June 2018 Edition

2018 TOP 10
European Cloud Providers

EUROPE REPORT
Price-Performance Analysis of the Top 10 Public IaaS Vendors

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EXECUTIVE SUMMARY

This report examines the results of a study measuring and comparing Cloud compute and storage performance along with the price-performance (the ratio of Cloud service performance per Euro spent) of 10 Cloud Service Providers (CSPs) within the greater European region. While the CSPs included in the study did not have to be headquartered in Europe, they must have at least one data center located within the European continent (see Methodology page 11).

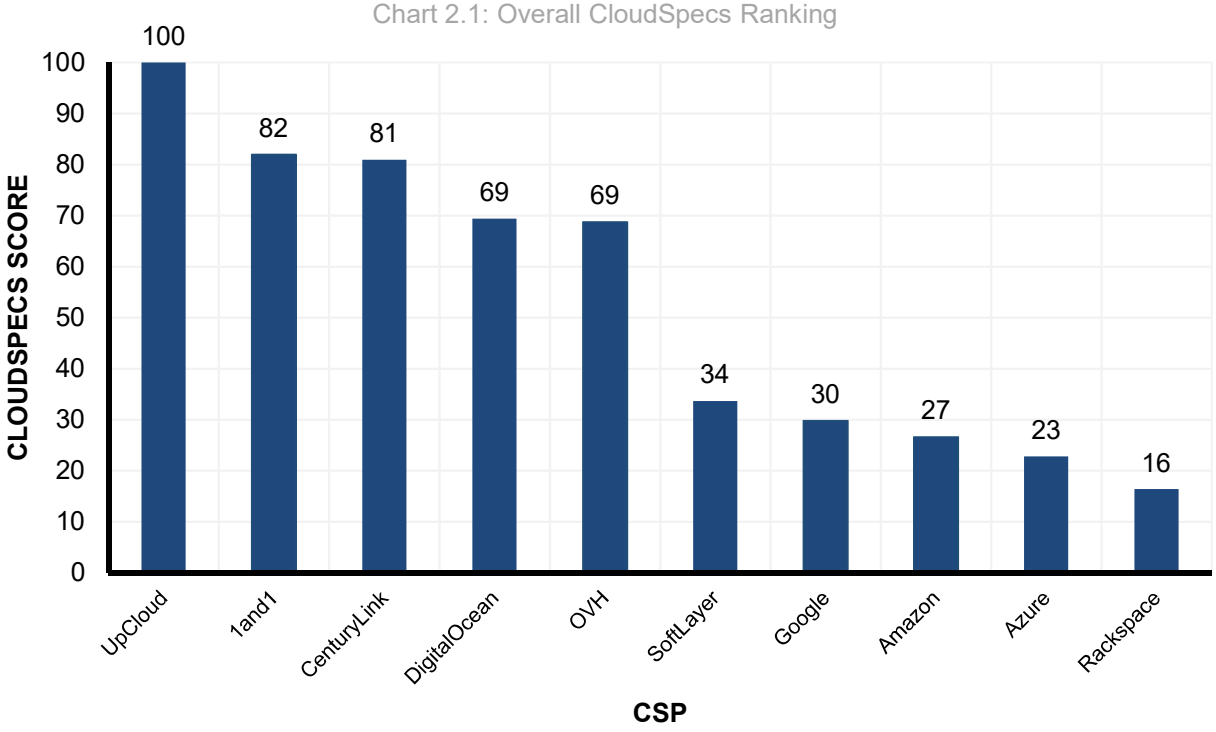
This analysis includes major Cloud providers such as Amazon AWS, Google Compute Engine, Microsoft Azure and IBM SoftLayer. In addition, smaller CSPs, which specialize in either high performance and/or aggressive pricing discounts, were also included in order to cover a wide range of public clouds that cater to various business and consumer profiles.

The performance results are separated into two categories: Virtual machine (VM) Performance and Block Storage Performance. VM Performance tests the CPU and Memory of a virtual machine. This performance data is aggregated into a single score that includes both CPU and memory. Block storage is evaluated using two different tests as detailed in the methodology section (page 11).

PRICE-PERFORMANCE KEY FINDINGS

The chart below displays the overall price-performance scores of the providers included in this report. Price and performance of the VM compute and storage are incorporated into the values.

Chart 2.1: Overall CloudSpecs Ranking



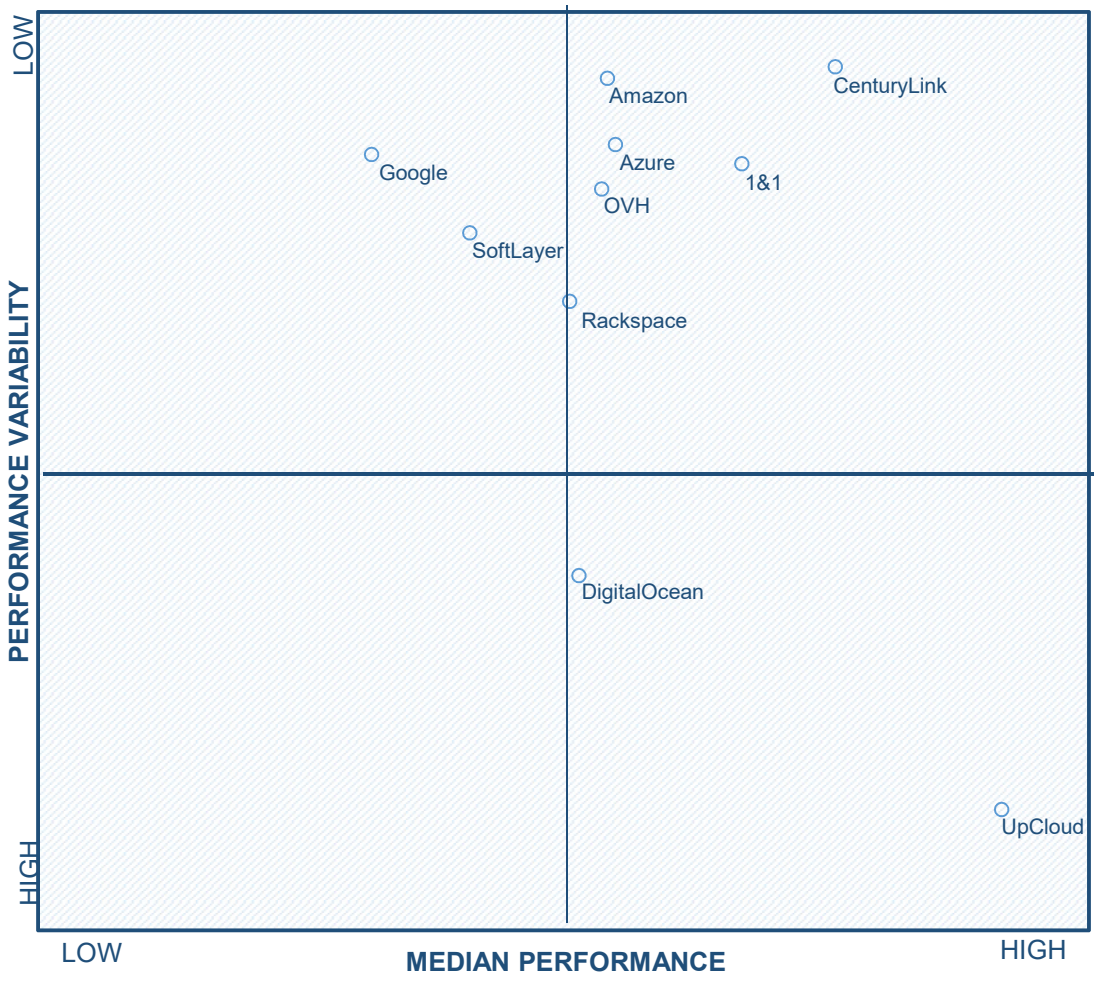
- Value, defined as the ratio of price and performance (see Methodology page 16) varies by 6.3x across the compared IaaS providers.
- **UpCloud** achieves the highest CloudSpecs Score™ in the Top 10 cloud IaaS providers ranking. **1&1**, and **CenturyLink** follow closely behind due to higher prices, or lower performance compared to UpCloud.
- **OVH** and **Digital Ocean** represent the tail end of the higher value clouds (value meaning better performance per Euro spent) as illustrated in chart 2.1. After these five CSPs, there is a significant drop in Cloud service value. It is important to note that, while the larger clouds tend to offer lower price-performance, this is not the only factor to consider when choosing a cloud service provider.

