluctuation**, and no significant spike was detected.

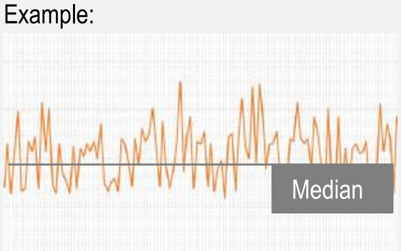
IBM SoftLayer has its 95th percentile line, median line and 5th percentile line closely compact together, and neither the minimum nor the maximum line stretches outward significantly. This indicates a highly stable performance pattern where **very little fluctuation** was detected.

Dimension Data's performance graph shows a median line closer to the 5th percentile line than the 95th percentile line, as well as a longer maximum line than the minimum line. This indicates a **positive fluctuation**, with slightly larger high performing spikes than low performing spikes.

AWS's performance graph exhibits a median line extremely close to the 5th percentile line while the difference between the 95th percentile and median lines is vast. This pattern is caused by AWS T2 family' burst function (see Performance: AWS Burst Analysis on Page 19)

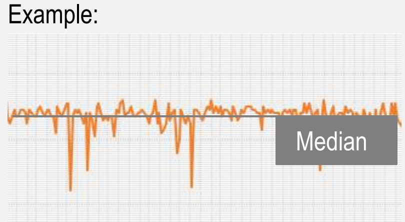
Neutral Fluctuation:
One type of fluctuation where the scores spread evenly above and below median.

Example:



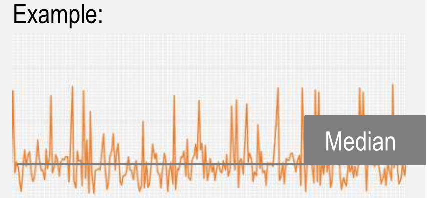
Negative Fluctuation:
One type of fluctuation where the scores below median have a larger magnitude.

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 AWS and Internap 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.

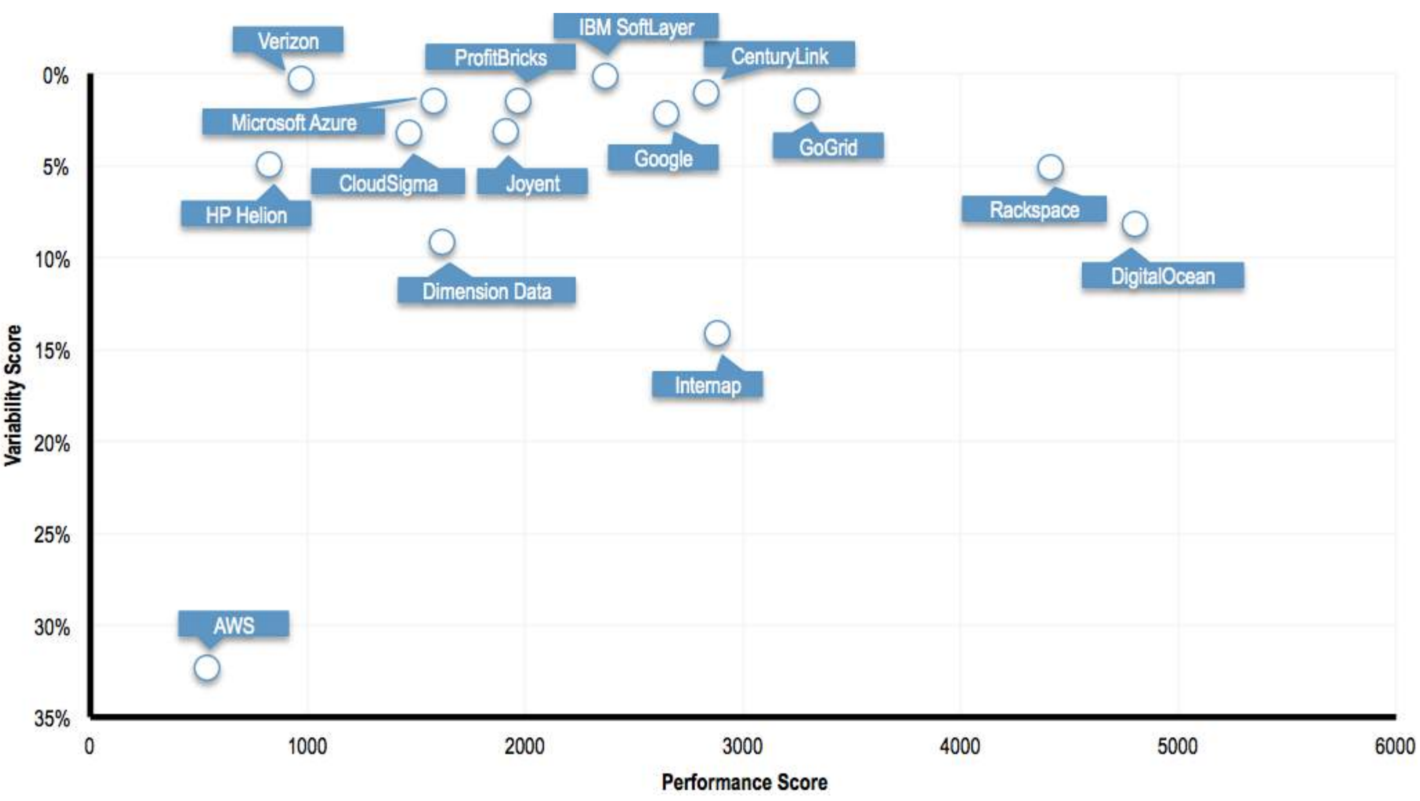
Table 2.2: Aggregated CPU & Memory Performance Variability – Small VMs

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Variability	32.3%	1.0%	3.2%	8.2%	9.1%	1.5%	2.2%	5.0%	0.2%	14.2%	3.2%	1.5%	1.5%	5.1%	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. In addition, as is mentioned before, the AWS VM's high variability score was largely due to its bursting function instead of a lack of stability. For AWS burst information, see Performance: AWS Burst Analysis on Page 19.

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 1000 and 3000 with variability lower than 5%.

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

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	463	2719	852	2964	1263	2774	2017	682	2446	2227	1111	1399	1602	3463	908
5th Per.	547	2896	1377	4754	1399	3442	2700	828	2482	2291	2026	1627	1945	4466	923
Median	**558**	**2961**	**1524**	**5035**	**1680**	**3466**	**2787**	**857**	**2497**	**2948**	**2073**	**1662**	**2024**	**4581**	**930**
95th Per.	2842	2984	1563	5150	1922	3484	2848	970	2505	3033	2084	1679	2048	4663	938
Max.	2895	2993	1583	5235	2128	3499	2871	991	2511	3072	2093	1750	2081	4701	942
Variability	32.1%	1.0%	2.9%	8.4%	8.9%	1.5%	2.5%	5.2%	0.2%	14.4%	3.4%	1.0%	1.5%	4.6%	0.1%

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. AWS and Internap 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 – Small VMs – Ranked by Median

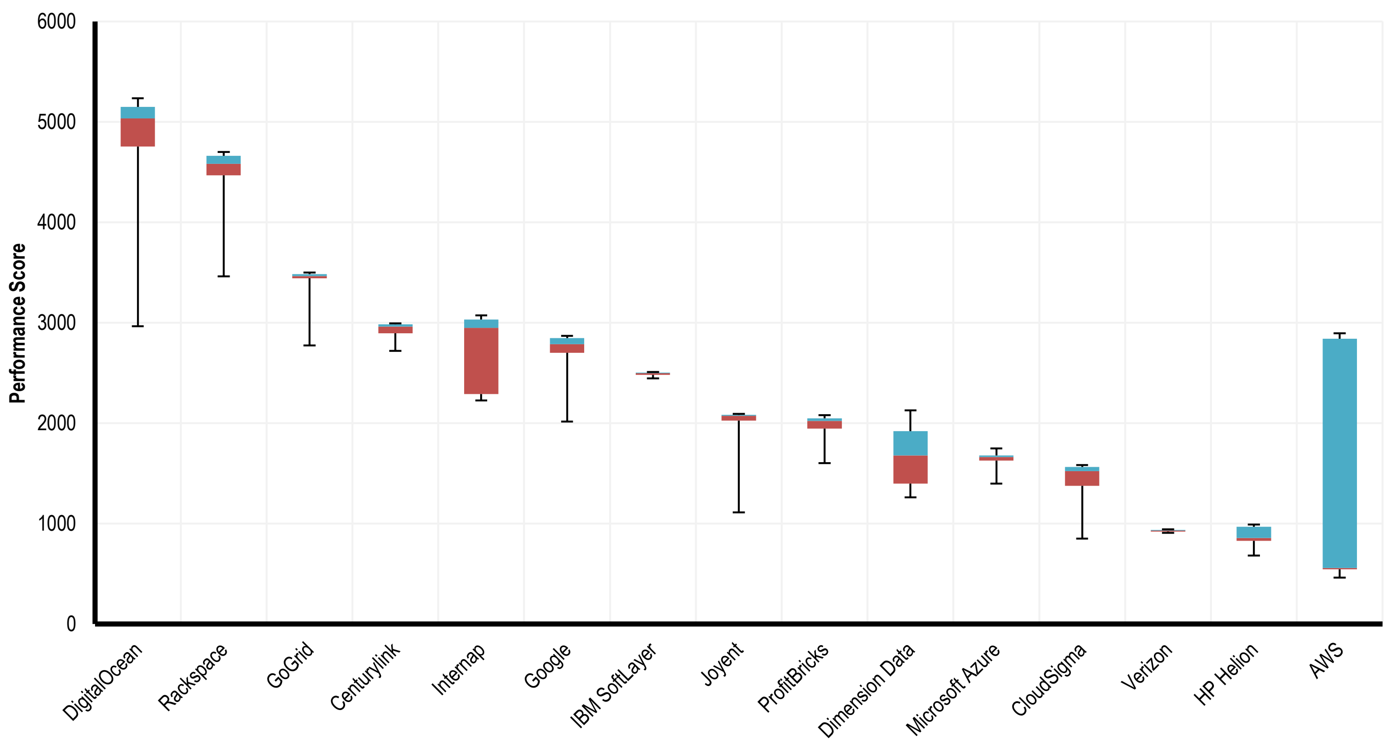
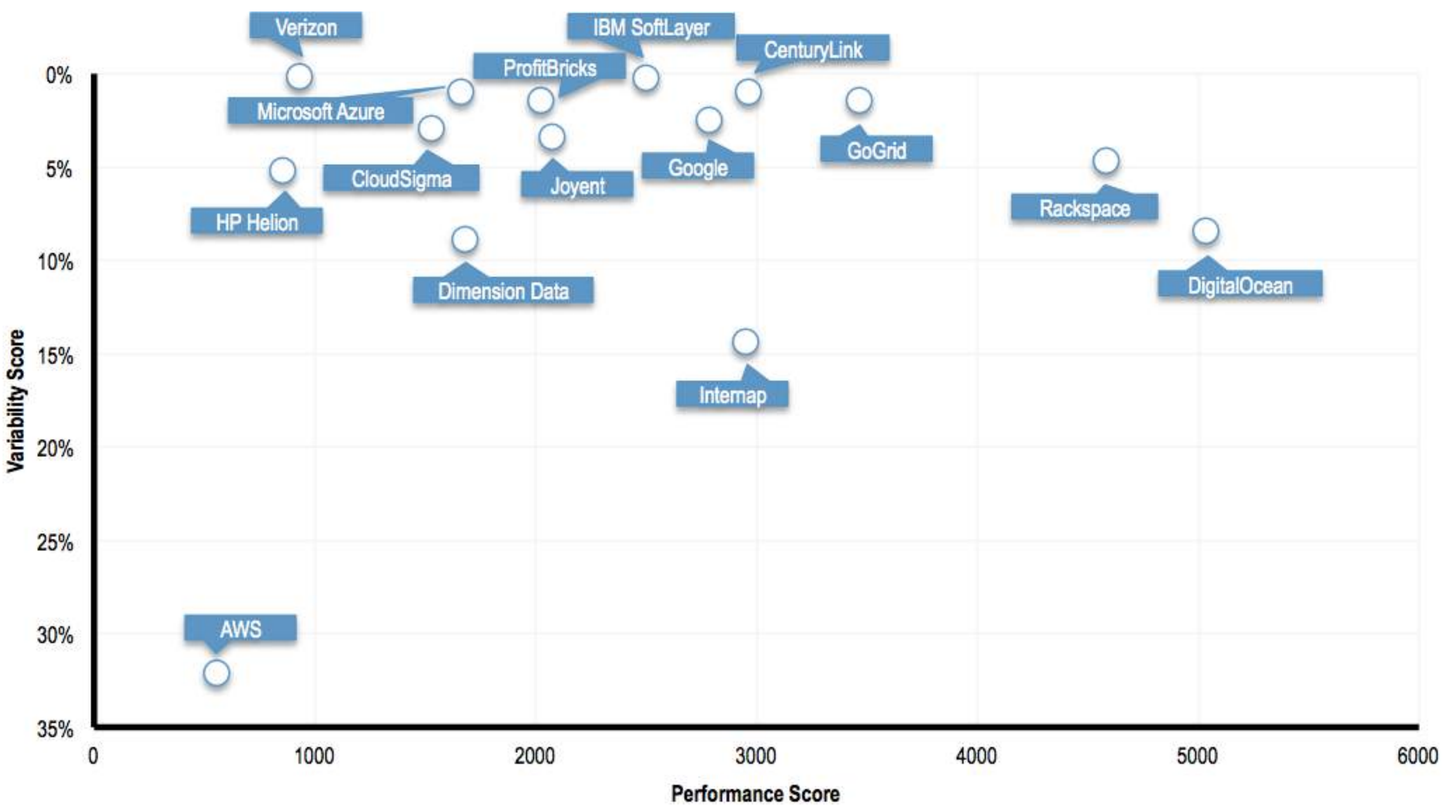


Figure 2.5 shows that DigitalOcean, Rackspace and GoGrid are the top three providers for Small VM CPU performance. It is important to keep in mind that the VMs from those three providers were 2 vCPU machines, while 1 vCPU machines were used on the majority of the other providers based on Cloud Spectator's selection criteria consistent with that of the *Cloud Vendor Benchmark 2015 Part 1: Pricing* report. For detailed information, see Preface: VM Configurations and Pricing.

AWS and Internap VMs displayed high CPU performance variability, while CenturyLink, IBM SoftLayer, 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 AWS VM's high variability score was largely due to its bursting function instead of a lack of stability. For AWS burst information, see Performance: AWS Burst Analysis.

The CPU performance-variability matrix is shown in *Figure 2.6*. The x-axis shows the median CPU performance scores, with higher performance on the right and lower performance on the left. The y-axis shows the CPU performance variability, with the more stable VMs above the less stable VMs. In the top right corner are VMs with both high performance and high stability. Most VMs have a performance score between 1000 and 3000 with variability lower than 5%.

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

	AWS	CenturyLink	CloudSigma	DigitalOcean	Dimension Data	GoGrid	Google	HP Helion	IBM SoftLayer	Internap	Joyent	Microsoft Azure	ProfitBricks	Rackspace	Verizon
Min.	395	2162	960	2446	1165	2037	1945	420	1830	1601	901	1080	1369	3106	1112
5th Per.	450	2211	1018	3655	1206	2542	2035	537	1837	2203	1208	1145	1683	3541	1123
Median	**460**	**2308**	**1211**	**3855**	**1363**	**2595**	**2075**	**693**	**1839**	**2620**	**1233**	**1228**	**1740**	**3747**	**1134**
95th Per.	2285	2327	1280	3964	1798	2632	2099	732	1841	2715	1255	1406	1813	4037	1142
Max.	2316	2340	1305	3999	2061	2669	2113	780	1843	2744	1264	1640	1852	4173	1150
Variability	33.7%	1.4%	4.9%	7.0%	10.8%	1.6%	0.3%	3.7%	0.0%	12.8%	1.8%	4.5%	2.0%	7.7%	1.2%

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. AWS, Dimension Data 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 – Small VMs – Ranked by Median