- While certain providers, such as **IBM SoftLayer**, **GCE**, **AWS**, **Rackspace**, and **Microsoft Azure** tend to lag behind in price-performance, these providers generally offer the most consistent performance, which will be highlighted later in this report.

VM PERFORMANCE KEY FINDINGS

Figure 2.2 below displays the median VM Compute and Memory performance and performance variability captured across the VMs tested on each of the providers included in the study. The ideal cloud service provides high median performance and low variability, which would place them in the (upper right quadrant of chart 2.2). Most providers offered relatively low compute variability while offering average to high compute performance. This is why it is critical to use a holistic view of not only Cloud performance and pricing, but performance variability, or service consistency. Some workloads may benefit from service performance that can burst similar to AWS EBS machines, while others require very consistent service performance. Because of this there's not necessarily a winner here, but there are a few providers that stand out.

Chart 2.2: VM Performance and Variability Over 24 Hours



- **CenturyLink** displayed the highest CPU and Memory performance while displaying the least amount of variability (less variability means more consistent).

- **Amazon**, **Azure**, **1&1**, **SoftLayer**, and **OVH** offer slightly lower compute performance but are just as consistent as Century Link.

- **UpCloud** displayed the highest CPU and Memory performance overall, but also displayed the most variability (least consistent performance) for CPU and Memory.

- **Rackspace and Digital Ocean** offered similar performance to each other, however Rackspace tended to be more consistent than Digital Ocean for CPU and Memory performance.

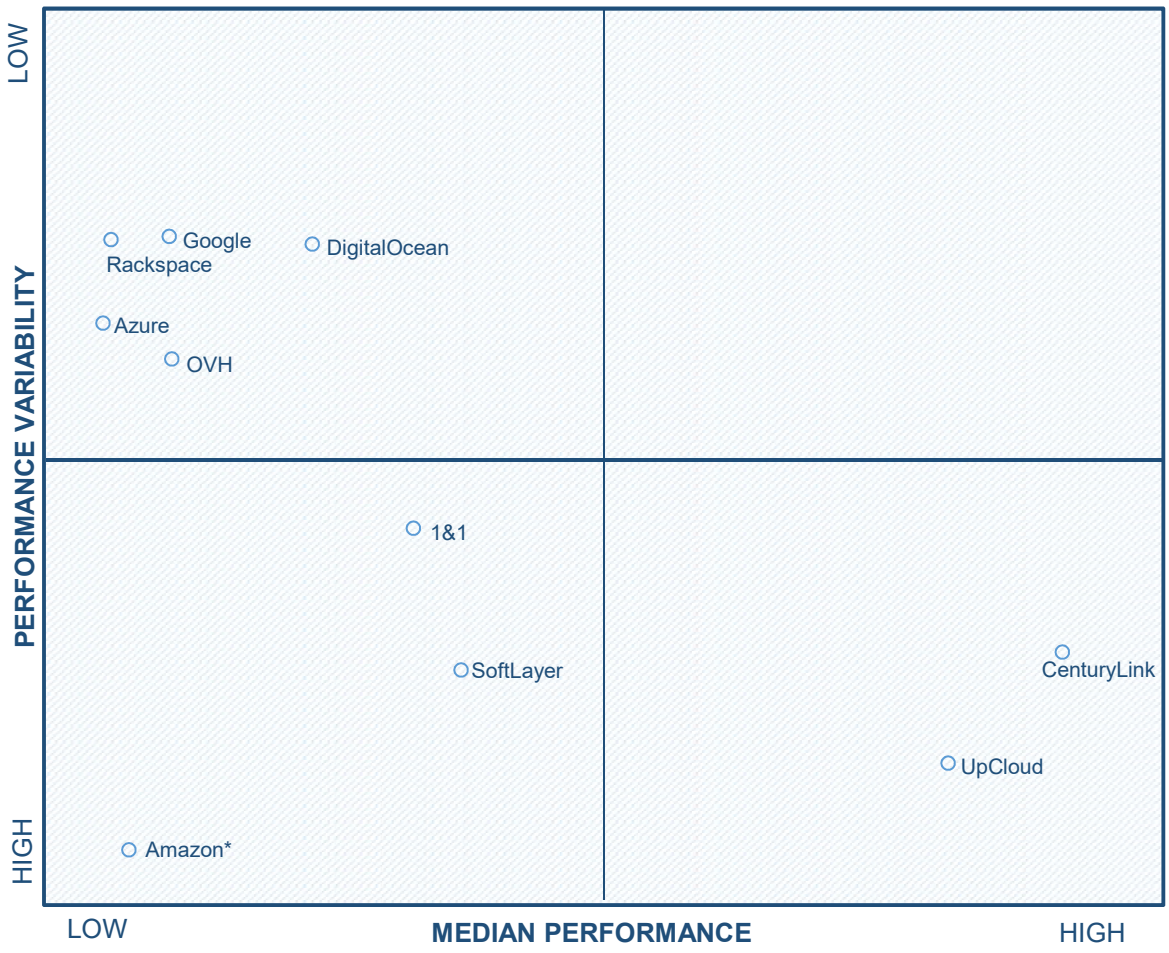
- **Google offered the lowest CPU and Memory performance** out of the pack but is just as consistent as the leading providers in the chart above.

BLOCK STORAGE PERFORMANCE KEY FINDINGS

Chart 2.3 below displays the median performance and performance variability captured across the Type 1 & 2 storage testing on the providers included in the study.

The ideal cloud block storage service provides high median performance and low variability, which would place that provider in the upper right quadrant of Chart 2.3. As the chart shows, there is no "ideal" provider when it comes to block storage, at least as of this analysis. This is because it is extremely difficult to create a single storage service that will satisfy every application or use case requirement. (For details on storage volumes tested, see Appendix).

Chart 2.3: Block Storage Performance and Variability Over 24 Hours



*Amazon's disk variability is artificially high due to an initial burst period that lasted until the volume ran out of I/O credits.

Key observations from the block storage test results are highlighted below:

- **None of the providers in this report offered high performance, highly consistent block storage,** at least as a default storage option**.** This is not surprising, as it is difficult to provide a high-performance and consistent block storage at a reasonable price point. This is why providers offer multiple tiers of block storage, along with VM types that focus specifically on high performance or high capacity storage.

- **CenturyLink** displayed the **highest** block storage performance, but also displayed a large amount of performance variability. This may not be an issue if the primary requirements focus on outright performance and less so on storage performance consistency.

- **UpCloud** displayed the **second highest** Block Storage performance, but also exhibited the most performance variability (excluding AWS EBS Burst). Again, this is not necessarily bad for all workloads. If consistency matters for particular business or application requirements, then an alternative storage service from the same or other providers may satisfy those needs.

- **Google, Rackspace, Microsoft Azure, and Digital Ocean** offered **the most consistent** block storage performance, but also tended to exhibit the slowest performance of the block storage services.

- **Amazon's block storage displayed low, but consistent performance,** even when including Amazon's burstable EBS benchmark results. AWS tends to cause performance data skew when compared to other providers due to the fact that EBS initially bursts up in performance, then eventually drops down to an extremely consistent level. If the AWS burst performance was eliminated from the sample, the EBS burst results would be very comparable to Google, Rackspace and Digital Ocean. The cloud can be inherently noisy, and not all providers offer burstable storage. Therefore, Cloud Spectator chose to include the AWS burst performance in the variability test data to be fair to all other providers.

Table 2.1 below lists the indexed performance scores and variability percentages by provider. Higher Performance Index values are better, while lower variability percentages are better. These numbers are used in generating Charts 2.2 and 2.3.

Table 2.1: Performance and Variability of CSPs Over 24 Hours

	VM (CPU and Mem)		Block Storage	
	Performance Index	Variability	Performance Index	Variability
1and1	80	1%	30	16%
Amazon	73	1%	7	32%*
Azure	73	1%	5	6%
CenturyLink	86	1%	82	22%
Digital Ocean	71	6%	22	2%
UpCloud	95	8%	73	28%
Google	59	1%	10	1%
OVH	72	2%	10	8%
Rackspace	70	3%	5	2%
SoftLayer	65	2%	34	23%

*Amazon's disk variability is artificially high due to an initial burst period that lasted until the volume ran out of I/O credits.

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

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

INTRODUCTION

Many public cloud service providers (CSPs) purport to offer lightning fast, instantaneous, scalable virtual infrastructure with on-demand, pay as you go billing, all at a low cost. In reality there is wide variance in CSP cloud performance as well as pricing and features.

With the rapid growth in the Cloud computing industry, CSPs have rapidly innovated their Cloud services offerings with new configurations, new pricing models, and other methods of differentiating their Cloud services from the competition. Pricing comparisons can often be challenging between CSPs, as the sizing and performance of equivalent VM and storage configurations and pricing models is not standardized across the industry. Furthermore, maintaining some degree of price and performance opacity is in a CSP's competitive interests, generally speaking. With respect to Cloud service performance, there is wide variability across CSPs and their respective Cloud service offerings. For example, a particular VM configuration might have a low price, but also low performance, which means more of those VMs might be required to support a particular workload. A competitor CSP may have a similar VM configuration with much better performance, meaning that fewer machines could support the target workload, ultimately reducing costs. Therefore, it is important to compare the VM configuration specifications, as well as pricing and performance data to make a truly informed purchasing decision for Cloud services.

Cloud Spectator tested 10 of the largest public cloud service providers (CSPs) with data centers in Europe. This report measures and ranks CSPs using a comprehensive performance and price-performance methodology designed by Cloud Spectator specifically for the purpose of measuring IaaS performance. This report examines the performance of vCPU, memory and block storage, as

well as the overall value (the CloudSpecs™ Score) which incorporates pricing and performance from each provider to establish an overall measure of Cloud service performance and value, or price-performance metrics.

In conjunction with an appropriate cloud vendor selection process, this report will assist purchasing decisions by assessing performance and price-performance from a holistic industry perspective. The report is specifically designed to educate Information Technology (IT) leadership on the variation in performance and price-performance value across public cloud providers, and thereby facilitate better decision making when selecting CSPs and their respective Cloud services for inclusion in their Cloud portfolio. Performance is a critical and often overlooked component when making a cloud purchasing decision, as it can substantially impact annual operating costs. Cloud price and price-performance analytics are essential when planning your Cloud service providers and the associated portfolio of Cloud services in support of a Cloud computing strategy.

WHY IS THIS STANDARDIZED PERFORMANCE INFORMATION NECESSARY?

A lack of price and performance transparency in the public cloud IaaS marketplace makes meaningful comparisons of CSPs, as well as specific Cloud services, difficult. With the volatility of Cloud pricing strategies, combined with the rapid evolution of Cloud service offerings, VM configurations, and Cloud storage options, the variety and choice of Cloud services is dizzying. Comparing specific Cloud services by CPU counts, Random Access Memory (RAM) and storage capacity, and then by pricing options, is a common method for comparing Cloud services from various CSPs. However, there are many other factors that contribute to “value” of Cloud services, such that comparisons solely based on public specifications and pricing can often be misleading. Cloud performance is rarely used in the

decision calculus during purchasing activities. However, Cloud performance is an important consideration.

A variety of factors such as the physical hardware (e.g., Intel or AMD, SSD or spinning disk), hypervisor (Xen, KVM, VMware, etc.), and density levels (multi-tenant, single tenant, somewhere in between) can greatly affect VM performance, which ultimately can affect application performance. By evaluating cloud services based on performance and price, rather than solely price or VM configurations, Cloud consumers will be better able to optimize their overall Cloud service portfolio, reduce their Cloud computing spend, and optimizing performance by "right-sizing" workloads and running them on the appropriate cloud services.

MISCONCEPTIONS ABOUT CLOUD PERFORMANCE

A number of common misconceptions about performance of cloud-based servers continue to persist. Some of the key Cloud performance myths are examined below:

1. VM performance is the same from CSP to CSP.

While CSPs often use the same terms to describe cloud services (e.g., vCPUs, RAM or memory, and block storage), differences in the underlying hardware, architecture, virtualization technology and performance tuning lead can dramatically change the actual performance between two VMs with seemingly the exact same specifications. For example, the 10 IaaS providers in this report exhibited smaller differences between each other when it came to CPU and Memory performance compared to block storage performance, while differences were much more pronounced between VM sizes and CSPs.

2. There is a correlation between price and performance.

When it comes to additional services such as support, security, geographical location, and managed services on CSPs, you get what you pay for. However, with respect to performance, this study found no correlation between price and performance. The study demonstrated the best-value CSPs in this report (defined as the ratio of price and performance as ranked by the CloudSpecs Score™) offer Cloud services at the lowest prices. VMs within the 10 IaaS providers tested displayed a large range of prices between the least and most expensive CSPs.

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

Almost all CSPs place multiple tenants on a single physical host, which means a VM may share (and therefore compete) for the same physical resources that other VMs are using. This means that another VM running resource-intensive workloads could potentially affect the performance of other VMs on the host machine. While resource contention is constantly being addressed by many of the largest providers in an attempt to stabilize VM CPU and Memory performance, block storage offerings still exhibit either high performance and high levels of performance fluctuations, or low performance and low performance fluctuations. Many CSPs are adding new types of block storage that serve specific workloads and use cases.

3a. Dampening the noisy neighbor.

Some CSPs, especially major ones such as Google, Microsoft Azure, and Amazon Web Services, use performance throttling to deliver a consistent user experience. This means that, while performance may be lower for a particular VM configuration the consistency of that performance will be much higher than a Cloud service with limited or no throttling of resources.

METHODOLOGY

Cloud Spectator is a pioneer in Cloud performance testing. The methodology presented in this section was specifically developed by Cloud Spectator to enable the measurement of Cloud service performance of public Cloud IaaS services from various CSPs. These results provide insights into the public Cloud IaaS industry along the dimensions of Cloud service specifications, pricing and price-performance comparisons. However, businesses may have varying needs when defining and comparing their workload performance requirements. Therefore, enterprises may choose to apply testing methodologies relevant to their business and technical use cases to yield more relevant results. For example, some industries have specialized requirements for workloads, such as Life Sciences and Financial Services, as well as specific application requirements that may demand more specific testing regimens. Thus, augmenting Cloud Spectator's testing with more specific testing models may be necessary.