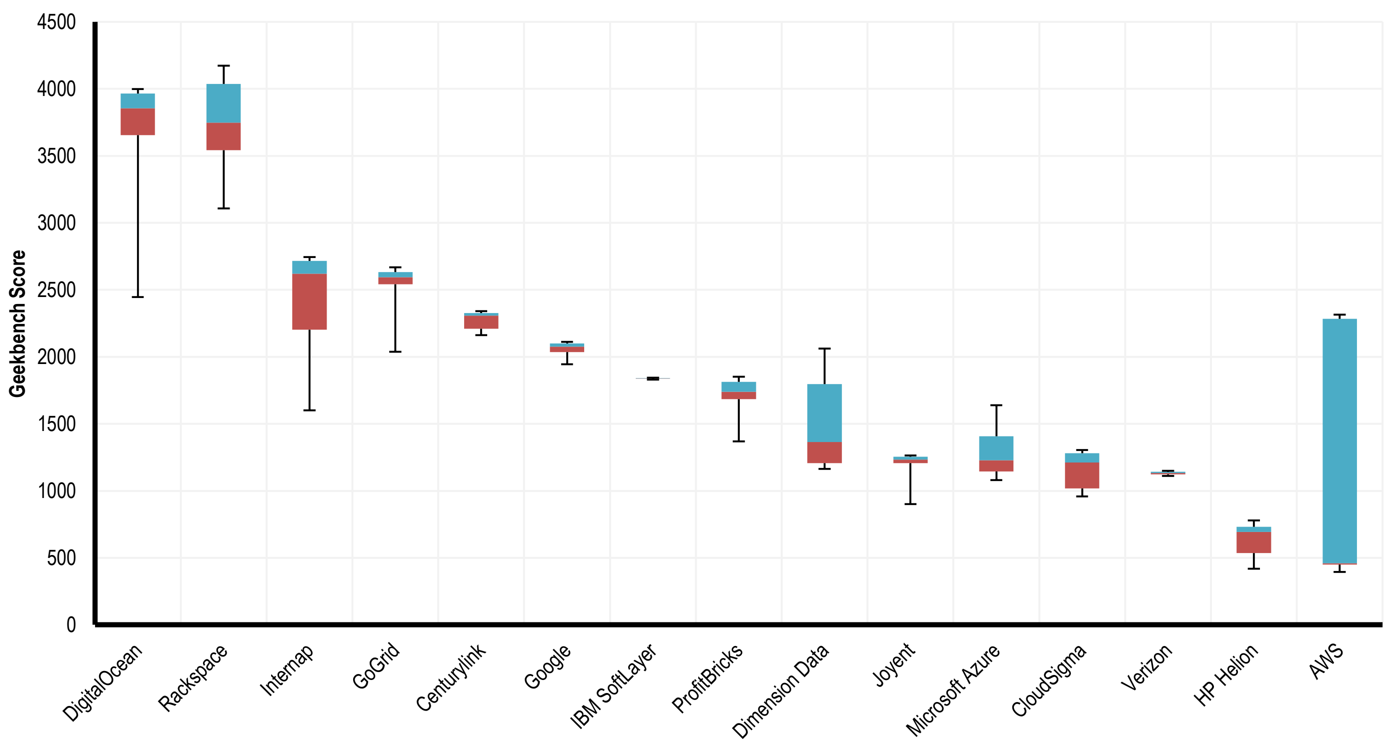
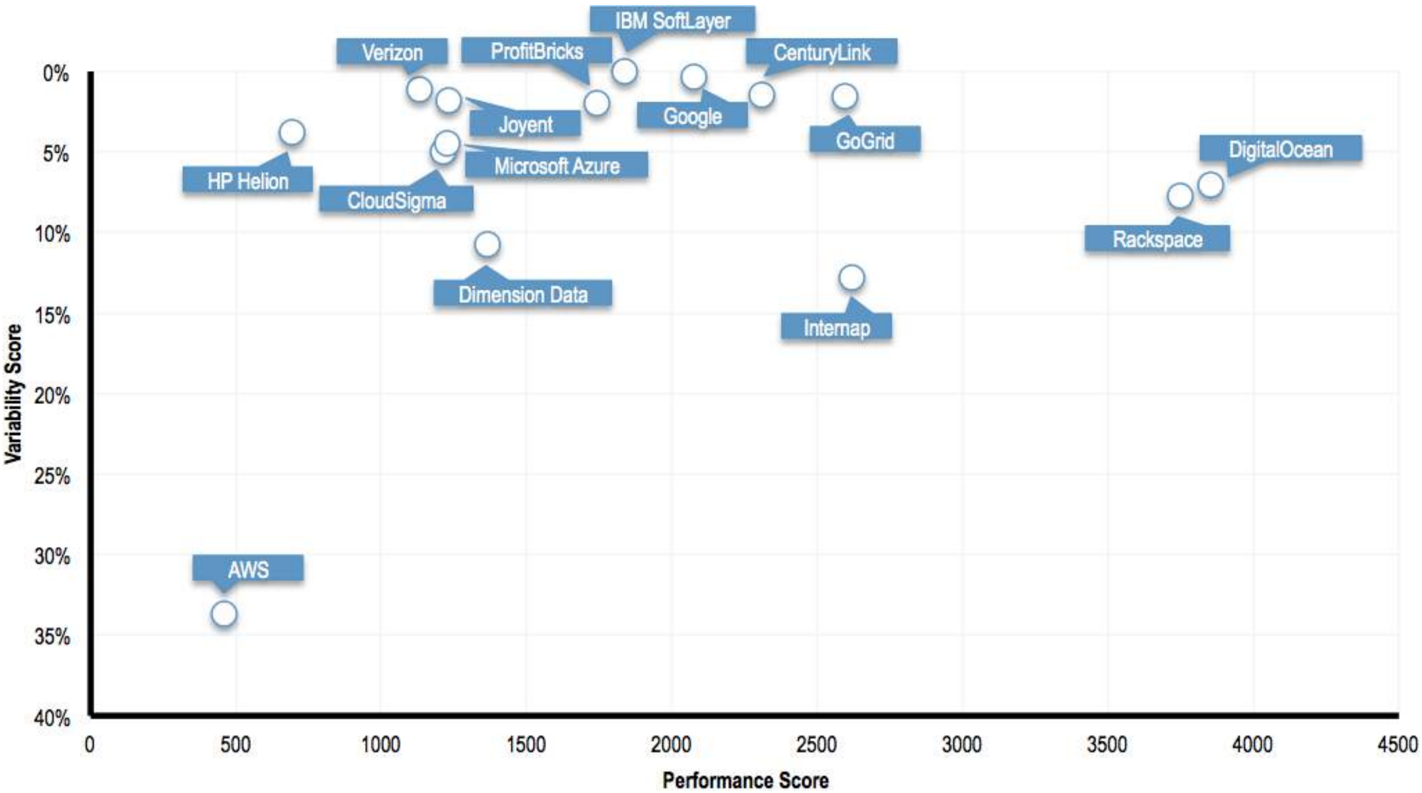


Figure 2.7 shows that DigitalOcean, Rackspace and Internap VMs are the top three providers for Small VM memory performance. AWS, Dimension Data and Internap VMs displayed high memory performance variability, while GoGrid and IBM SoftLayer VMs showed high stability with their variability scores being 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 AWS VM's high variability score was largely due to its bursting function instead of a lack of stability. For AWS burst information, see Performance: AWS Burst Analysis.

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 VMs with both high performance and high stability. Most VMs have a performance score between 1000 and 3000 with variability lower than 5%.

Figure 2.8: Memory Performance-Variability Matrix – Small 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, Lua, Dijkstra, Black Scholes, SGEMM, DGEMM, STREAM Copy, STREAM Scale, STREAM Add and STREAM Triad 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, DigitalOcean, Rackspace and GoGrid VMs had the highest performance rankings across all providers for the majority of tasks. DigitalOcean's VM displayed the highest performance output for 23 out of the 27 tasks, with Rackspace's VM leading the Dijkstra, SGEMM, STREAM Add and STREAM Triad tasks.

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

Table 2.5: High Variability VM Summary – Small VMs

	High Variability Score*	Low Variability Score*	Average Variability Score	Variability Pattern
AWS	40.9%	23.0%	32.3%	Mostly positive fluctuations**
Dimension Data	22.3%	2.8%	9.1%	Positive, negative and neutral fluctuations
Internap	18.6%	11.3%	14.2%	Mostly negative fluctuations

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

***AWS VM's performance fluctuation wasn't distributed evenly over time. For specific analysis on AWS VM performance, see AWS Burst Analysis below.*

The AWS VM showed an average variability of 32.3%, with 90% of the variability scores ranging between 23.0% and 40.9%, mostly positive fluctuations; the Internap VM showed an average variability of 14.2%, with 90% of the variability scores ranging between 11.3% and 18.6%, mostly negative fluctuations; and the Dimension Data VM showed an average variability of 9.1%, with 90% of the variability scores ranging between 2.8% and 22.3%, which included a mixture of positive, negative, and neutral fluctuations. All variability scores can be viewed in the performance analysis tables. These recurring fluctuations across tasks explain the aggregated performance variations exhibited by AWS, Dimension Data and Internap 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.

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

Table 2.6: Low Variability VM Summary – Small VMs

	High Variability Score (95%)	Low Variability Score (5%)	Average Variability Score	Variability Pattern
CenturyLink	3.1%	0.0%	1.0%	-
IBM SoftLayer	1.1%	0.0%	0.2%	-
Microsoft Azure	4.4%	0.0%	1.5%	-
Verizon	1.0%	0.0%	0.3%	-

The CenturyLink VM showed an average variability of 1.0%, with 90% of the variability scores ranging between 0.0% and 3.1%; the IBM SoftLayer VM showed an average variability of 0.2%, with 90% of the variability scores ranging between 0.0% and 1.1%; the Microsoft Azure VM showed an average variability of 1.5%, with 90% of the variability scores ranging between 0.0% and 4.4%; and the Verizon VM showed an average variability of 0.3%, with 90% of the variability scores ranging from 0.0% and 1.0%. No variability patterns are attributed to VMs with variability scores less than 5%. All variability scores can be viewed in the performance analysis tables. The small degree of variability of these VMs indicates stable aggregate performance outputs during the 24-hour testing. For variability calculation information, see Methodology: Performance.

CloudSigma, DigitalOcean, GoGrid, Google, Joyent and Rackspace VMs exhibited performance outliers on the lower end for the majority of the tasks tested. This implies that some extremely low, but infrequent scores were detected over the course of the 24-hour continuous testing.

AWS Burst Analysis

While the performance variability of other provider VMs was mainly a result of an alternation of high and low scores, the large performance variation of the AWS VM was caused by its T2 family burst function. According to AWS's official description, "T2 instances are designed to provide moderate baseline performance and the capability to burst to significantly higher performance as required by your workload." (See AWS's T2 burst function webpage) AWS allocates a certain number of vCPU credits per 24 hours, and depending on the user's application requirements, the T2 VMs can burst to 100% CPU power instead of the baseline capacity, until the CPU credits are used up within the 24 hours. For specific information, visit AWS's T2 burst function webpage.

During the 24-hour continuous testing, Cloud Spectator detected the AWS t2.small VM's positive fluctuation, which was recurring across all integer, floating point and memory tasks, the magnitude of which was relatively consistent. In order to analyze the performance pattern, Cloud Spectator calculated the performance difference between the 95th percentile (representing the bursting condition) and 5th percentile (representing the non-bursting condition) performance outputs for each task (see *Table 2.7*):

Table 2.7: AWS Burst and Non-Burst Performance Comparison – t2.small

	95TH Percentile Performance (Burst)	5TH Percentile Performance (Non-Burst)	Burst Performance Multiplier (=Burst/Non-Burst)
AES (MB/sec)	2140.16	443.20	4.8x
Twofish (MB/sec)	140.61	27.50	5.1x
SHA1 (MB/sec)	316.21	61.89	5.1x
SHA2 (MB/sec)	138.70	27.00	5.1x
BZip2 Compression (MB/sec)	9.55	1.78	5.4x
BZip2 Decompression (MB/sec)	12.61	2.40	5.3x
JPEG Compression (Mpixels/sec)	36.01	7.00	5.1x
JPEG Decompression (Mpixels/sec)	91.12	17.49	5.2x
PNG Compression (Kpixels/sec)	2037.76	383.55	5.3x
PNG Decompression (Kpixels/sec)	31744.00	6144.00	5.2x
Sobel (Mpixels/sec)	126.61	24.99	5.1x
Lua (KB/sec)	2398.21	453.58	5.3x
Dijkstra (Mflops/sec)	7.57	1.34	5.6x
BlackScholes (Mnodes/sec)	9.70	1.89	5.1x
Mandelbrot (Mflops/sec)	2621.44	500.19	5.2x
Sharpen Filter (Mflops/sec)	1720.32	328.29	5.2x
Blur Filter (Mflops/sec)	1792.00	340.90	5.3x
SGEMM (Mflops/sec)	9853.95	2017.28	4.9x
DGEMM (Mflops/sec)	4896.77	952.89	5.1x
SFFT (Mflops/sec)	2764.80	525.20	5.3x
DFFT (Mflops/sec)	2561.02	487.49	5.3x
N-Body (Kpairs/sec)	1597.44	304.69	5.2x
Ray Trace (Kpixels/sec)	4056.06	770.29	5.3x
STREAM Copy (GB/sec)	7.97	1.54	5.2x
STREAM Scale (GB/sec)	10.50	2.07	5.1x
STREAM Add (GB/sec)	10.20	2.02	5.0x
STREAM Triad (GB/sec)	10.20	2.01	5.1x
			Average = 5.2x

The result shows that on average the VM's burst performance was 5.2 times the baseline performance. The baseline performance is 20% of the full CPU performance, as claimed on AWS's T2 burst function webpage. In order to visualize the performance pattern over time, Cloud Spectator produced a line graph with data collected from AWS t2.small's PNG Compression performance:

Figure 2.9: AWS Performance Line Graph – t2.small – PNG Compression

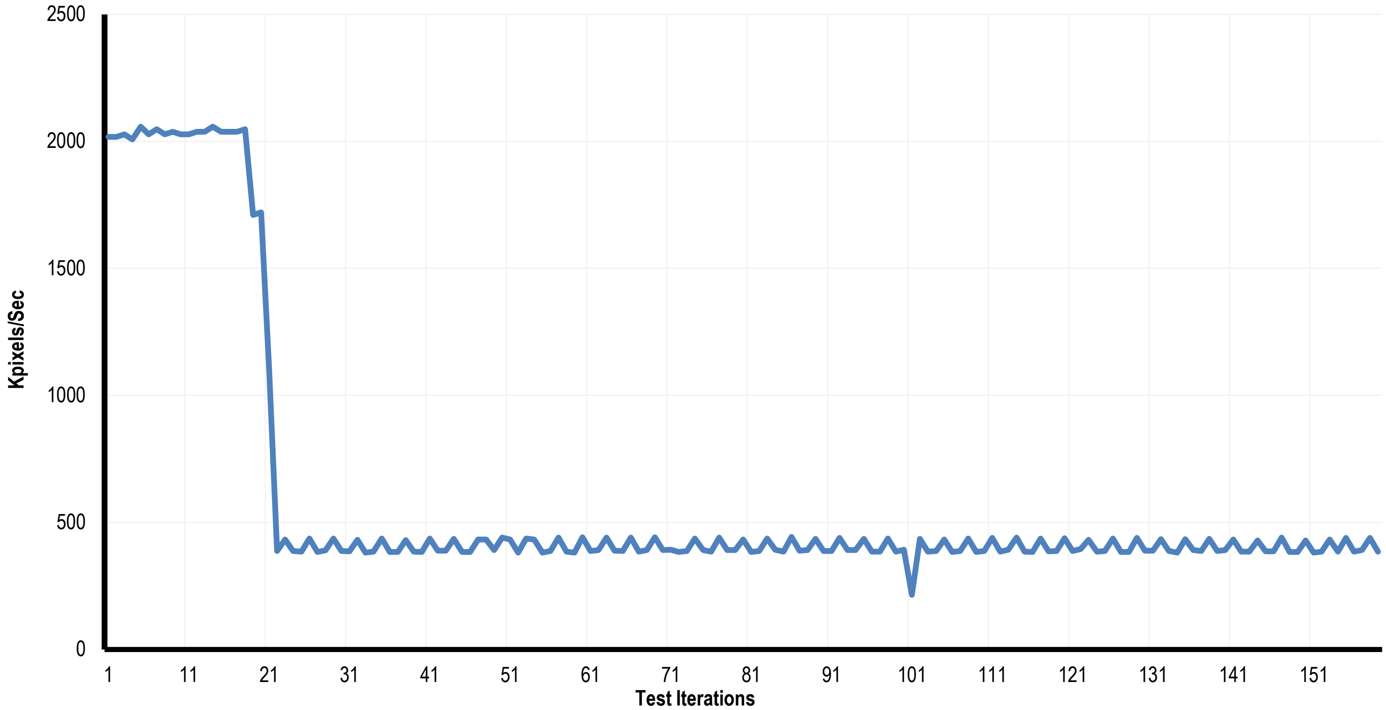


Table 2.8: AWS PNG Compression Performance Statistics – t2.small

Total Iterations	Burst Iterations	Non-burst Iterations	Burst Average (Kpixels/Sec)	Non-burst Average (Kpixels/Sec)	Total Duration (Hour)	Burst Duration (Minutes)
159.0	21.0	138.0	1959.7	402.7	24.0	46.0

According to the data Cloud Spectator collected, a total of 159 test iterations of the PNG Compression task were completed on the AWS t2.small VM, among which 138 iterations were operated under the baseline condition and 21 iterations were operated under the burst condition. The AWS VM burst 46.0 minutes during the 24 hours of continuous testing.

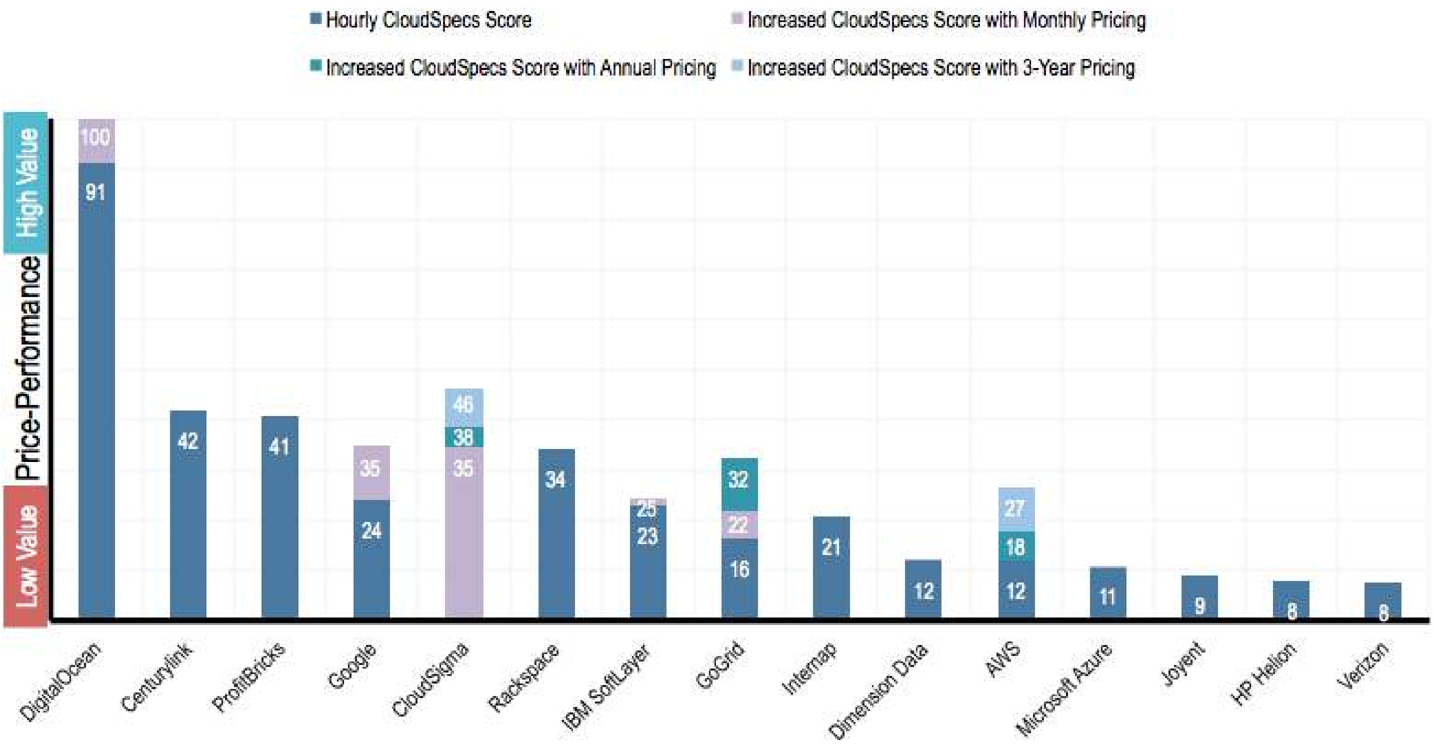
The graph indicates that AWS's burst duration was concentrated at the beginning of the 24-hour testing due to the vCPU power demanded by the testing. Operating a different application on the VM may yield different performance patterns from the one shown above.

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 – Small 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 Digital Ocean VM had the highest price-performance values, outperforming the next highest machine, the CenturyLink VM, by an average of 56%. CenturyLink, ProfitBricks and Rackspace VMs exhibited high price-performance value for hourly pricing, and CloudSigma and Google VMs 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's long-term price-performance resulted in ranking increases.

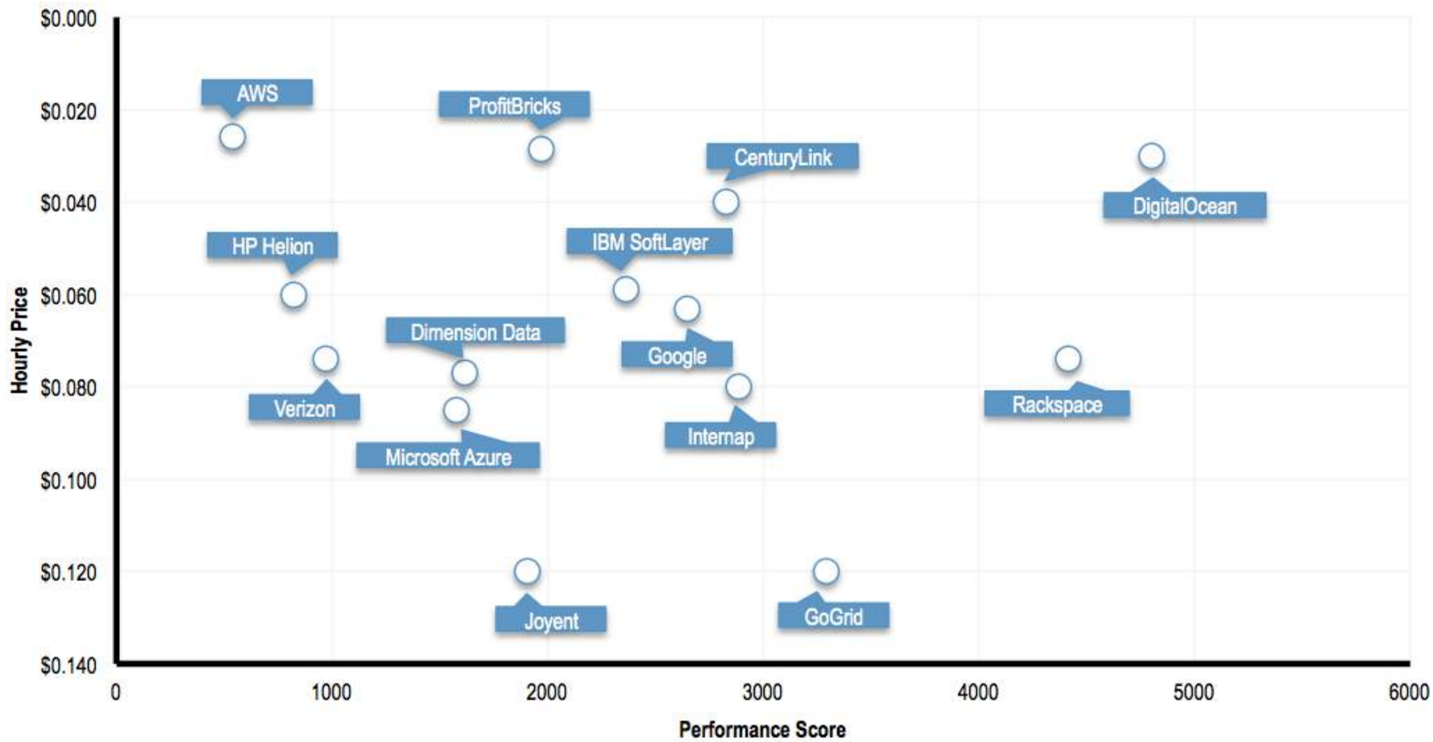
The graphs on the next few pages show the relationship between price and performance for hourly, monthly, annual and 3-year pricing individually, using median performance data, and display the CloudSpecs Score™ price-performance comparison for each pricing model using low scores, median scores and high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

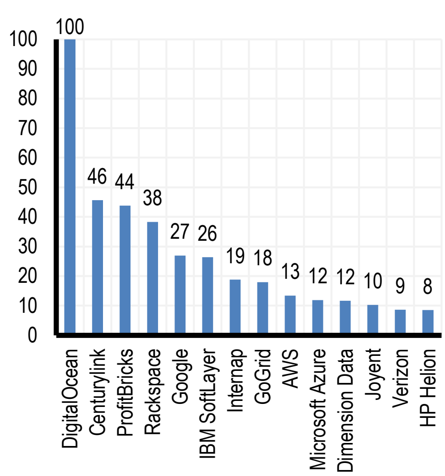


Figure 3.4: Median-Score Category Price-Performance – Small VMs (Hourly)

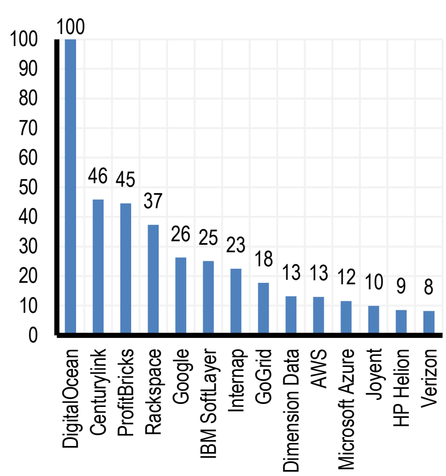
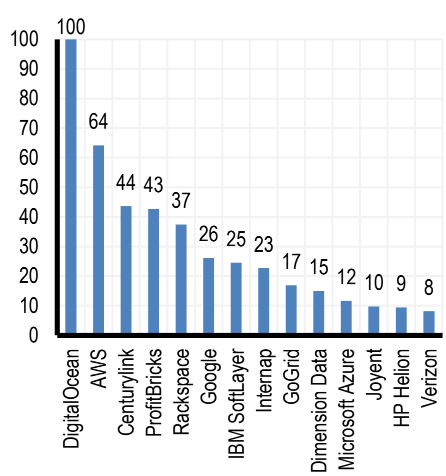


Figure 3.5: High-Score Category Price-Performance – Small VMs (Hourly)



**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 – Small VMs

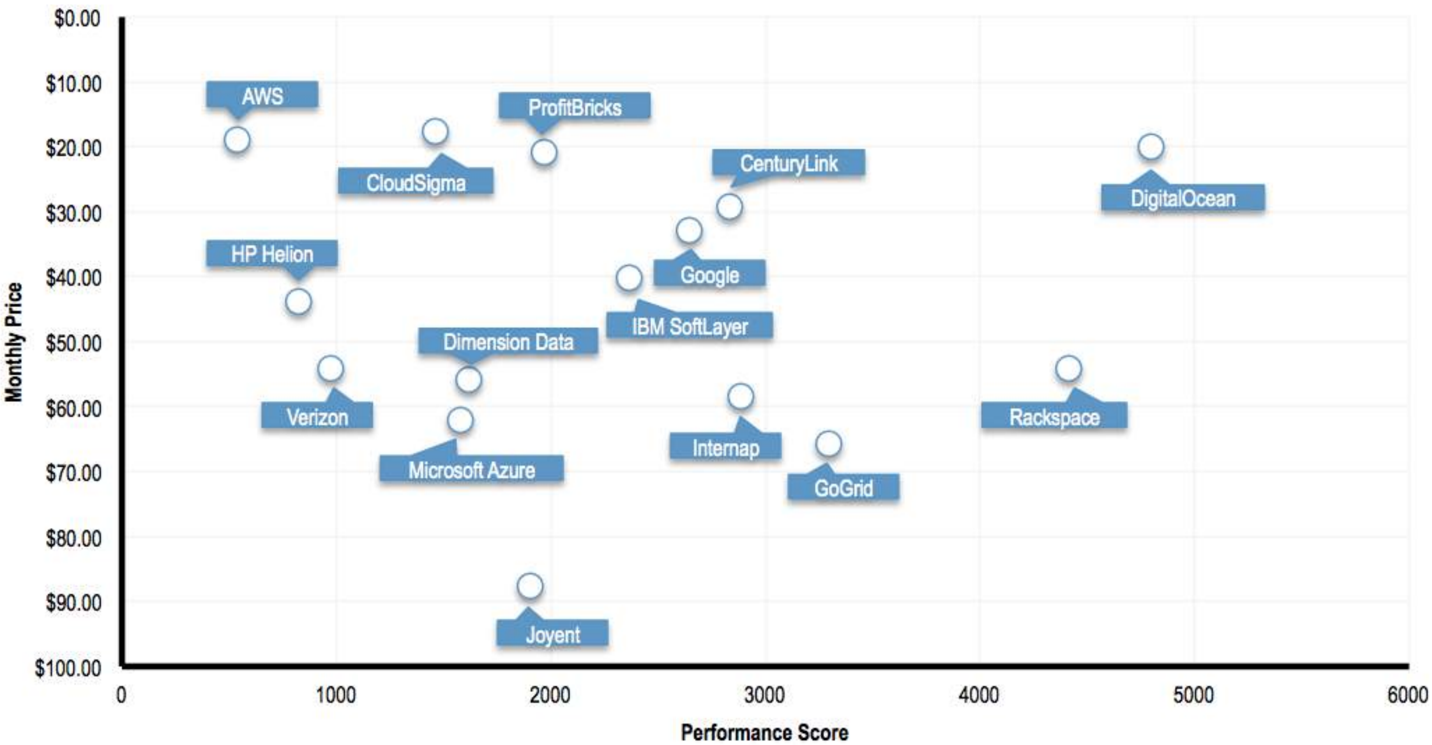


Figure 3.7 – 3.9 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and monthly prices.

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

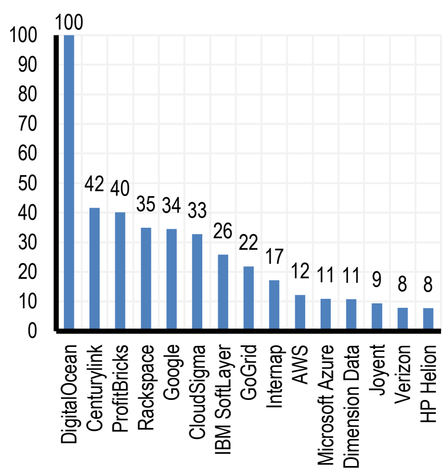


Figure 3.8: Median-Score Category Price-Performance – Small VMs (Monthly)

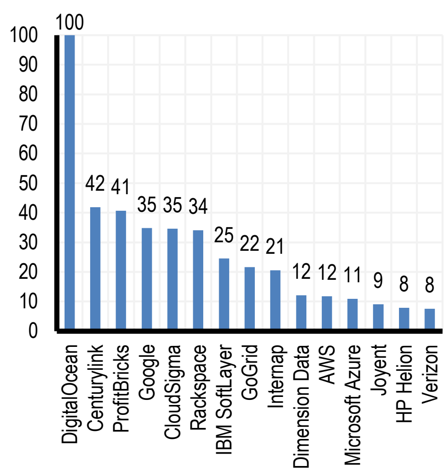
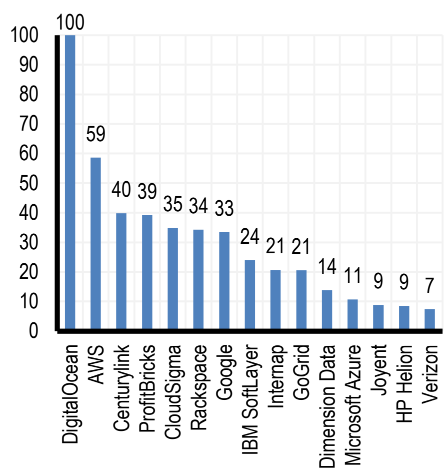


Figure 3.9: High-Score Category Price-Performance – Small VMs (Monthly)



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 – Small VMs

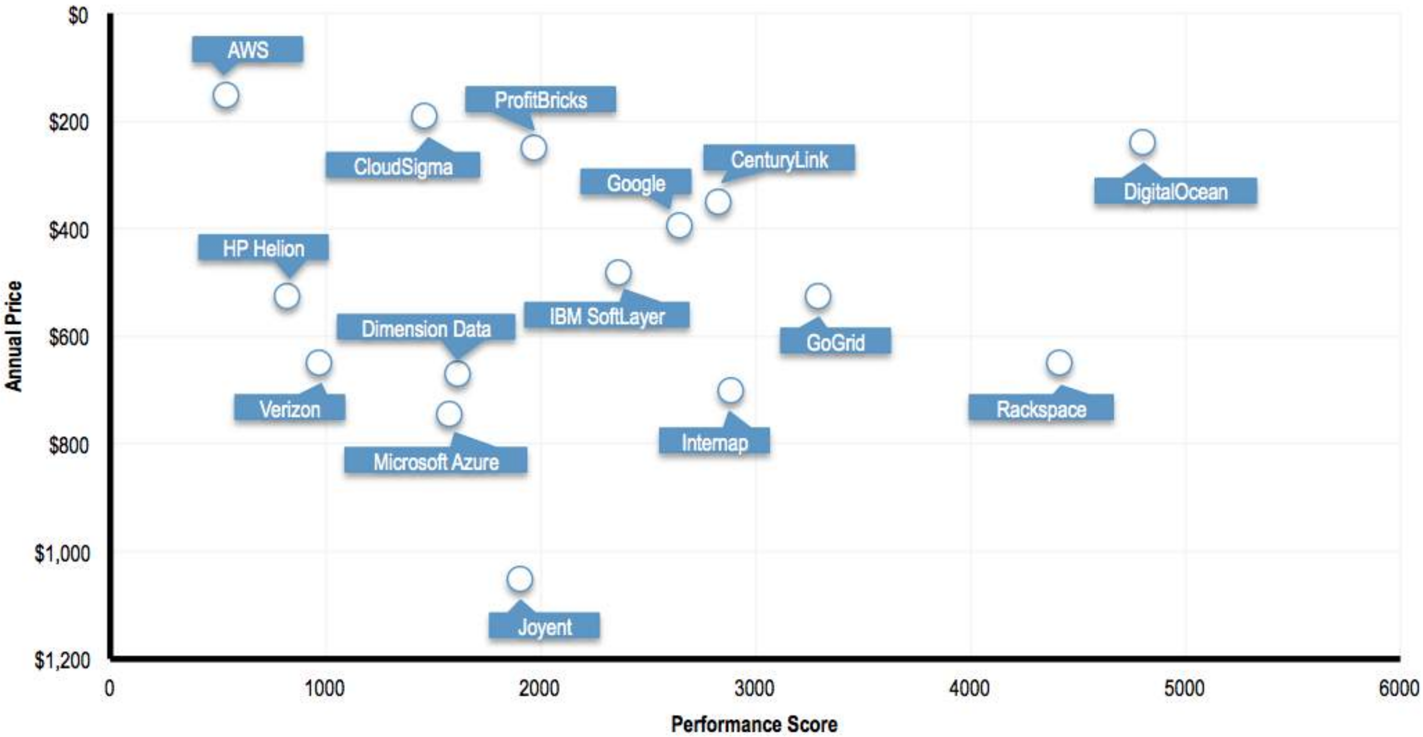


Figure 3.11 – 3.13 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and annual prices.