CSP SELECTION CRITERIA

In order to be considered and tested as one of the IaaS providers in this report, a CSP must meet the following criteria as part of its IaaS offering:

1. European Data Center: The CSP must have at least one data center located within the European continent. The CSP does not need to be headquartered in Europe, however the VM we tested does need to reside in Europe.
2. Self-Sign-up: A user must be able to sign up for a CSP's services online, rather than reaching out to a sales representative. Contact forms that request users to message the CSP for signup are not considered self-sign up / cloud.

3. Self-Service: A user must be able to log into a portal that allows the user to provision, manage, and terminate virtual machines and other cloud-related services without interacting with another human.
4. Hourly Billing Intervals: the CSP must provide billing by the hour or less. Some CSPs offer billing by the minute.
5. Block Storage Offerings: Only providers with persistent block storage offerings are included in this study. Cloud Spectator measured disk performance by running performance tests on only one type of block storage per provider.

These criteria helped with the identification and selection of the Top 10 EU providers that were included in this analysis.

BENCHMARKING ENVIRONMENT SETUP

For all VMs, the latest available Ubuntu 16.04 LTS images were used. Virtual machines were parsed into four separate categories: Small, Medium, Large and Extra-Large. Each VM category is described by a distinct set of sizing configurations, as illustrated below:

Table 4A: VM Sizing

SIZE	vCPU COUNT	RAM COUNT (GB)	DISK SIZE (GB)
Small	2	4	100
Medium	4	8	150
Large	8	16	200
Extra Large	16	32	500

CSPs were segmented into two categories: (1) Packaged Offering CSPs and (2) Customizable Offering CSPs. Packaged Offering CSPs include providers such as Amazon AWS and Microsoft Azure, which deliver VMs based on pre-packaged sizes. For example, a customer can purchase an

instance size of c5.xlarge on AWS. Customizable Offering CSPs allow users to define custom VM sizes by setting resources such as vCPUs, RAM, and disk space.

Only persistent block storage was tested for the storage benchmarks. This meant that CSPs that only offer local, ephemeral storage were not included in the report. A single block storage size was paired and tested with each VM size. Cloud Spector used high performance SSD based block storage for all providers where available, however we did not use pay for IOPs block storage. For other CSPs such as Digital Ocean, which offers persistent local storage and block storage, the local storage was not measured and did not affect the performance or price-performance ranking of the CSP beyond the potential effect on pricing if local storage is included in packaged VM prices. **Please see the Appendix for a specific list showing what was tested on which providers.** For Packaged Offering CSPs, Cloud Spectator selected VMs that most closely corresponded to the four categories of sizes. For Customizable Offering CSPs, the team provisioned servers designed to the exact requirements of the four categories of sizes where possible.

CLOUD PERFORMANCE VARIABILITY TESTED OVER TIME

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

Testing over several iterations impacted the ranking of performance for CSPs. In an uncontrollable public cloud multi-tenant environment, VM performance can be affected by issues that arise with

neighboring VMs. Therefore, measuring performance over the course of at least 24 hours is critical to obtain an accurate assessment of how each provider's respective Cloud services perform, and how that performance varies over time.

Single-VM performance results may not necessarily provide an accurate assessment of a CSP's overall performance. Thus, measuring more than a single VM of each size helps to establish a more accurate performance sample for each CSP. To that end, Cloud Spectator runs the following benchmarking test design:

1. Run a sequence of benchmarks
2. Tear down the VM
3. Create a new VM with the same configuration, in the same datacenter, but preferably not on the exact same physical host

This results in a more accurate representation of a VM's potential performance. Given that businesses generally scale out horizontally or migrate to newer VMs as they are released, it is important to understand how much variance each provider's services might exhibit when simply moving from one physical host to another.

At other times, the physical host itself may experience performance issues, which would thereby affect all VMs residing on it. By re-provisioning all VMs at the start of each test sequence, in addition to testing multiple VMs in parallel, Cloud Spectator can capture as much of this variance as possible, which leads to a more "real world" view of each VMs overall performance.

While all of these processes and methodologies are implemented to provide a realistic view of VM performance at each provider, it should be noted that these practices cannot guarantee a 100%

accurate performance analysis, since the cloud is inherently noisy and unpredictable. These processes and methodologies do, however, provide an accurate view of each provider's general performance and variability.

DATA COLLECTION

Testing was conducted throughout Q2 2018 (May and June). The rankings were produced based on the CloudSpecs Score™, which is a price-performance ratio of the cost and median performance output of the VM. Each VM size category received a VM compute CloudSpecs Score™ and a block storage CloudSpecs Score™, which were averaged to calculate an overall CloudSpecs Score™ for each provider and each VM. The CSPs with the highest average CloudSpecs Scores™ across all VMs were then ranked from high to low, higher CloudSpecs Scores indicate better price-performance.

BENCHMARKING TOOLS & COMPONENTS

The following sections lists the tools and parameters used for the evaluation of the providers in this study. Table 4B below highlights the testing tools used for each Cloud resource:

Table 4B: Testing Tools

TEST	TOOL	TASKS
CPU	Geekbench 4	All Multi Core Workloads
Memory	Geekbench 4	Read, Write, Copy
Block Disk	Fio	Random Read and Write

CPU and Memory (Compute)

CPU and Memory performance were measured using Geekbench 4's multi core workloads. Geekbench 4 factors in CPU and Memory performance using a wide range of workloads, including

integer and floating point focused CPU workloads, along with Memory latency and bandwidth tests, which provide a solid overall picture of CPU and Memory performance.

Block Storage

Table 4C: Testing Specifics

CATEGORY	TYPE 1	TYPE 2
Block Size	4KB	128KB
File Size	5GB	128MB

Table 4D: Total Files Used in Block Storage Testing

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

Block storage performance was measured using FIO. Two storage scenarios were run to capture performance data on small and medium block sizes: Type 1 and Type 2. In both scenarios, random read & write IOPS were recorded as the indicator of storage performance. Type 1 represents extremely small, random I/O. Type 2 represents medium sized, random I/O. Sequential I/O was not tested in this report.

In both testing scenarios, the number of parallel jobs run were set equal to the number of virtual processors in the VM. Each storage scenario test used with “end fsync” at the end to ensure all data was written to disk (and not cached in memory) before recording the result.

Please note that the IOPs values between Type 1 and Type 2 are not the same in the sense that more data will be read or written when performing 1 x 128KB IOP compared to 1 x 4KB IOP. Cloud Spectator tests using two block sizes because storage devices perform differently depending on the size of the I/O. Testing just one size may not capture the full story around storage performance.

CLOUD RANKING CALCULATION

The rankings of the 10 CSPs were determined by calculating the median performance of both vCPU-memory and storage with the monthly cost corresponding to each VM size for two price-performance

scores per VM size (one for CPU and Memory and one for storage). The resulting values were normalized in relation to the highest-value provider for each resource, which receives a score of 100. Then the two price-performance scores for each VM size were averaged together to get one score per VM size. The providers were then ordered based on their value across all each VM size, and then their scores were averaged for all VM sizes to come up with a final score. The providers that sustained higher ratios across all VM categories ranked highly.

PRICE-PERFORMANCE VALUE (CLOUDSPECS SCORE)

Cloud Spectator's CloudSpecs Scores™, provides a general view on how much performance you get per Euro spent for CPU and Memory, as well as Block Storage. 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 based on the following formula:

price-performance_value = [VM performance score] / [VM cost]

best_VM_value = max{price-performance_values}

*CloudSpecs Score™ = 100*price-performance_value / best_VM_value*

Higher CloudSpecs™ Scores are better and indicate better overall price-performance. Lower values indicate lower price-performance.

CPU and Memory CloudSpecs Score

Cloud Spectator used the median Geekbench 4 performance scores as the [VM performance score] to calculate each VM's CPU and Memory CloudSpecs Score™.

Block Storage CloudSpecs Score

For both block storage scenarios, median random r/w IOPS are used as the [VM performance score] to calculate each machine's Type 1 and Type 2 storage CloudSpecs Score™.

Overall CloudSpecs Score

The Overall CloudSpecs Score™ was calculated by averaging block storage and vCPU-memory scores together so that they have equal weight for each VM size. Then, all resulting VM size scores were averaged together.

VARIABILITY

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

CONSIDERATIONS

There are a few considerations to take into account when evaluating the providers under the methodology used in this study. The limitations of the methodology and shifting nature of the pricing and services offered by the providers introduce a number of variables that have to be taken into account.

Limitations within the Methodology

The IaaS industry lacks a standard methodology for evaluating CSPs. While the most effective methodology for measuring value of a CSP varies among use cases, the methodology developed by Cloud Spectator for this study was designed to capture performance statistics based on synthetic performance uniquely adopted for cloud infrastructure, which requires steps including extended testing over a period of time and running multiple VMs in parallel.

The results are used for comparison purposes only and cannot be applied to predict application performance.

VM Sizes

The performance data in this report only applies to the tested VM configurations and specific volume types (listed in appendix). Larger VMs may yield better results with both VM scores and block storage scores. Larger block storage volumes may also yield better block storage performance scores (AWS EBS is one example). In those cases, the CloudSpecs Score was calculated by averaging the four available sizes for each provider.

Pricing Calculations and Discounts

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

Additional Features and Costs

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

pay-to-scale IOPS option, such as Provisioned IOPS. The amount and cost of the pay-to-scale IOPS option can affect a provider's ranking.

DATA CENTER LOCATIONS

All VM sizes for each provider were provisioned in a European data center. Please note that most of the CSPs have multiple locations across Europe, for this report we focused on one specific data center for each provider.

Table 4F: Data Center Locations

Provider	Data Center Location
1&1	Germany
Amazon	Ireland
Azure	North Europe
CenturyLink	Great Britain
Digital Ocean	London
UpCloud	Germany
Google	West Europe
OVH	France
Rackspace	London
SoftLayer	Amsterdam

VM PRICE-PERFORMANCE VALUE

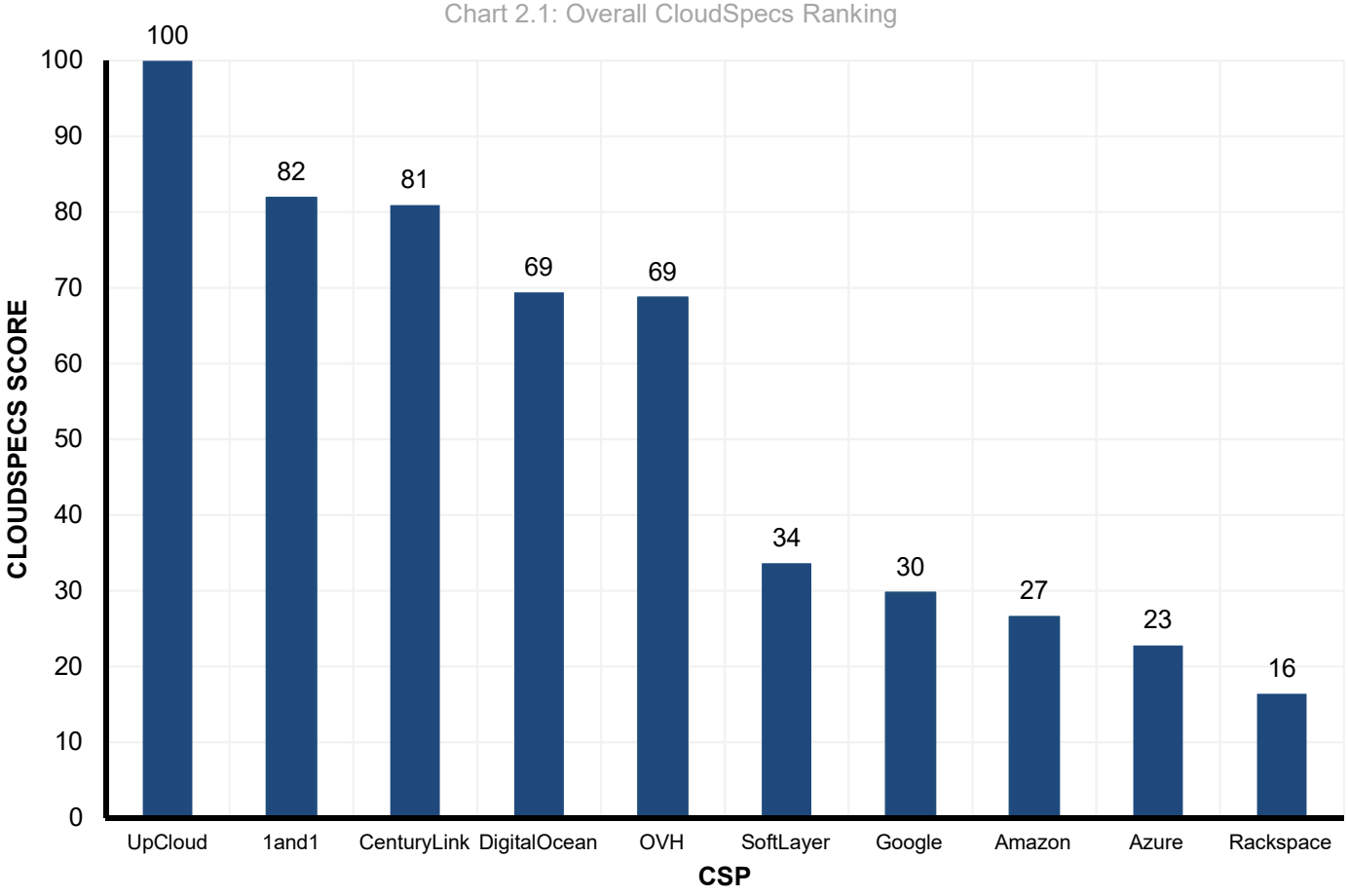
This section examines the price-performance of each VM size group (i.e. performance per Euro spent) of the 10 European IaaS providers, which is used in determining each CSP's CloudSpecs Score™ in this report. The CloudSpecs Score™ is calculated as the ratio between the price, defined as the monthly cost of the VM and block storage, and median performance of the VM and block storage. For more information on the calculation of the CloudSpecs Score™, please see the Methodology.

UpCloud achieves the highest CloudSpecs Score™ in this study (a CloudSpecs Score of 100). CSPs such as Rackspace, which achieved high performance scores in the previous section, ranked lower overall due to higher costs of infrastructure.

OVERALL CLOUDSPECS RANKING

A difference in value of 6.3x exists between UpCloud, the highest-ranked CSP, and Rackspace, the lowest-ranked CSP in the Top 10. Chart 2.1 below shows the overall CloudSpecs Score for each CSP.