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

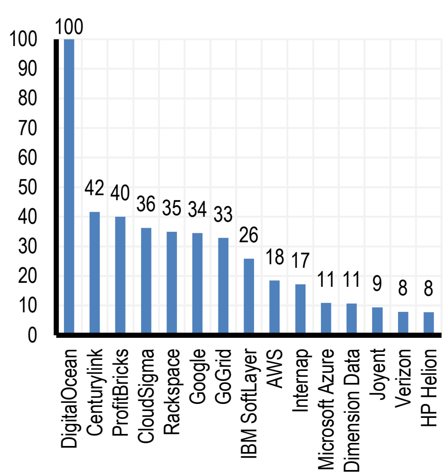


Figure 3.12: Median-Score Category Price-Performance – Small VMs (Annual)

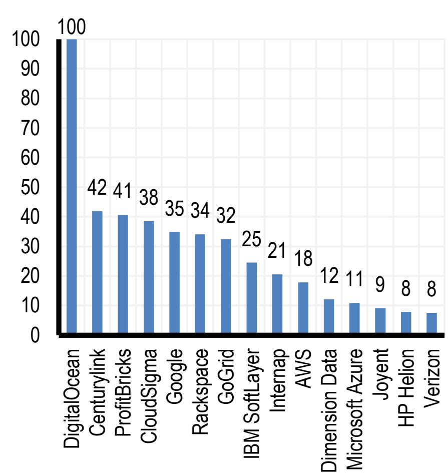
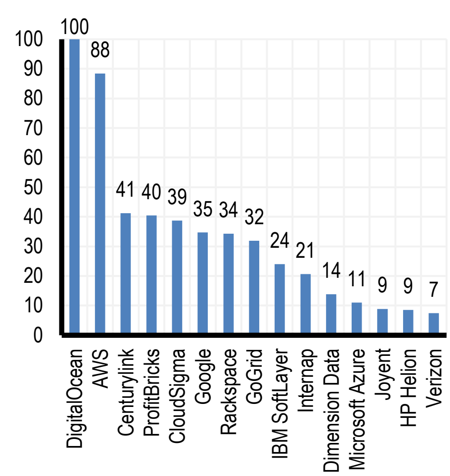


Figure 3.13: High-Score Category Price-Performance – Small VMs (Annual)



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 – Small VMs

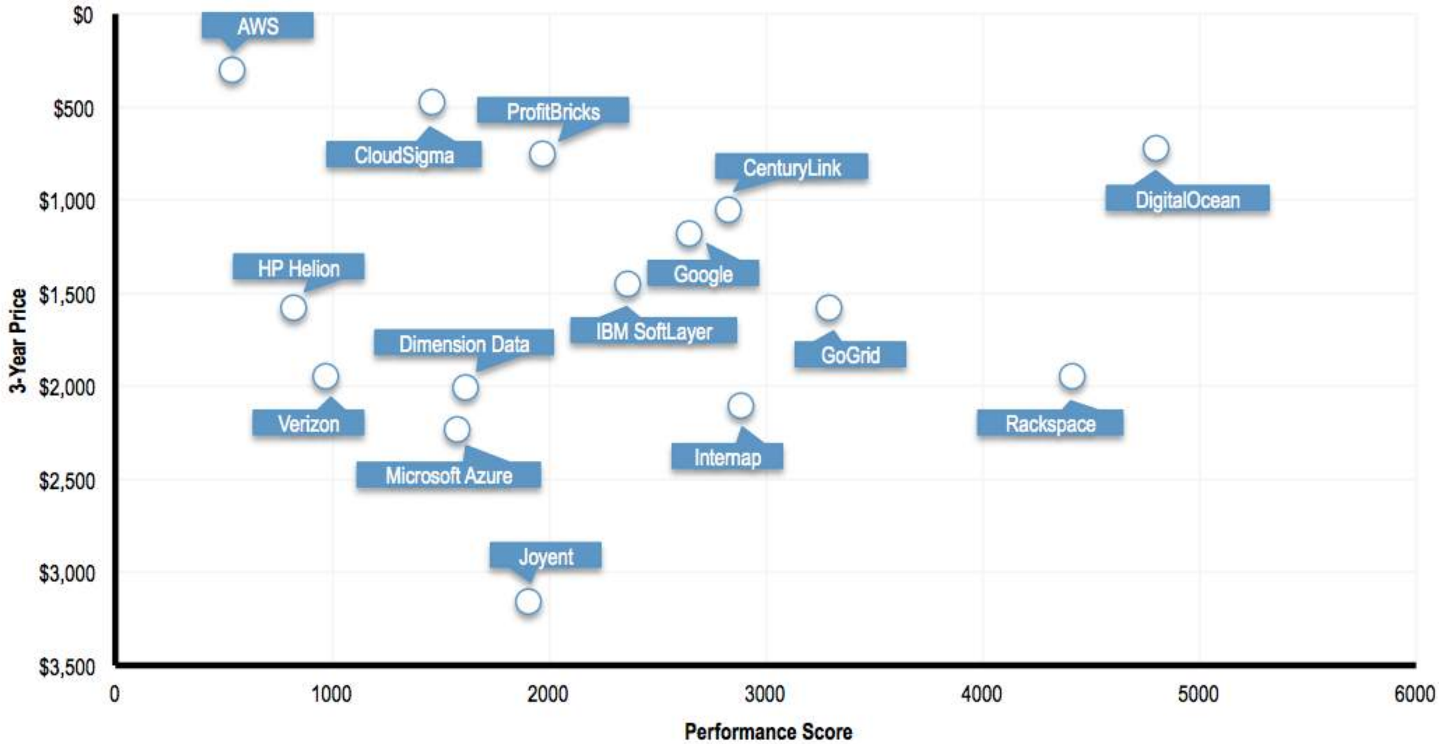


Figure 3.15 – 3.17 are price-performance rankings using the CloudSpecs Score™ calculation. The VMs are ranked from high to low by CloudSpecs Score™ calculated using low, median and high CPU & memory performance scores and 3-year prices.

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

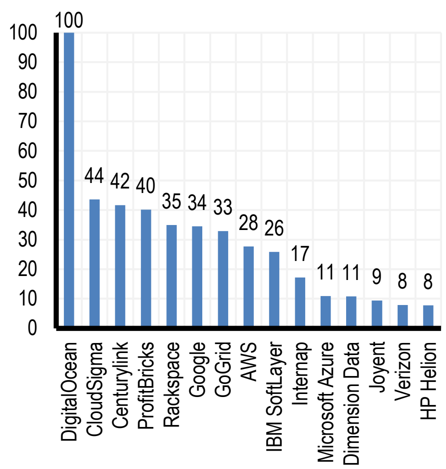


Figure 3.16: Median-Score Category Price-Performance – Small VMs (3-Year)

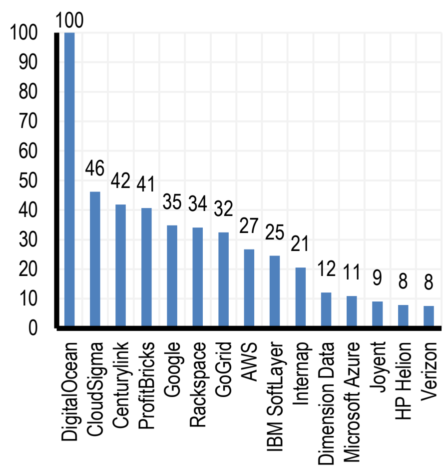
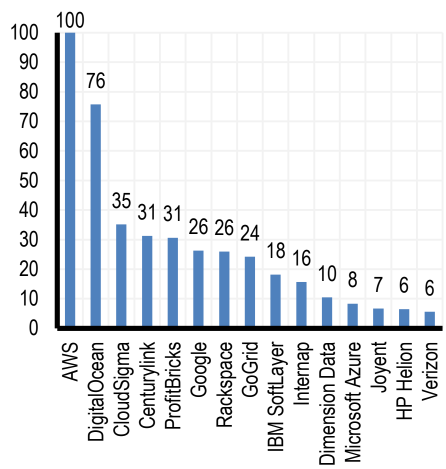


Figure 3.17: High-Score Category Price-Performance – Small VMs (3-Year)

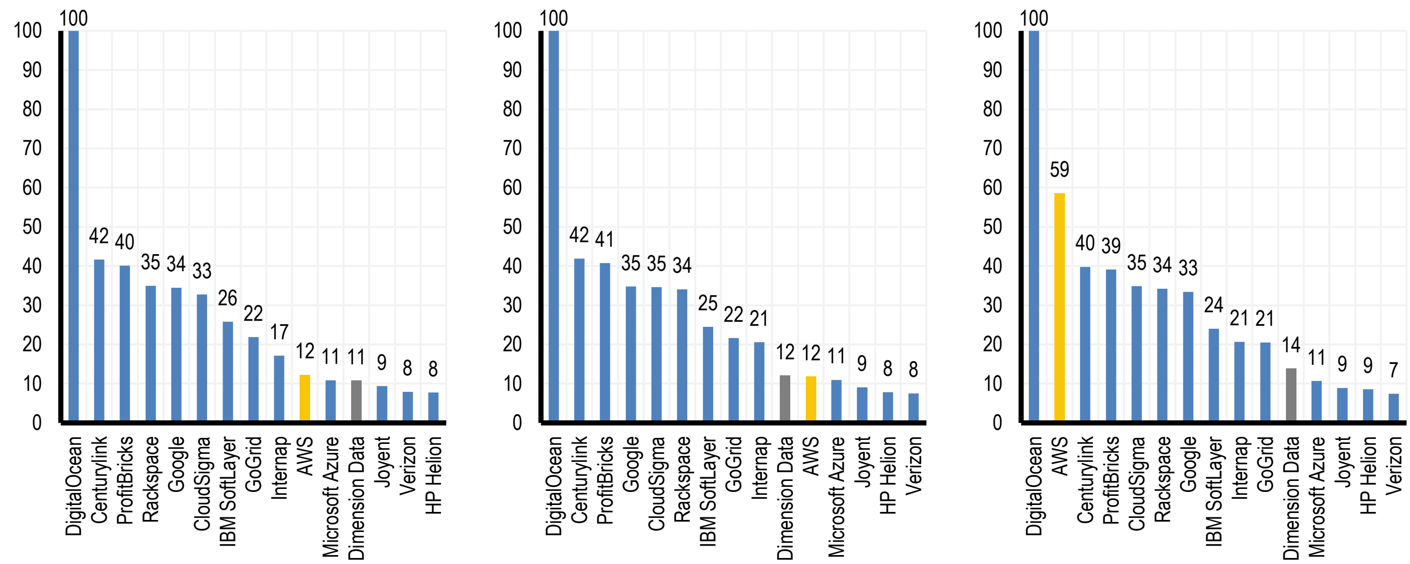


Overall, DigitalOcean, CenturyLink and ProfitBricks VMs had the highest rankings in low, median and high CloudSpecs scores of all pricing intervals. The DigitalOcean VM led the price-performance comparison, outperforming the next highest provider machine by around 50% on average, in all except the 3-year price-performance ranking in the High-Score Category. The AWS VM exhibited higher price-performance for the High-Score Category 3-year price-performance ranking.

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 – Small VMs

Low-Score Category **Median-Score Category** **High-Score Category**



As illustrated above using the monthly examples, the Dimension Data VM's price-performance ranking in the Low-Score Category is lower than in the Median- and High-Score Categories, and the AWS VM displayed significantly higher price-performance in the High-Score Category in comparison with the Low- and Median-Score Categories.

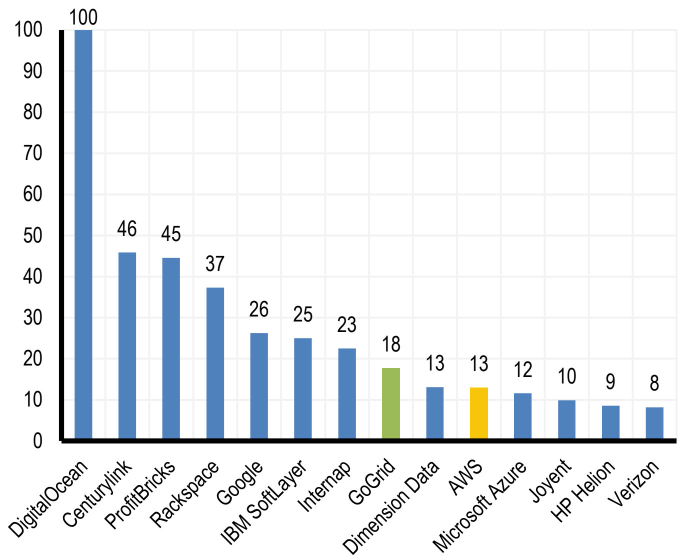
The price-performance value ranges reflected by the three categories are consistent with their performance variations, which are shown in the section titled Performance Comparison.

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 and GoGrid VMs' price-performance rankings increase as the pricing structure changes to longer-term prices, because they offer discounts that increase with longer time commitments (i.e., AWS offers a 34% discount on its annual pricing and a 56% 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). The trend is illustrated below using median performance as an example:

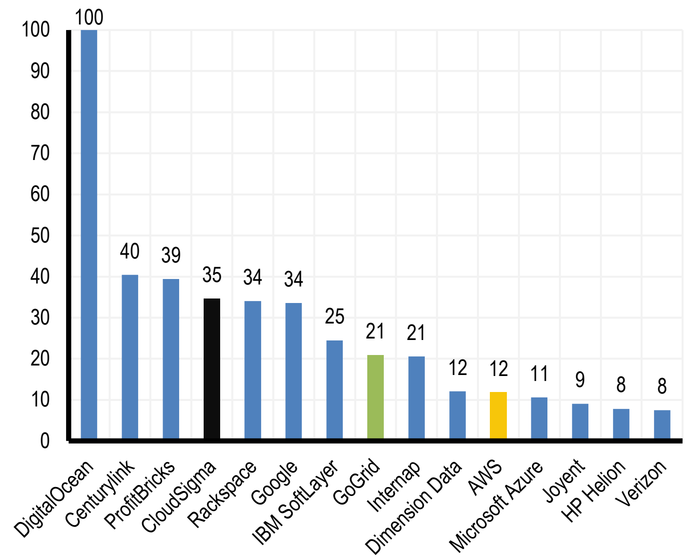
[2] This AWS discount information only applies to the t2.small instance at their Virginia data center assuming full payment upfront. Any changes in conditions may change the discount information for both annual and 3-year pricing.

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

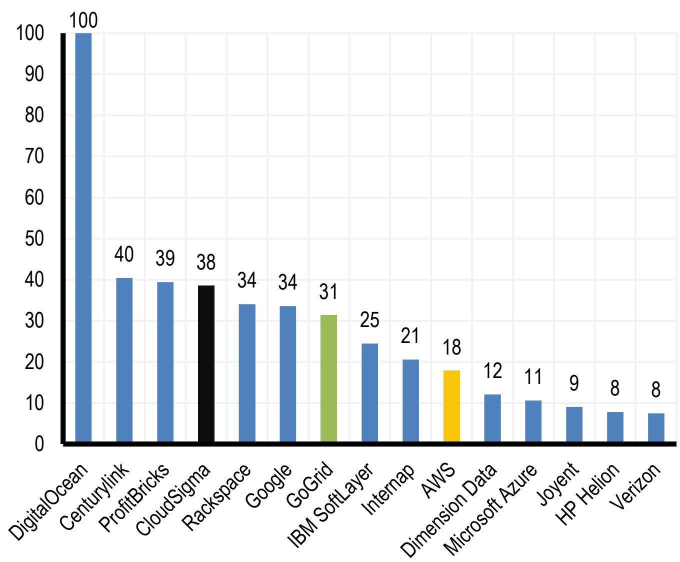
Hourly Price-Performance



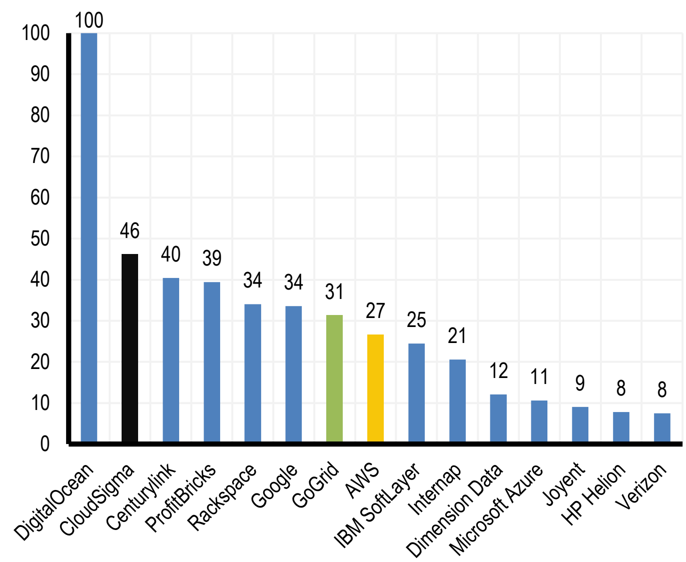
Monthly Price-Performance



Annual Price-Performance



3-Year Price-Performance



AWS, CloudSigma and GoGrid VMs' price-performance rankings increase as the pricing structure changes to longer-term prices, because they 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 Small 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 AWS's t2.small as an example, while the VM ranks first in the hourly pricing comparison, its median performance output ranks last among the 15 providers, and its price-performance calculated using the data supporting the first two graphs ranks 11th. 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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- Cloud Vendor Benchmark 2015 Part 2.5: Performance and Price-Performance (2XLarge VMs, Linux)
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- Cloud Vendor Benchmark 2015 Part 2.8: Performance and Price-Performance (Large VMs, Windows)
- Cloud Vendor Benchmark 2015 Part 2.9: Performance and Price-Performance (XLarge VMs, Windows)
- Cloud Vendor Benchmark 2015 Part 2.10: Performance and Price-Performance (2XLarge VMs, Windows)

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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 Small VM report are also included in the tables. For price-performance comparisons for Medium, Large, 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	-	-	-	-

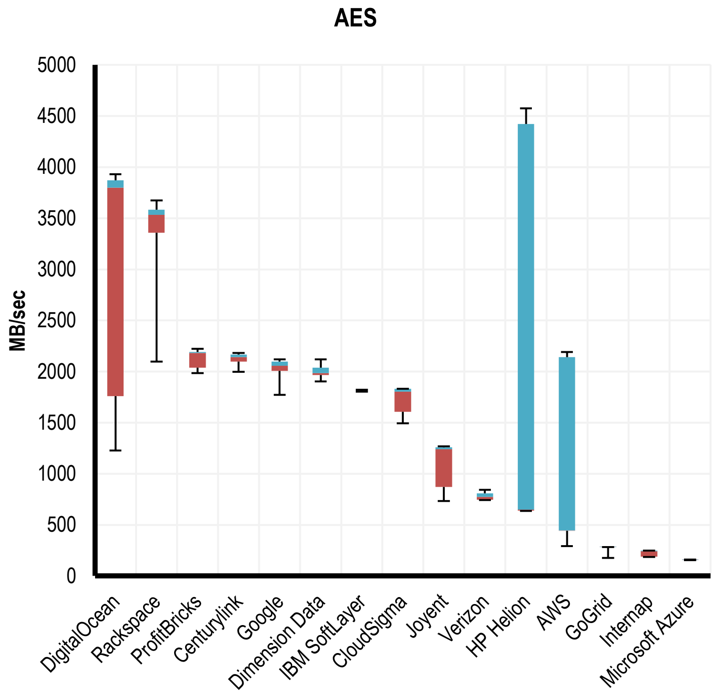
VM Processor Information

Provider	OS	Python Version	Processor (Small)
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
Digital Ocean	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

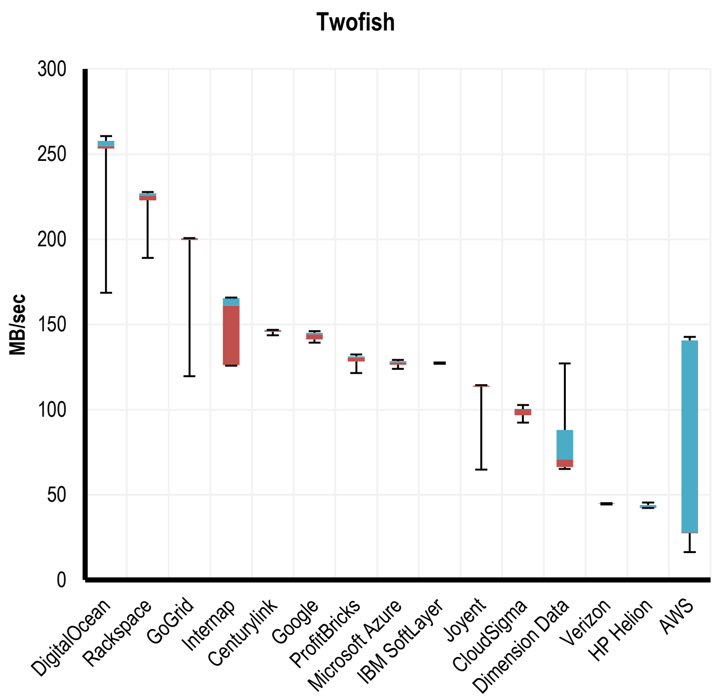
The following tables and graphs describe the performance ranking through each individual task. The rankings are from high to low based on median.