Chart 2.1: Overall CloudSpecs Ranking

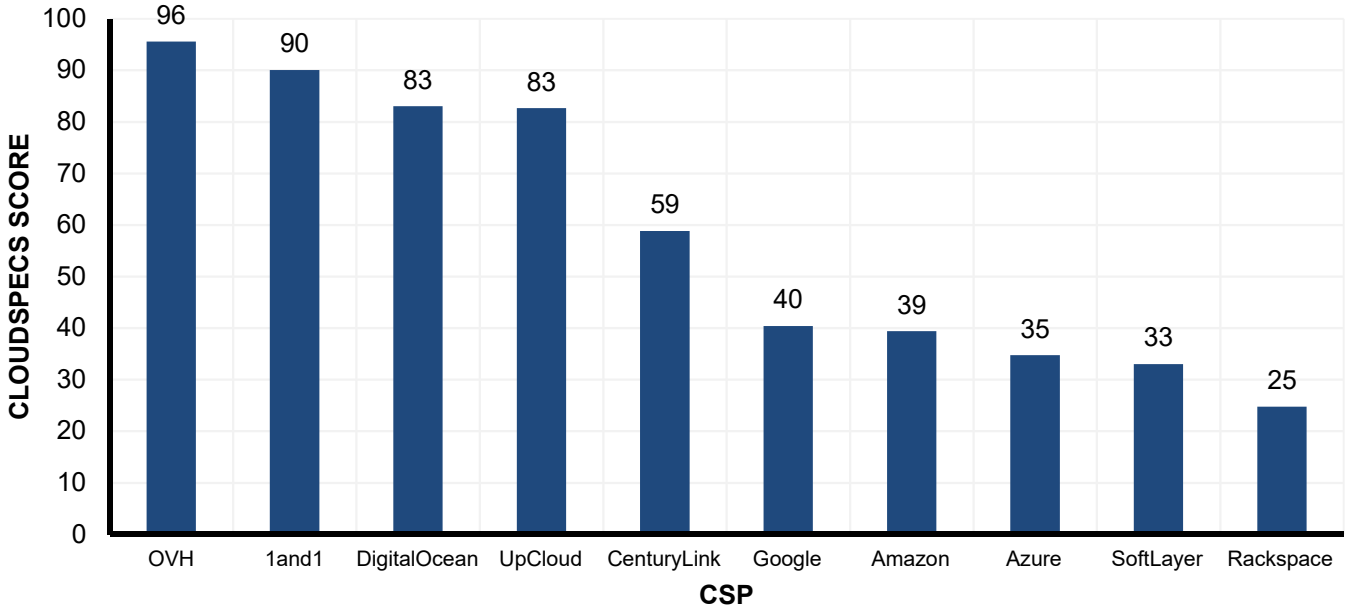


The following sections (vCPU and Memory Value and Block Storage Value) illustrate the individual Value scores segregated by section, which are the scores used to calculate the overall CloudSpecs ranking (shown above). Providers that scored well in both areas tend to have a higher overall CloudSpecs score.

VCPU AND MEMORY VALUE

The chart below displays the overall price-performance values of the providers' VM CPU and Memory.

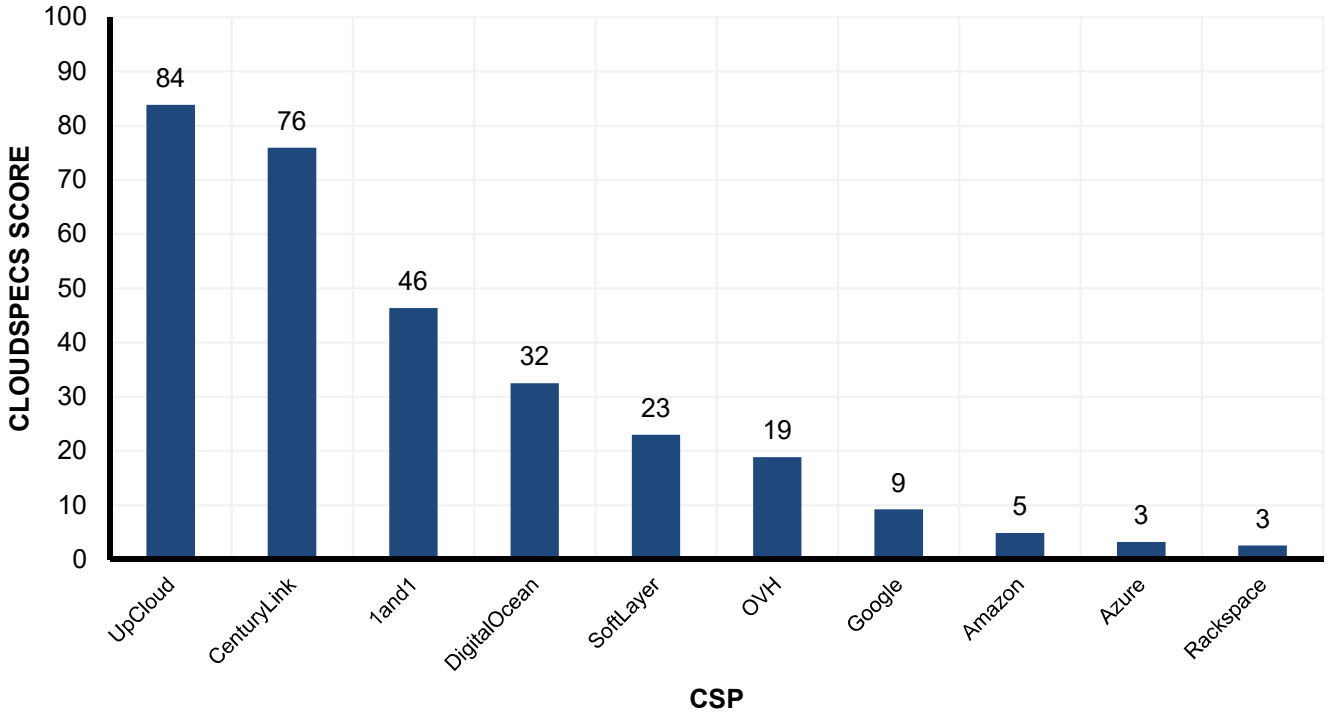
Chart 6B: Average CPU Price-performance Value of CSP's VM Infrastructure



BLOCK STORAGE VALUE

The chart below displays the overall price-performance values of the providers' Block Storage.

Chart 6C: Average Price-performance Value of CSP's Block Disk



PERFORMANCE

This section examines the performance of the 10 IaaS providers ranked in this report. This section does not use the CloudSpecs Score™, which is used to rank providers and can be found in the Price-Performance section of the report.