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.



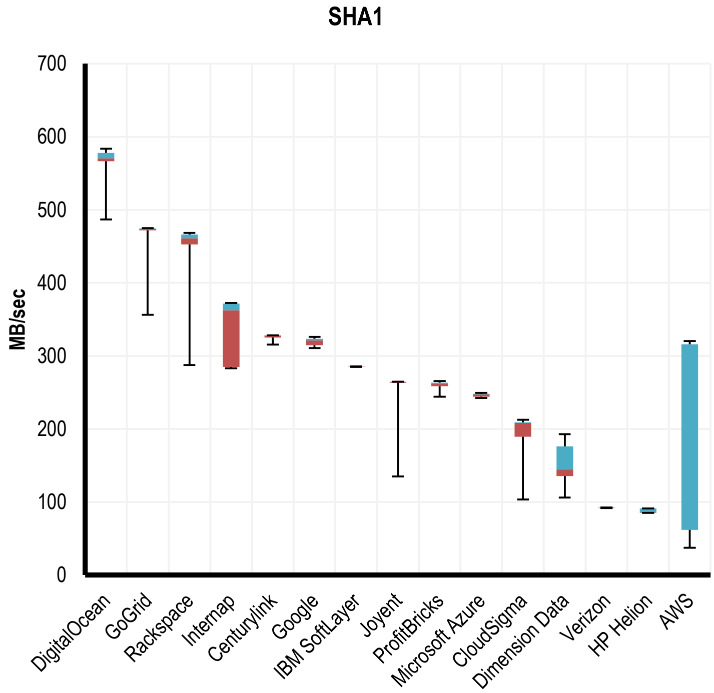
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	293	443	446	2140	2191	557	30.9%
CenturyLink	1997	2099	2140	2165	2181	19	1.1%
CloudSigma	1495	1608	1802	1833	1833	78	4.3%
DigitalOcean	1229	1761	3799	3871	3932	847	47.0%
Dimension Data	1905	1966	1987	2038	2120	27	1.5%
GoGrid	178	282	283	284	284	4	0.2%
Google	1772	2007	2058	2099	2120	30	1.7%
HP Helion	638	641	648	4424	4577	1567	86.9%
IBM SoftLayer	1802	1812	1812	1812	1823	1	0.1%
Internap	186	188	241	248	249	47	2.6%
Joyent	735	870	1239	1260	1270	107	5.9%
Microsoft Azure	155	157	159	160	161	0	0.0%
ProfitBricks	1987	2038	2181	2191	2222	57	3.2%
Rackspace	2099	3360	3533	3584	3676	215	11.9%
Verizon	743	745	773	807	842	18	1.0%

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.



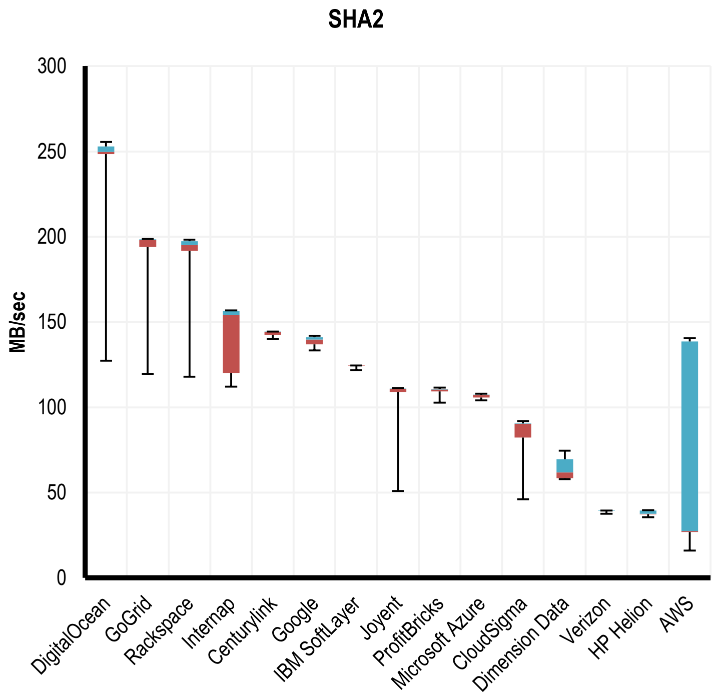
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	16.4	27.5	27.8	140.6	142.8	35.7	27.9%
CenturyLink	143.7	145.8	146.6	146.8	146.8	0.0	0.0%
CloudSigma	92.4	96.7	100.3	100.4	102.8	1.0	0.8%
DigitalOcean	168.7	253.4	254.6	257.9	260.7	5.1	4.0%
Dimension Data	65.3	66.3	70.6	88.1	127.2	9.6	7.5%
GoGrid	119.6	199.6	200.5	200.6	200.7	2.0	1.6%
Google	139.3	141.3	144.2	145.2	146.2	1.0	0.8%
HP Helion	42.3	42.4	42.6	44.1	45.5	0.4	0.3%
IBM SoftLayer	126.9	127.7	127.7	127.7	127.8	0.0	0.0%
Internap	125.9	126.3	161.1	165.5	165.9	17.8	13.9%
Joyent	64.9	113.4	114.1	114.3	114.5	3.4	2.7%
Microsoft Azure	124.0	126.4	127.8	128.5	129.2	0.0	0.0%
ProfitBricks	121.5	128.3	130.6	131.3	132.4	1.3	1.0%
Rackspace	189.2	223.0	225.5	227.1	227.8	2.3	1.8%
Verizon	44.4	44.8	44.9	45.0	45.1	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.



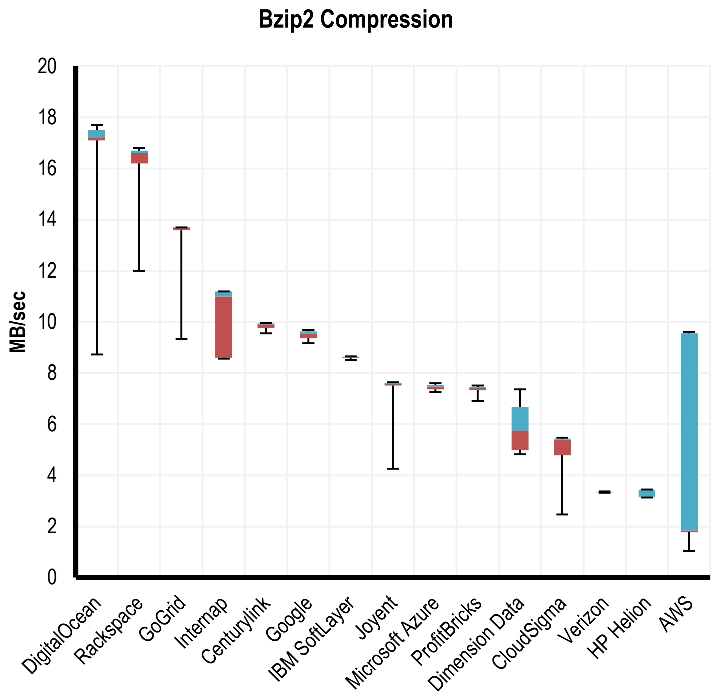
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	37.5	61.9	62.9	316.2	320.2	80.6	30.5%
CenturyLink	315.6	325.3	327.8	328.3	328.4	1.0	0.4%
CloudSigma	103.6	189.6	208.3	209.1	212.6	6.1	2.3%
DigitalOcean	486.7	566.8	570.4	578.0	583.7	5.0	1.9%
Dimension Data	106.0	135.6	144.9	176.4	192.8	13.7	5.2%
GoGrid	356.4	471.8	473.9	474.6	474.9	4.7	1.8%
Google	310.7	314.8	321.1	323.6	326.2	2.0	0.8%
HP Helion	85.1	85.2	85.7	91.1	91.5	2.6	1.0%
IBM SoftLayer	285.1	285.4	285.6	285.6	285.6	0.0	0.0%
Internap	283.0	284.8	362.5	371.7	372.6	40.2	15.2%
Joyent	135.1	263.0	264.1	264.6	264.9	7.9	3.0%
Microsoft Azure	242.3	244.3	247.2	248.3	249.4	1.0	0.4%
ProfitBricks	244.1	258.8	262.1	263.5	265.6	2.6	1.0%
Rackspace	287.7	452.9	460.9	466.2	468.6	8.0	3.0%
Verizon	91.6	91.8	92.0	92.4	92.6	0.0	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.



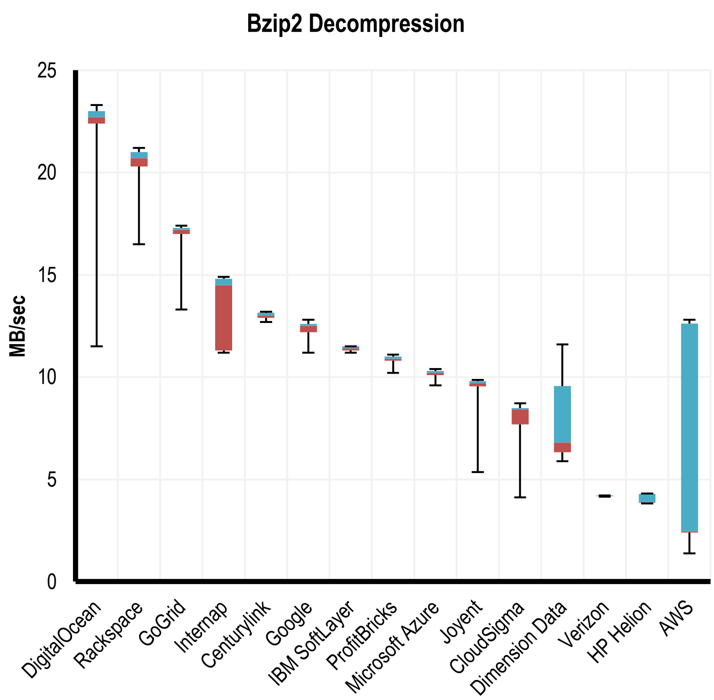
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	16.0	27.0	27.5	138.7	140.6	35.7	32.2%
CenturyLink	140.1	142.5	144.1	144.4	144.5	0.0	0.0%
CloudSigma	46.1	82.3	90.3	90.6	91.8	2.6	2.3%
DigitalOcean	127.4	248.4	249.8	253.0	255.5	5.0	4.5%
Dimension Data	57.9	58.5	61.9	69.6	74.7	3.1	2.8%
GoGrid	119.7	194.1	198.1	198.6	198.8	2.0	1.8%
Google	133.3	136.9	139.8	141.0	142.1	1.0	0.9%
HP Helion	35.5	37.3	37.6	39.6	39.7	0.4	0.4%
IBM SoftLayer	121.7	124.3	124.4	124.4	124.5	0.0	0.0%
Internap	112.1	120.0	154.0	156.4	156.8	15.6	14.1%
Joyent	50.9	109.0	110.8	111.1	111.3	3.3	3.0%
Microsoft Azure	104.0	105.8	107.2	107.5	108.1	0.0	0.0%
ProfitBricks	102.7	109.3	110.4	110.9	111.6	0.0	0.0%
Rackspace	118.0	191.9	195.1	197.3	198.4	3.9	3.5%
Verizon	37.6	39.4	39.4	39.5	39.6	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.



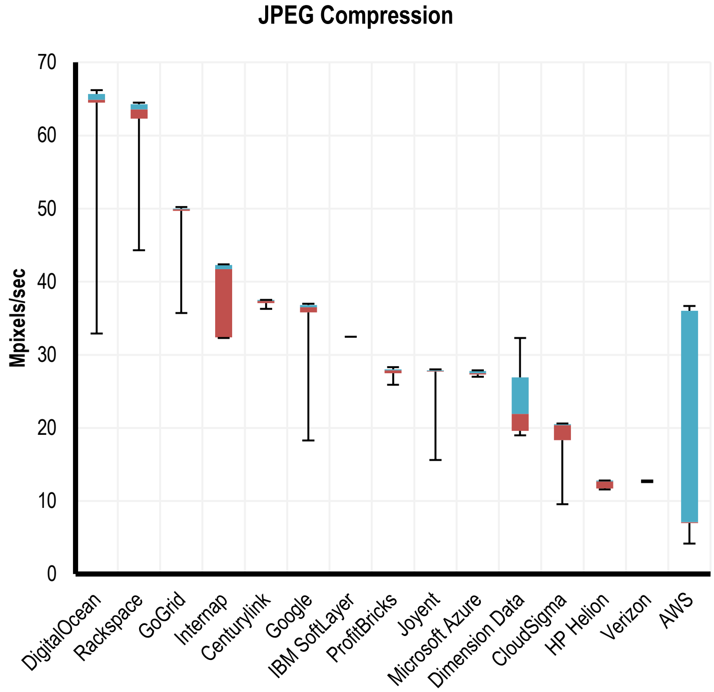
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1.05	1.78	1.85	9.55	9.62	1.74	23.0%
CenturyLink	9.55	9.77	9.91	9.94	9.97	0.00	0.0%
CloudSigma	2.47	4.79	5.40	5.44	5.47	0.25	3.3%
DigitalOcean	8.73	17.10	17.20	17.50	17.70	0.51	6.7%
Dimension Data	4.82	4.99	5.74	6.67	7.37	0.45	5.9%
GoGrid	9.33	13.60	13.70	13.70	13.70	0.13	1.7%
Google	9.17	9.37	9.54	9.63	9.69	0.00	0.0%
HP Helion	3.14	3.15	3.17	3.44	3.45	0.09	1.2%
IBM SoftLayer	8.51	8.61	8.63	8.64	8.65	0.00	0.0%
Internap	8.57	8.60	11.00	11.20	11.20	1.10	14.5%
Joyent	4.26	7.51	7.57	7.62	7.64	0.21	2.8%
Microsoft Azure	7.25	7.37	7.48	7.54	7.60	0.00	0.0%
ProfitBricks	6.90	7.34	7.41	7.45	7.51	0.00	0.0%
Rackspace	12.00	16.20	16.60	16.70	16.80	0.32	4.2%
Verizon	3.32	3.34	3.35	3.36	3.37	0.00	0.0%

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



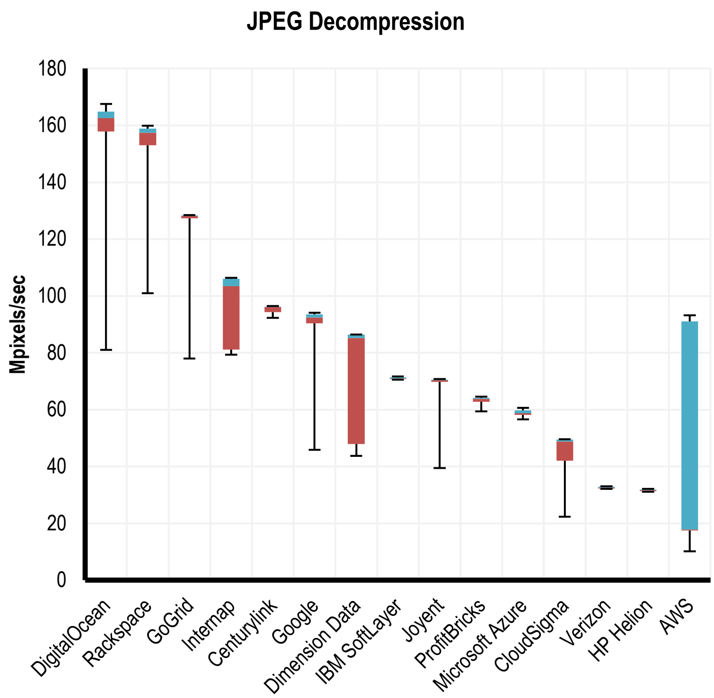
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1.39	2.40	2.47	12.61	12.80	2.58	23.7%
CenturyLink	12.70	12.90	13.00	13.15	13.20	0.00	0.0%
CloudSigma	4.12	7.69	8.43	8.48	8.72	0.32	2.9%
DigitalOcean	11.50	22.40	22.70	23.00	23.30	0.44	4.0%
Dimension Data	5.89	6.32	6.80	9.57	11.60	0.98	9.0%
GoGrid	13.30	17.00	17.20	17.30	17.40	0.17	1.6%
Google	11.20	12.20	12.50	12.60	12.80	0.12	1.1%
HP Helion	3.83	3.85	3.88	4.30	4.31	0.20	1.8%
IBM SoftLayer	11.20	11.30	11.40	11.50	11.50	0.00	0.0%
Internap	11.20	11.30	14.50	14.80	14.90	1.43	13.1%
Joyent	5.35	9.55	9.70	9.80	9.86	0.27	2.5%
Microsoft Azure	9.60	10.10	10.20	10.30	10.40	0.00	0.0%
ProfitBricks	10.20	10.80	10.90	11.00	11.10	0.10	0.9%
Rackspace	16.50	20.30	20.70	21.00	21.20	0.20	1.8%
Verizon	4.16	4.18	4.19	4.21	4.22	0.00	0.0%