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

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

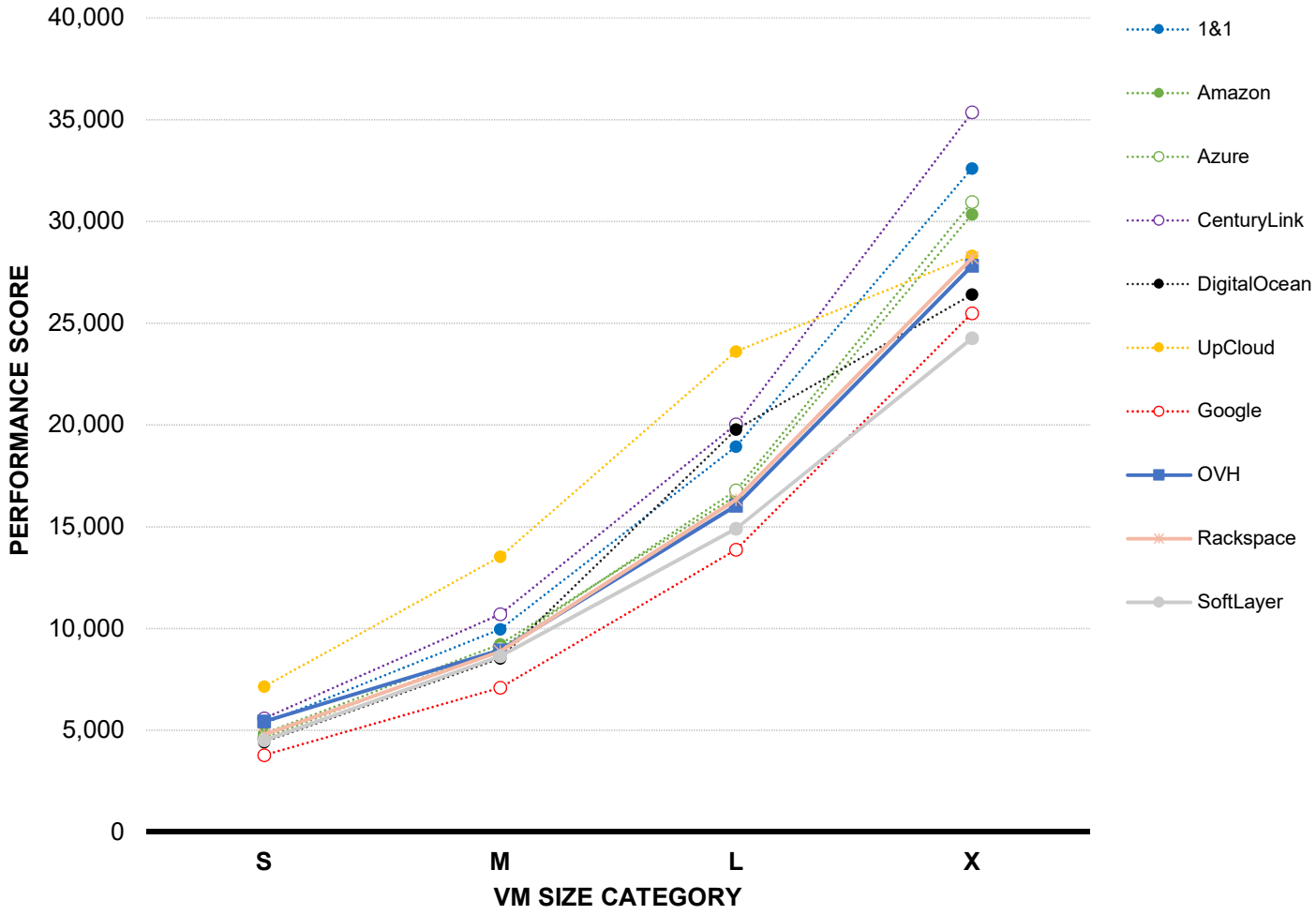
CPU AND MEMORY PERFORMANCE

CPU and Memory performance between CSPs remained relatively consistent across the VM sizes and scales up fairly consistently as the VM size increases.

- Small VM CPU performance is extremely similar for all providers other than UpCloud, which offers above average CPU performance for small, medium and large VMs.
- The Extra Large VM category exhibits a wide range of variance.

The chart below displays the median performance scores exhibited by the VMs in this study.

Chart 5A: vCPU and Memory Performance (Median Scores Displayed)



BLOCK STORAGE PERFORMANCE

This section covers the block storage performance for each CSP. Detailed results can be found in the Performance by VM Size on page 32. Each varying disk size corresponded with a VM category (see Methodology page 11). More information on the two scenarios can be found in the Methodology (page 11).

- Block storage performance varies greatly between providers and even size groups in some cases. Performance tended to either remain flat across each provider's small through large VM sizes, or it tended to scale upwards as the volume sizes increased. Detailed performance charts for each VM size will be covered later in this report.
- Reads and writes were targeted to the storage disks themselves and made to avoid hitting the File System cache.
- Raw block storage devices were tested with FIO for this report. This was done to eliminate any filesystem caches or buffering, which can skew results in some cases. Direct I/O was also used to ensure that data was read and written directly to / from the block storage. While this is not a real-world scenario, it does produce a fairly accurate view of storage performance.

  The charts on the following page display the median performance scores achieved by each of the providers for Type1 and Type2 Read/Write operations.

Chart 6B: Scenario Type 1 - Read (4K) Performance (Median Scores Displayed)

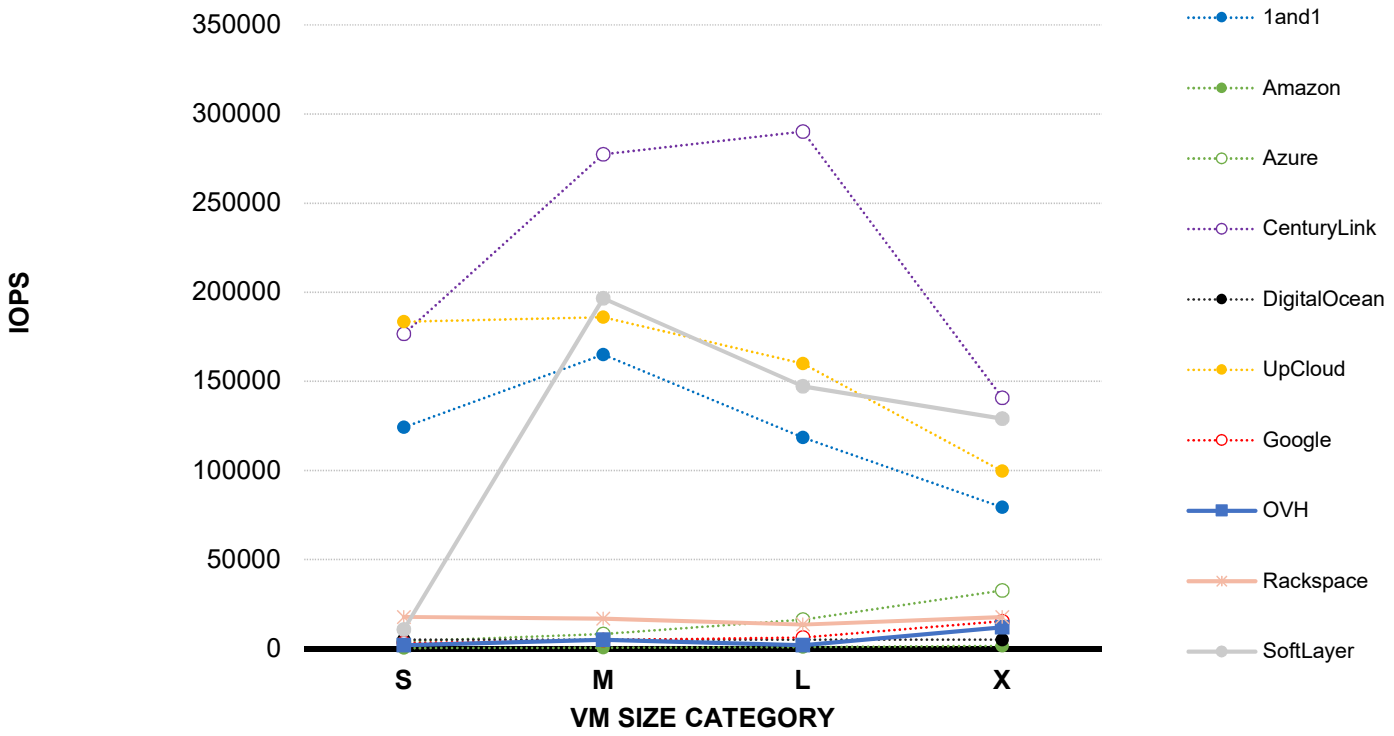


Chart 6C: Scenario Type 1 - Write (4K) Performance (Median Scores Displayed)