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



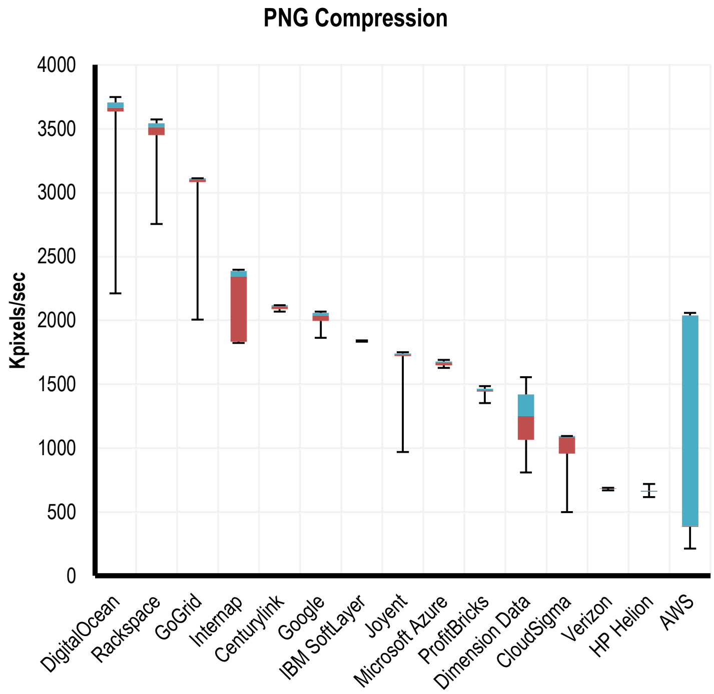
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	4.19	7.00	7.13	36.01	36.70	8.50	30.5%
CenturyLink	36.30	37.10	37.40	37.50	37.50	0.00	0.0%
CloudSigma	9.59	18.31	20.40	20.50	20.60	0.76	2.7%
DigitalOcean	32.90	64.50	64.90	65.70	66.20	1.28	4.6%
Dimension Data	19.00	19.60	21.90	26.90	32.30	2.20	7.9%
GoGrid	35.70	49.70	49.90	50.00	50.20	0.49	1.8%
Google	18.30	35.80	36.50	36.80	37.00	0.72	2.6%
HP Helion	11.60	11.70	12.70	12.80	12.80	0.36	1.3%
IBM SoftLayer	32.50	32.50	32.50	32.50	32.50	0.00	0.0%
Internap	32.30	32.40	41.70	42.30	42.40	4.18	15.0%
Joyent	15.60	27.70	27.80	27.90	28.00	0.81	2.9%
Microsoft Azure	27.00	27.30	27.50	27.80	27.90	0.00	0.0%
ProfitBricks	25.90	27.50	27.90	28.00	28.30	0.00	0.0%
Rackspace	44.30	62.30	63.60	64.30	64.50	1.26	4.5%
Verizon	12.60	12.70	12.70	12.70	12.80	0.00	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.



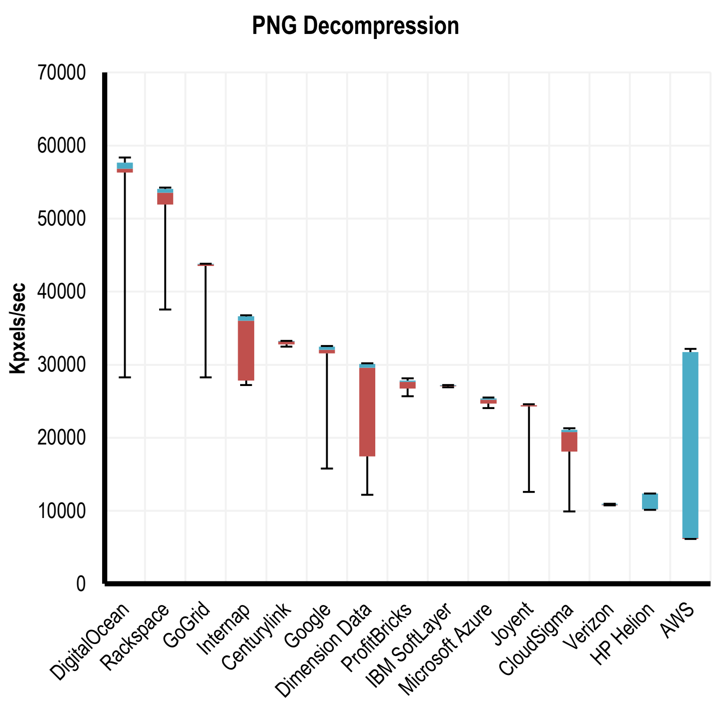
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	10.20	17.49	17.90	91.12	93.20	23.22	32.7%
CenturyLink	92.30	94.30	96.10	96.30	96.50	0.00	0.0%
CloudSigma	22.40	42.01	48.80	49.50	49.60	2.82	4.0%
DigitalOcean	81.00	157.85	162.60	164.86	167.50	6.56	9.2%
Dimension Data	43.70	47.94	85.20	86.40	86.50	15.84	22.3%
GoGrid	78.00	127.30	128.10	128.30	128.50	2.54	3.6%
Google	45.90	90.36	92.40	93.50	94.10	1.84	2.6%
HP Helion	31.10	31.40	31.70	31.90	32.20	0.00	0.0%
IBM SoftLayer	70.60	70.80	71.00	71.40	71.70	0.00	0.0%
Internap	79.40	81.20	103.45	106.00	106.40	10.56	14.9%
Joyent	39.50	69.80	70.30	70.60	70.80	2.10	3.0%
Microsoft Azure	56.60	58.13	58.70	59.70	60.60	0.00	0.0%
ProfitBricks	59.40	62.80	63.80	64.10	64.60	0.63	0.9%
Rackspace	101.00	153.06	157.45	158.90	159.90	4.68	6.6%
Verizon	32.10	32.30	32.60	32.90	33.10	0.00	0.0%

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.



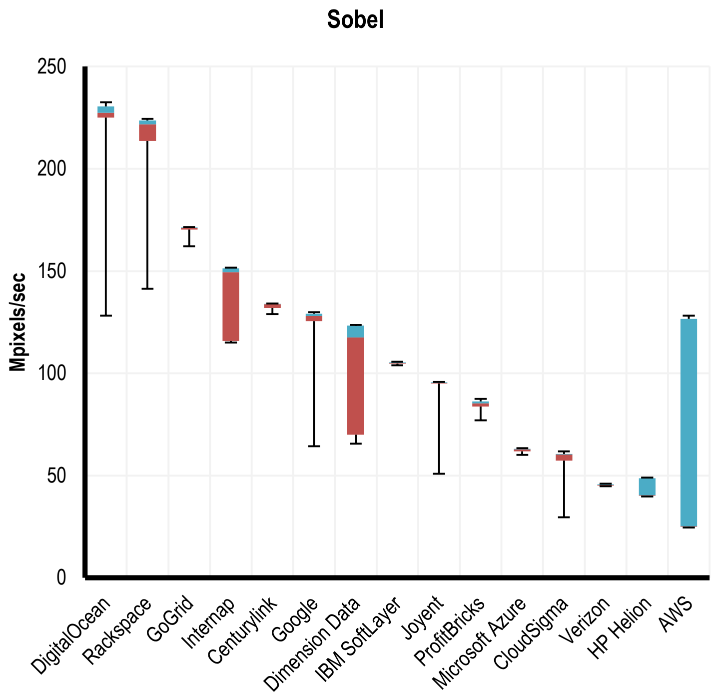
	Min.	5^{th} Per.	Median	95^{th} Per.	Max.	Stdev.	Variability
AWS	215	384	392	2038	2058	533	30.8%
CenturyLink	2068	2089	2109	2120	2120	10	0.6%
CloudSigma	498	957	1085	1096	1096	58	3.4%
DigitalOcean	2212	3635	3666	3707	3748	84	4.9%
Dimension Data	809	1065	1249	1419	1556	125	7.2%
GoGrid	2007	3082	3103	3113	3113	44	2.5%
Google	1864	1997	2038	2058	2068	18	1.0%
HP Helion	617	659	664	668	718	10	0.6%
IBM SoftLayer	1833	1843	1843	1843	1843	1	0.1%
Internap	1823	1833	2345	2386	2396	225	13.0%
Joyent	971	1720	1731	1741	1751	44	2.5%
Microsoft Azure	1628	1649	1669	1679	1690	10	0.6%
ProfitBricks	1352	1444	1454	1464	1485	10	0.6%
Rackspace	2755	3451	3512	3543	3574	49	2.8%
Verizon	671	683	685	688	689	1	0.1%

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.



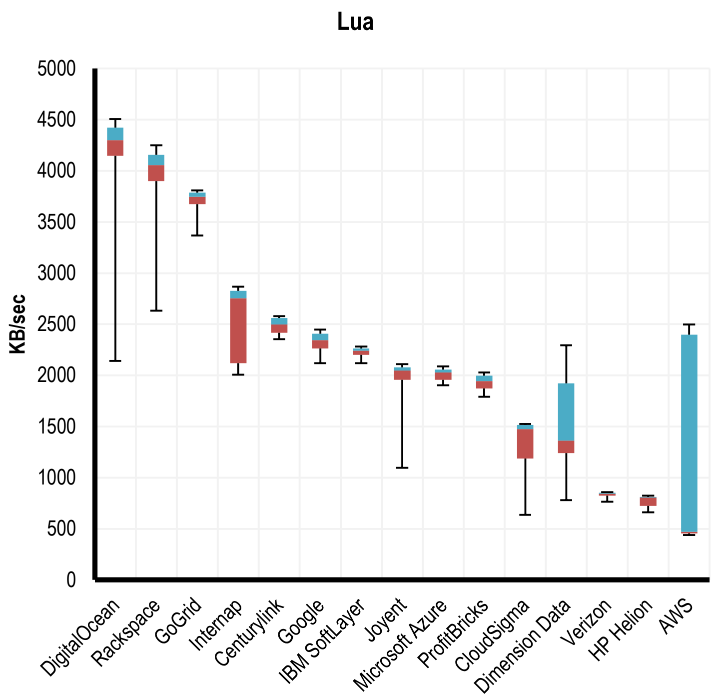
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	6134	6144	6287	31744	32154	8264	29.9%
CenturyLink	32461	32768	33178	33280	33280	169	0.6%
CloudSigma	9933	18125	20787	21094	21299	995	3.6%
DigitalOcean	28262	56320	56832	57651	58368	2286	8.3%
Dimension Data	12186	17449	29594	30106	30208	5982	21.6%
GoGrid	28262	43520	43725	43827	43827	629	2.3%
Google	15770	31539	32051	32461	32563	685	2.5%
HP Helion	10127	10189	10240	12390	12390	559	2.0%
IBM SoftLayer	26931	27034	27136	27238	27238	74	0.3%
Internap	27238	27853	36045	36659	36762	3604	13.0%
Joyent	12595	24269	24474	24474	24576	855	3.1%
Microsoft Azure	24064	24678	25190	25395	25498	225	0.8%
ProfitBricks	25702	26726	27648	27853	28160	266	1.0%
Rackspace	37581	51917	53555	54067	54272	1683	6.1%
Verizon	10752	10757	10854	10957	10957	59	0.2%

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.



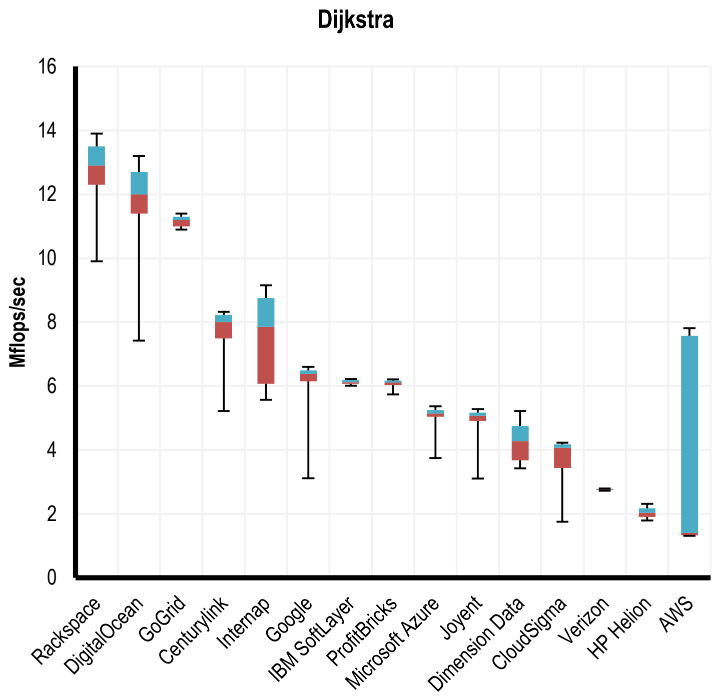
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	24.6	25.0	25.3	126.6	128.2	31.9	30.4%
CenturyLink	129.0	132.0	133.8	134.0	134.2	0.0	0.0%
CloudSigma	29.6	57.3	60.3	60.6	61.9	1.2	1.1%
DigitalOcean	128.2	225.1	227.4	230.5	232.5	4.5	4.3%
Dimension Data	65.6	70.0	117.5	123.3	123.6	23.8	22.7%
GoGrid	162.2	170.3	171.1	171.4	171.5	0.0	0.0%
Google	64.3	125.5	128.0	129.2	129.9	2.5	2.4%
HP Helion	39.8	40.1	40.4	48.8	49.0	3.9	3.7%
IBM SoftLayer	104.0	104.8	105.0	105.4	105.6	0.0	0.0%
Internap	115.1	115.8	149.4	151.3	151.7	15.2	14.5%
Joyent	50.9	95.0	95.4	95.7	95.8	3.8	3.6%
Microsoft Azure	60.1	61.9	62.8	63.1	63.5	0.0	0.0%
ProfitBricks	77.1	83.8	85.4	86.2	87.6	0.9	0.9%
Rackspace	141.3	213.6	221.8	223.7	224.4	8.8	8.4%
Verizon	44.8	45.1	45.4	45.7	46.0	0.0	0.0%

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	441	454	470	2398	2499	625	30.5%
CenturyLink	2355	2417	2499	2560	2580	42	2.1%
CloudSigma	636	1188	1475	1516	1526	114	5.6%
DigitalOcean	2140	4147	4301	4424	4506	129	6.3%
Dimension Data	781	1239	1362	1921	2294	204	10.0%
GoGrid	3369	3676	3748	3789	3809	45	2.2%
Google	2120	2263	2345	2406	2447	48	2.3%
HP Helion	661	725	806	813	824	37	1.8%
IBM SoftLayer	2120	2202	2243	2263	2284	22	1.1%
Internap	2007	2120	2755	2826	2867	300	14.6%
Joyent	1096	1956	2048	2079	2109	87	4.2%
Microsoft Azure	1905	1956	2028	2058	2089	32	1.6%
ProfitBricks	1792	1874	1946	1997	2028	37	1.8%
Rackspace	2632	3901	4055	4157	4250	130	6.3%
Verizon	764	825	842	852	859	9	0.4%

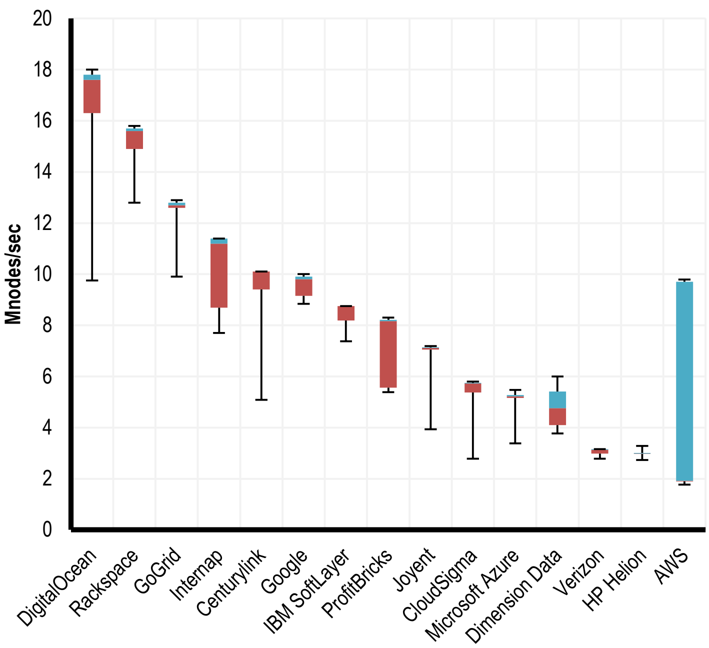
CPU Integer – Dijkstra: The Dijkstra workload computes driving directions between a sequence of destinations. Similar techniques are used by AIs to compute paths in games and by network routers to route computer network traffic.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1.32	1.34	1.41	7.57	7.81	1.80	29.5%
CenturyLink	5.22	7.49	8.00	8.22	8.32	0.14	2.3%
CloudSigma	1.76	3.44	4.07	4.18	4.23	0.18	2.9%
DigitalOcean	7.42	11.40	12.00	12.70	13.20	0.33	5.4%
Dimension Data	3.43	3.68	4.28	4.75	5.22	0.32	5.2%
GoGrid	10.90	11.00	11.20	11.30	11.40	0.00	0.0%
Google	3.12	6.16	6.38	6.49	6.60	0.12	2.0%
HP Helion	1.80	1.91	2.04	2.18	2.32	0.08	1.3%
IBM SoftLayer	6.01	6.07	6.13	6.19	6.22	0.00	0.0%
Internap	5.57	6.07	7.86	8.76	9.16	0.84	13.7%
Joyent	3.11	4.91	5.07	5.17	5.28	0.15	2.5%
Microsoft Azure	3.75	5.04	5.14	5.25	5.37	0.05	0.8%
ProfitBricks	5.74	6.03	6.11	6.17	6.21	0.00	0.0%
Rackspace	9.91	12.30	12.90	13.50	13.90	0.36	5.9%
Verizon	2.73	2.75	2.77	2.79	2.80	0.00	0.0%

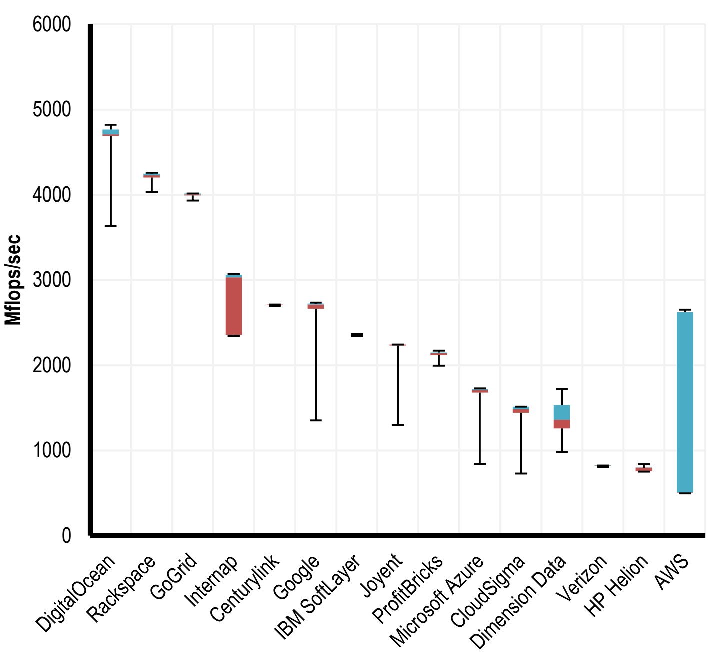
--- End of CPU Integer Results ---

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.



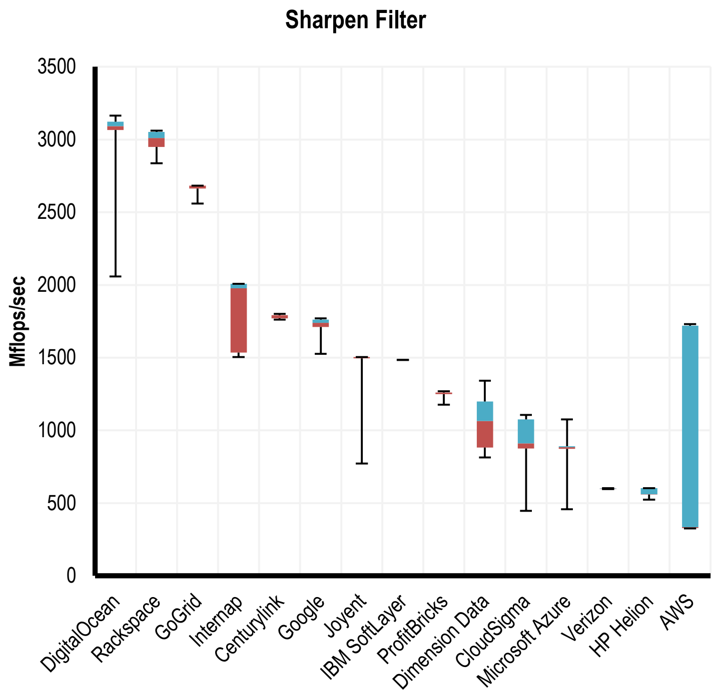
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	1.77	1.89	1.92	9.70	9.79	1.68	20.6%
CenturyLink	5.09	9.41	10.10	10.10	10.10	0.20	2.5%
CloudSigma	2.79	5.38	5.72	5.75	5.80	0.10	1.2%
DigitalOcean	9.75	16.30	17.60	17.80	18.00	0.51	6.3%
Dimension Data	3.77	4.09	4.76	5.41	6.00	0.32	3.9%
GoGrid	9.90	12.60	12.70	12.80	12.90	0.12	1.5%
Google	8.84	9.16	9.81	9.90	10.00	0.18	2.2%
HP Helion	2.73	2.97	2.99	3.01	3.29	0.04	0.5%
IBM SoftLayer	7.38	8.19	8.75	8.75	8.76	0.08	1.0%
Internap	7.70	8.69	11.20	11.40	11.40	1.10	13.5%
Joyent	3.93	7.05	7.11	7.14	7.19	0.21	2.6%
Microsoft Azure	3.38	5.16	5.23	5.27	5.48	0.10	1.2%
ProfitBricks	5.39	5.56	8.16	8.21	8.30	0.63	7.7%
Rackspace	12.80	14.90	15.60	15.70	15.80	0.15	1.8%
Verizon	2.79	2.99	3.14	3.16	3.16	0.03	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.



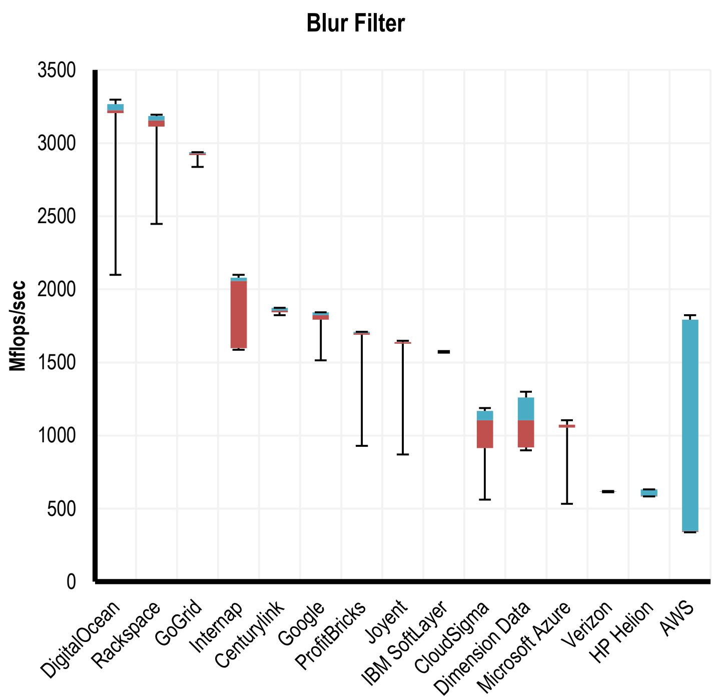
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	499	500	507	2621	2652	684	30.5%
CenturyLink	2693	2703	2714	2714	2714	3	0.1%
CloudSigma	729	1444	1485	1516	1516	36	1.6%
DigitalOcean	3635	4690	4710	4767	4823	59	2.6%
Dimension Data	981	1260	1362	1532	1720	84	3.7%
GoGrid	3932	3994	4004	4014	4014	9	0.4%
Google	1352	2662	2714	2724	2734	55	2.5%
HP Helion	753	757	796	799	840	17	0.8%
IBM SoftLayer	2345	2365	2365	2365	2365	1	0.0%
Internap	2345	2355	3031	3062	3072	327	14.6%
Joyent	1300	2232	2243	2243	2243	63	2.8%
Microsoft Azure	843	1679	1710	1720	1731	52	2.3%
ProfitBricks	1997	2120	2140	2150	2171	14	0.6%
Rackspace	4035	4204	4229	4250	4260	19	0.8%
Verizon	807	818	820	822	823	1	0.0%

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



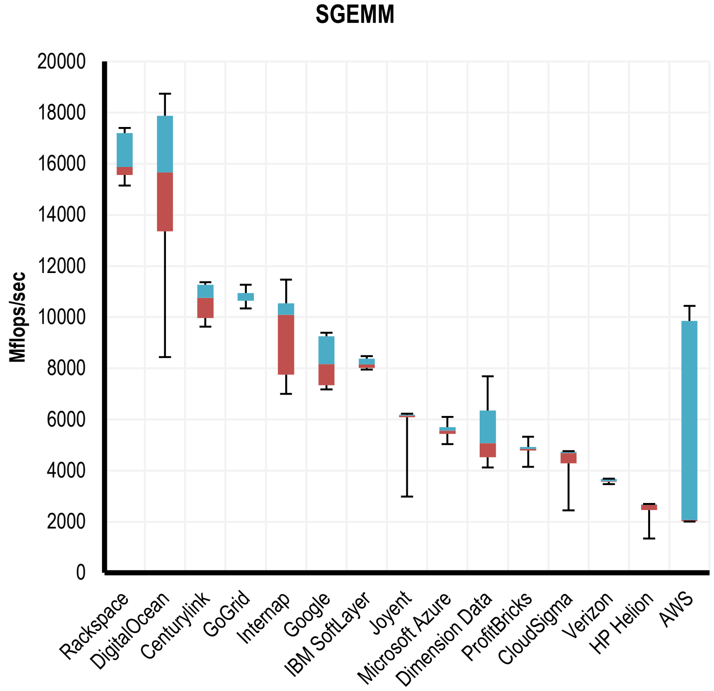
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	327	328	334	1720	1731	447	30.1%
CenturyLink	1761	1772	1792	1792	1802	6	0.4%
CloudSigma	446	876	910	1075	1106	72	4.8%
DigitalOcean	2058	3066	3092	3123	3164	47	3.2%
Dimension Data	815	883	1065	1198	1341	105	7.1%
GoGrid	2560	2662	2683	2683	2683	10	0.7%
5Google	1526	1710	1741	1761	1772	16	1.1%
HP Helion	523	558	562	603	604	17	1.1%
IBM SoftLayer	1485	1485	1485	1485	1485	0	0.0%
Internap	1505	1536	1976	2007	2007	213	14.3%
Joyent	772	1495	1505	1505	1505	64	4.3%
Microsoft Azure	459	873	885	890	1075	27	1.8%
ProfitBricks	1178	1249	1260	1260	1270	8	0.5%
Rackspace	2836	2949	3011	3052	3062	30	2.0%
Verizon	596	597	599	601	602	1	0.1%

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.



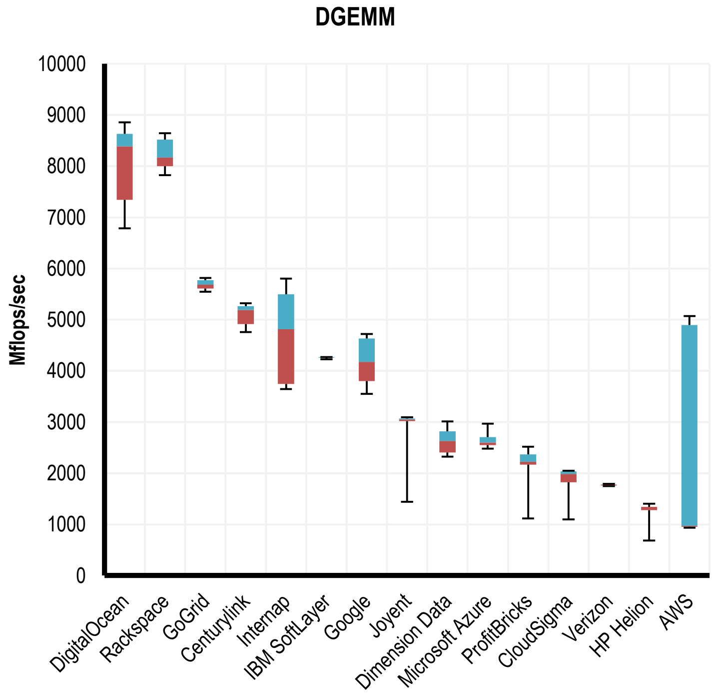
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	338	341	347	1792	1823	467	28.5%
CenturyLink	1823	1843	1853	1874	1874	8	0.5%
CloudSigma	562	914	1106	1167	1188	89	5.4%
DigitalOcean	2099	3205	3226	3267	3297	69	4.2%
Dimension Data	899	920	1106	1260	1300	109	6.7%
GoGrid	2836	2918	2929	2939	2939	10	0.6%
Google	1516	1792	1823	1843	1843	18	1.1%
HP Helion	583	584	588	631	632	16	1.0%
IBM SoftLayer	1567	1577	1577	1577	1577	0	0.0%
Internap	1587	1597	2058	2079	2099	218	13.3%
Joyent	870	1628	1638	1638	1649	63	3.8%
Microsoft Azure	533	1055	1075	1075	1106	31	1.9%
ProfitBricks	929	1690	1700	1710	1710	36	2.2%
Rackspace	2447	3113	3154	3185	3195	39	2.4%
Verizon	611	615	617	619	620	1	0.1%

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.



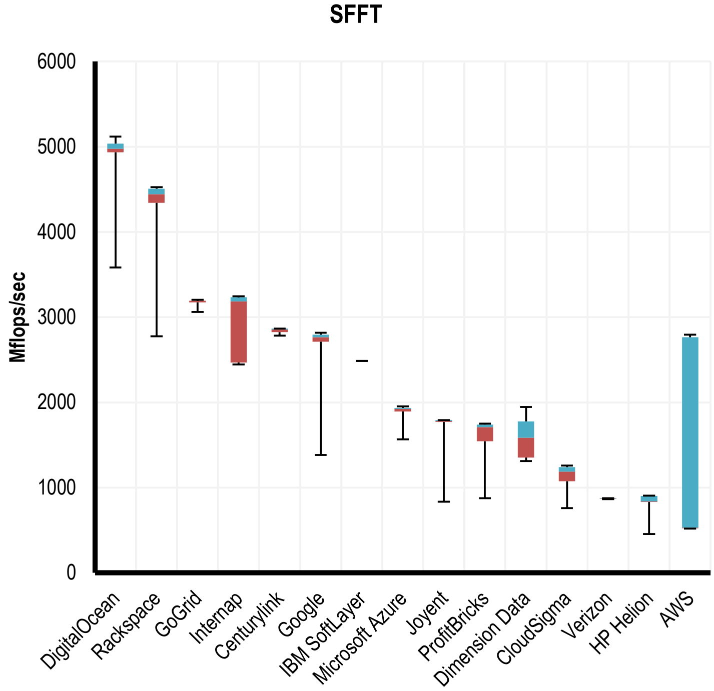
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	2007	2017	2068	9854	10445	2519	40.9%
CenturyLink	9626	9964	10752	11264	11366	336	5.5%
CloudSigma	2447	4289	4690	4741	4762	179	2.9%
DigitalOcean	8438	13358	15667	17874	18739	1691	27.5%
Dimension Data	4127	4520	5079	6349	7690	576	9.4%
GoGrid	10342	10650	10650	10947	11264	126	2.0%
Google	7178	7342	8161	9257	9390	638	10.4%
HP Helion	1341	2458	2662	2683	2693	138	2.2%
IBM SoftLayer	7956	8018	8151	8376	8479	110	1.8%
Internap	7004	7749	10092	10547	11469	1144	18.6%
Joyent	2990	6083	6154	6185	6226	262	4.3%
Microsoft Azure	5038	5437	5560	5704	6103	109	1.8%
ProfitBricks	4147	4792	4854	4925	5325	77	1.3%
Rackspace	15155	15565	15872	17203	17408	506	8.2%
Verizon	3471	3564	3584	3676	3686	42	0.7%

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.



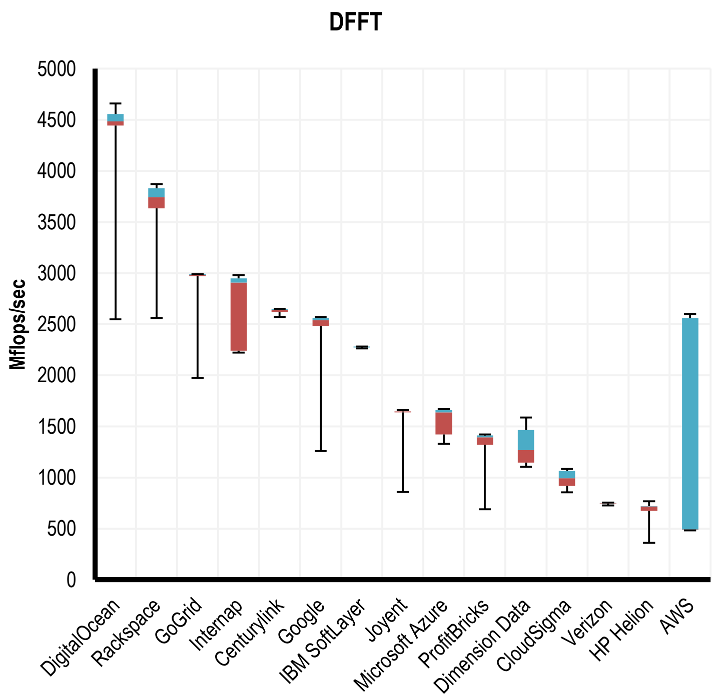
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	935	953	971	4897	5069	1247	40.9%
CenturyLink	4762	4915	5192	5263	5325	95	3.1%
CloudSigma	1096	1823	1987	2038	2048	78	2.6%
DigitalOcean	6789	7342	8387	8632	8858	386	12.6%
Dimension Data	2324	2406	2632	2816	3011	128	4.2%
GoGrid	5550	5612	5683	5774	5816	47	1.5%
Google	3553	3799	4178	4633	4721	256	8.4%
HP Helion	684	1280	1341	1341	1403	59	1.9%
IBM SoftLayer	4229	4260	4260	4270	4270	3	0.1%
Internap	3645	3747	4813	5499	5806	562	18.4%
Joyent	1444	3021	3052	3072	3092	137	4.5%
Microsoft Azure	2478	2553	2601	2703	2970	59	1.9%
ProfitBricks	1116	2171	2222	2366	2519	80	2.6%
Rackspace	7823	7997	8172	8520	8643	153	5.0%
Verizon	1751	1761	1772	1782	1792	8	0.3%

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.



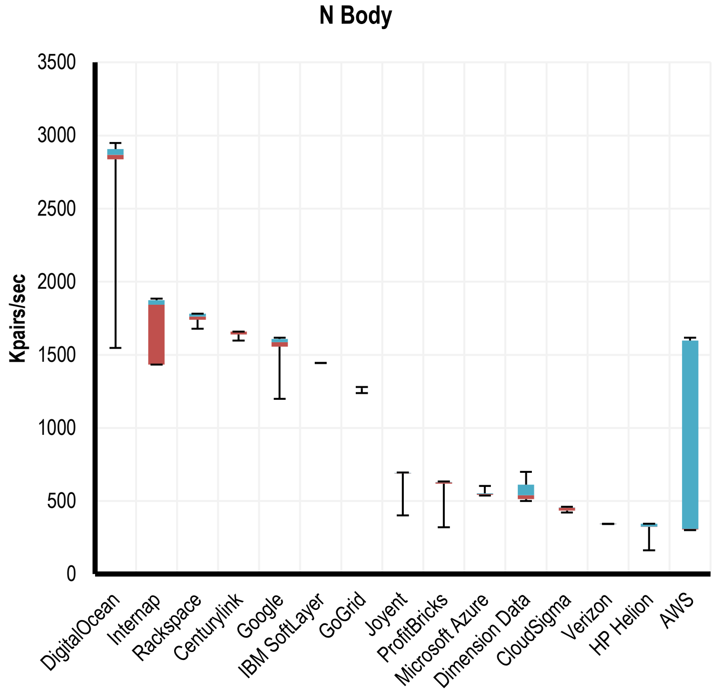
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	521	525	532	2765	2796	706	36.7%
CenturyLink	2785	2826	2857	2867	2867	12	0.6%
CloudSigma	760	1075	1188	1239	1260	57	3.0%
DigitalOcean	3584	4936	4977	5038	5120	71	3.7%
Dimension Data	1311	1352	1587	1778	1946	150	7.8%
GoGrid	3062	3174	3195	3195	3205	12	0.6%
Google	1382	2714	2765	2796	2816	59	3.1%
HP Helion	458	832	838	902	907	35	1.8%
IBM SoftLayer	2488	2488	2488	2488	2488	0	0.0%
Internap	2447	2468	3185	3236	3246	347	18.0%
Joyent	836	1772	1782	1792	1792	87	4.5%
Microsoft Azure	1567	1894	1925	1935	1956	23	1.2%
ProfitBricks	875	1546	1710	1741	1751	70	3.6%
Rackspace	2775	4342	4444	4506	4526	104	5.4%
Verizon	866	870	873	875	878	1	0.1%

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.



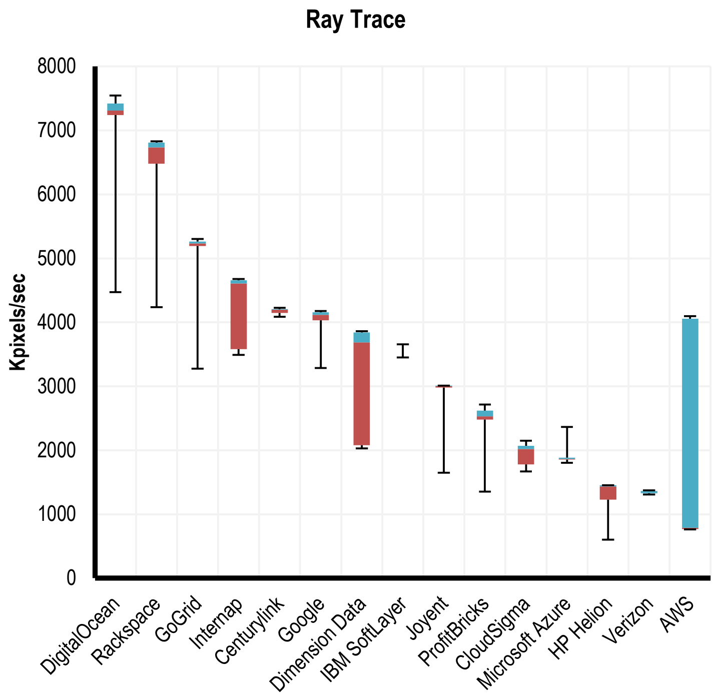
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	483	487	494	2561	2601	655	39.7%
CenturyLink	2570	2621	2642	2652	2652	11	0.7%
CloudSigma	856	918	995	1065	1085	44	2.7%
DigitalOcean	2550	4444	4485	4557	4659	113	6.9%
Dimension Data	1106	1147	1270	1464	1587	119	7.2%
GoGrid	1976	2970	2980	2990	2990	39	2.4%
Google	1260	2484	2540	2560	2570	54	3.3%
HP Helion	360	674	717	721	768	32	1.9%
IBM SoftLayer	2263	2273	2273	2284	2284	2	0.1%
Internap	2222	2243	2908	2949	2980	317	19.2%
Joyent	859	1638	1649	1649	1659	60	3.6%
Microsoft Azure	1331	1423	1638	1659	1669	70	4.2%
ProfitBricks	688	1320	1393	1413	1423	41	2.5%
Rackspace	2560	3635	3743	3830	3871	73	4.4%
Verizon	729	747	748	752	755	2	0.1%

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	301	305	309	1597	1618	409	59.2%
CenturyLink	1597	1638	1659	1659	1659	7	1.0%
CloudSigma	422	434	454	456	461	7	1.0%
DigitalOcean	1546	2836	2867	2908	2949	81	11.7%
Dimension Data	499	513	540	612	700	31	4.5%
GoGrid	1239	1270	1270	1270	1280	3	0.4%
Google	1198	1556	1587	1608	1618	22	3.2%
HP Helion	163	324	326	344	344	16	2.3%
IBM SoftLayer	1444	1444	1444	1444	1444	0	0.0%
Internap	1434	1434	1843	1874	1884	113	16.4%
Joyent	401	688	691	693	695	22	3.2%
Microsoft Azure	537	542	550	553	603	4	0.6%
ProfitBricks	320	618	627	631	634	0	0.0%
Rackspace	1679	1741	1761	1782	1782	12	1.7%
Verizon	342	343	343	344	345	0	0.0%

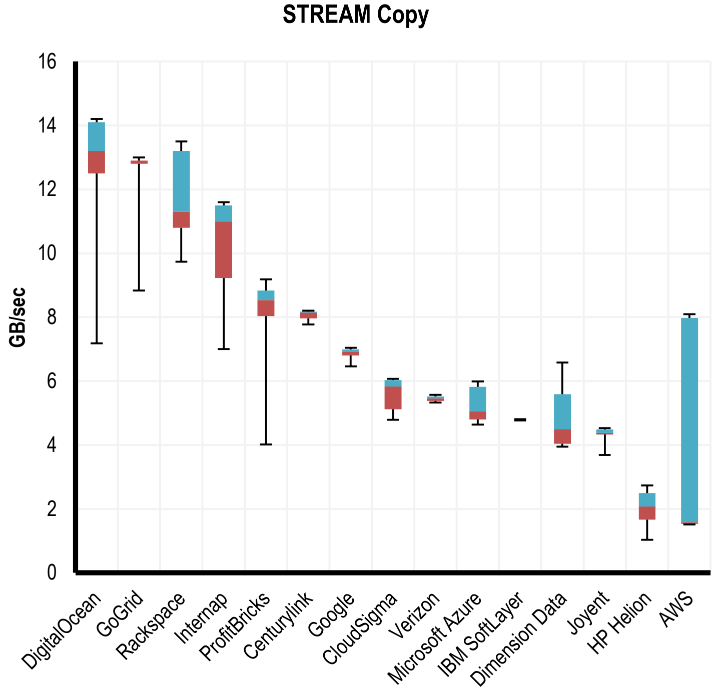
CPU Floating Points – Ray Trace: The ray trace workload renders a 3D scene from a geometric description.



	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	765	770	786	4056	4096	1038	28.6%
CenturyLink	4086	4147	4198	4209	4229	20	0.6%
CloudSigma	1669	1782	2017	2068	2150	101	2.8%
DigitalOcean	4475	7240	7311	7424	7547	156	4.3%
Dimension Data	2028	2079	3686	3840	3860	748	20.6%
GoGrid	3277	5192	5233	5263	5304	83	2.3%
Google	3287	4035	4116	4157	4178	56	1.5%
HP Helion	602	1229	1434	1454	1454	119	3.3%
IBM SoftLayer	3451	3625	3625	3625	3656	15	0.4%
Internap	3492	3584	4608	4659	4680	451	12.4%
Joyent	1649	2980	3000	3011	3011	107	3.0%
Microsoft Azure	1802	1853	1864	1884	2365	30	0.8%
ProfitBricks	1352	2478	2529	2621	2714	41	1.1%
Rackspace	4239	6482	6738	6810	6830	272	7.5%
Verizon	1311	1331	1331	1362	1372	0	0.0%

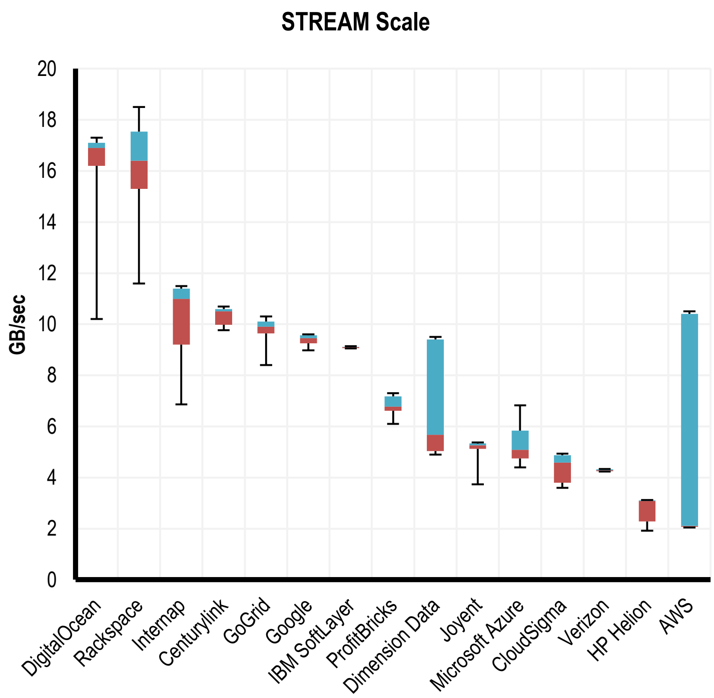
--- End of Floating Point Results ---

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.



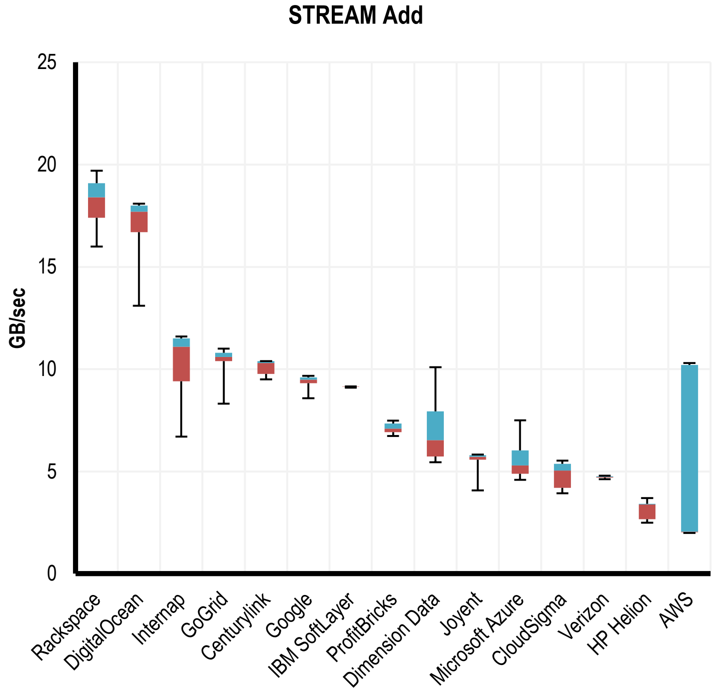
	Min	5th Per.	Median	95th Per.	Max	Stdev.	Variability
AWS	1.52	1.54	1.59	7.97	8.09	1.66	28.5%
CenturyLink	7.77	7.96	8.14	8.17	8.20	0.00	0.0%
CloudSigma	4.79	5.12	5.83	6.03	6.07	0.25	4.3%
DigitalOcean	7.18	12.50	13.20	14.10	14.20	0.52	8.9%
Dimension Data	3.95	4.04	4.50	5.60	6.58	0.44	7.5%
GoGrid	8.84	12.80	12.90	12.90	13.00	0.12	2.1%
Google	6.46	6.80	6.92	6.99	7.04	0.00	0.0%
HP Helion	1.04	1.67	2.08	2.50	2.74	0.28	4.8%
IBM SoftLayer	4.77	4.80	4.80	4.80	4.81	0.00	0.0%
Internap	7.00	9.22	11.00	11.50	11.60	0.90	15.4%
Joyent	3.69	4.33	4.38	4.49	4.53	0.08	1.4%
Microsoft Azure	4.64	4.80	5.06	5.82	5.99	0.25	4.3%
ProfitBricks	4.02	8.03	8.54	8.84	9.19	0.24	4.1%
Rackspace	9.74	10.80	11.30	13.20	13.50	0.66	11.3%
Verizon	5.33	5.38	5.46	5.52	5.57	0.27	4.6%

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



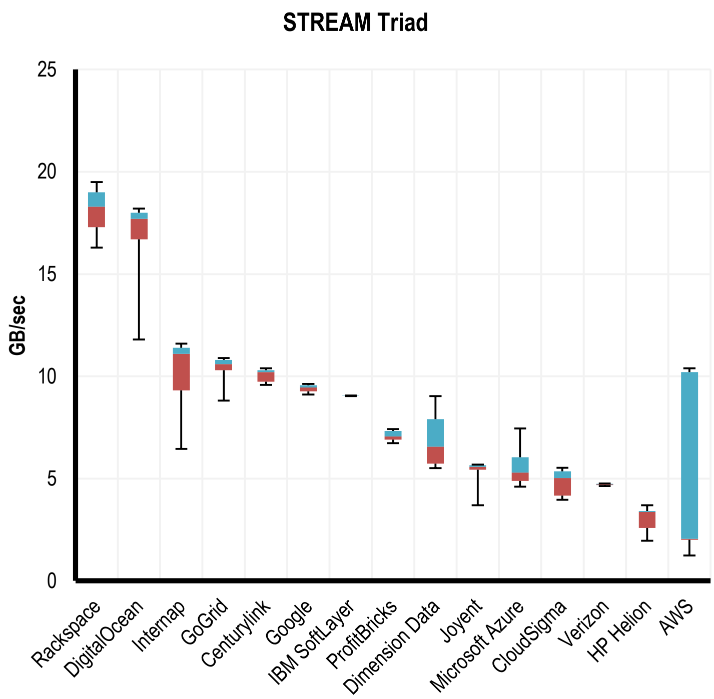
	Min.	5th Per.	Median	95th Per.	Max.	Stdev.	Variability
AWS	2.05	2.07	2.11	10.40	10.50	2.46	36.3%
CenturyLink	9.77	9.98	10.50	10.60	10.70	0.20	2.9%
CloudSigma	3.60	3.80	4.59	4.88	4.94	0.36	5.3%
DigitalOcean	10.20	16.20	16.90	17.10	17.30	0.32	4.7%
Dimension Data	4.90	5.03	5.67	9.41	9.50	1.26	18.6%
GoGrid	8.40	9.64	9.90	10.10	10.30	0.09	1.3%
Google	8.98	9.26	9.46	9.57	9.61	0.00	0.0%
HP Helion	1.92	2.28	3.08	3.11	3.12	0.20	2.9%
IBM SoftLayer	9.05	9.07	9.10	9.12	9.14	0.00	0.0%
Internap	6.86	9.21	11.00	11.40	11.50	0.90	13.3%
Joyent	3.74	5.13	5.26	5.34	5.37	0.10	1.5%
Microsoft Azure	4.40	4.75	5.09	5.84	6.83	0.30	4.4%
ProfitBricks	6.10	6.62	6.78	7.18	7.30	0.12	1.8%
Rackspace	11.60	15.30	16.40	17.55	18.50	0.64	9.4%
Verizon	4.24	4.25	4.29	4.32	4.34	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	1.99	2.02	2.06	10.20	10.30	2.46	34.7%
CenturyLink	9.51	9.77	10.30	10.40	10.40	0.10	1.4%
CloudSigma	3.93	4.20	5.05	5.38	5.53	0.36	5.1%
DigitalOcean	13.10	16.70	17.70	18.00	18.10	0.51	7.2%
Dimension Data	5.45	5.74	6.53	7.94	10.10	0.60	8.5%
GoGrid	8.32	10.40	10.60	10.80	11.00	0.10	1.4%
Google	8.58	9.31	9.49	9.60	9.68	0.09	1.3%
HP Helion	2.50	2.67	3.38	3.42	3.70	0.21	3.0%
IBM SoftLayer	9.10	9.14	9.15	9.15	9.16	0.00	0.0%
Internap	6.71	9.41	11.10	11.50	11.60	0.80	11.3%
Joyent	4.08	5.57	5.71	5.79	5.83	0.15	2.1%
Microsoft Azure	4.59	4.89	5.29	6.02	7.50	0.30	4.2%
ProfitBricks	6.74	6.92	7.09	7.35	7.48	0.07	1.0%
Rackspace	16.00	17.40	18.40	19.10	19.70	0.36	5.1%
Verizon	4.62	4.70	4.73	4.76	4.80	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	1.24	2.01	2.05	10.20	10.40	2.49	35.2%
CenturyLink	9.58	9.74	10.20	10.30	10.40	0.10	1.4%
CloudSigma	3.96	4.17	5.03	5.36	5.53	0.36	5.1%
DigitalOcean	11.80	16.70	17.70	18.00	18.20	0.51	7.2%
Dimension Data	5.52	5.74	6.56	7.91	9.04	0.60	8.5%
GoGrid	8.82	10.30	10.60	10.80	10.90	0.10	1.4%
Google	9.11	9.27	9.45	9.56	9.63	0.00	0.0%
HP Helion	1.97	2.59	3.37	3.41	3.70	0.30	4.2%
IBM SoftLayer	9.04	9.06	9.06	9.07	9.07	0.00	0.0%
Internap	6.46	9.32	11.10	11.40	11.60	0.80	11.3%
Joyent	3.70	5.44	5.57	5.66	5.69	0.15	2.1%
Microsoft Azure	4.60	4.88	5.29	6.05	7.46	0.35	5.0%
ProfitBricks	6.73	6.91	7.07	7.33	7.42	0.07	1.0%
Rackspace	16.30	17.30	18.30	19.00	19.50	0.36	5.1%
Verizon	4.63	4.68	4.72	4.75	4.77	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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