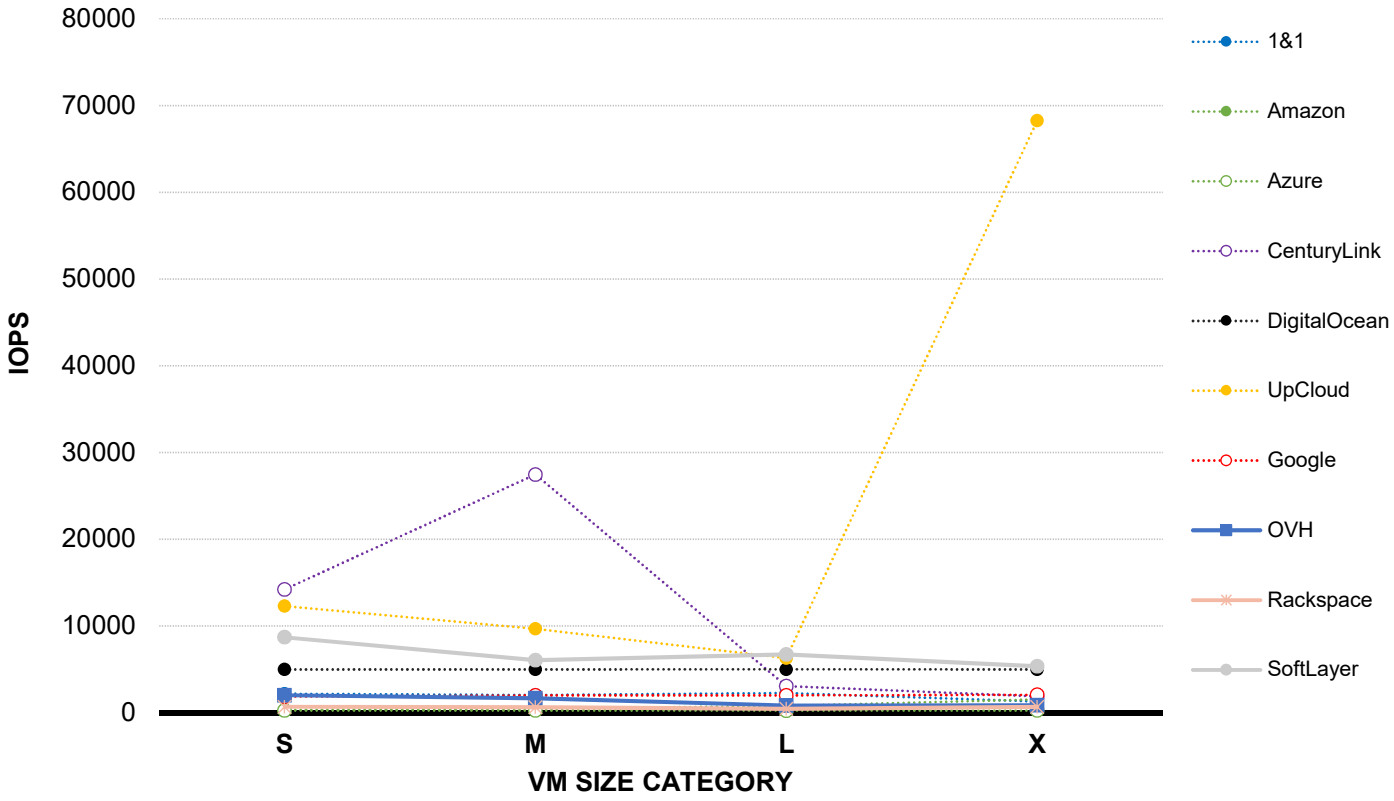


Chart 6D: Scenario Type 2 - Read (128K) Performance (Median Scores Displayed)

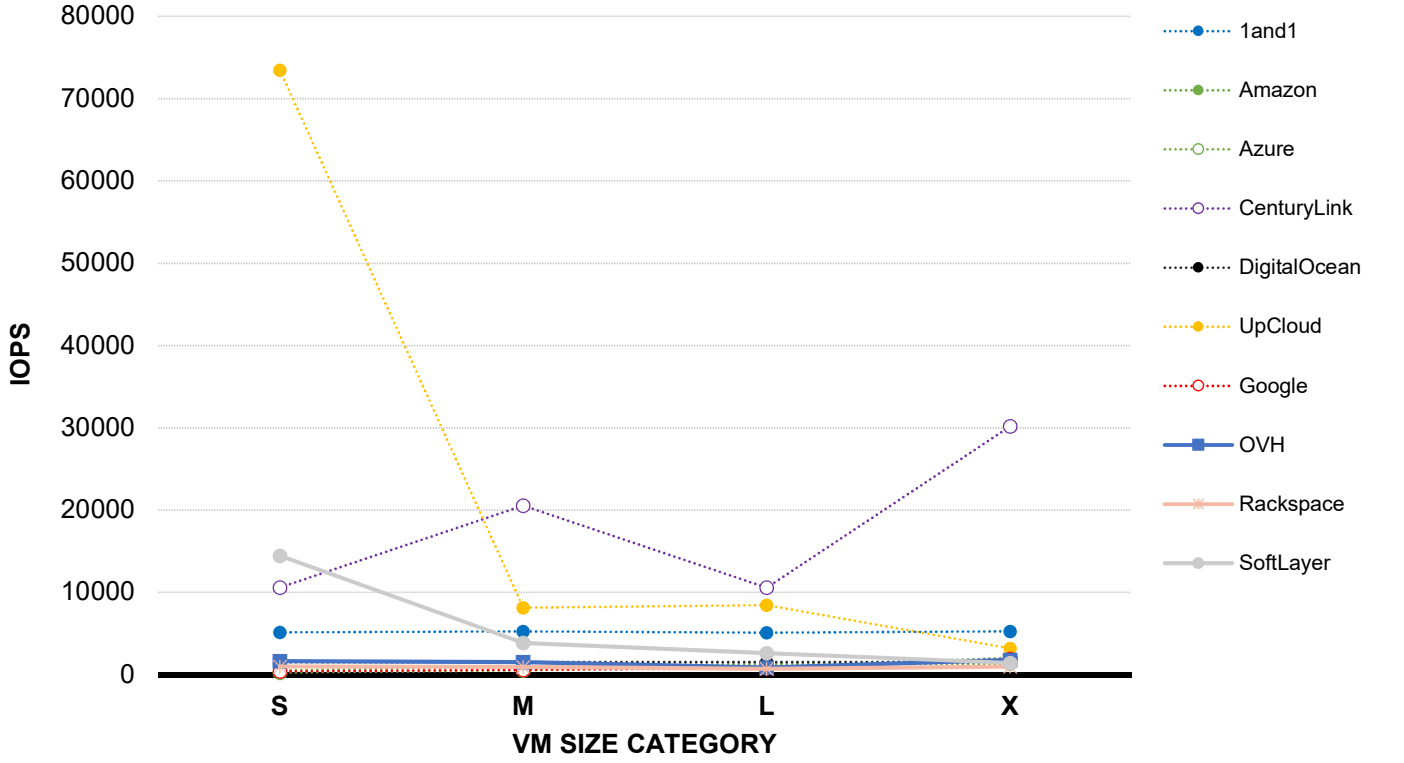
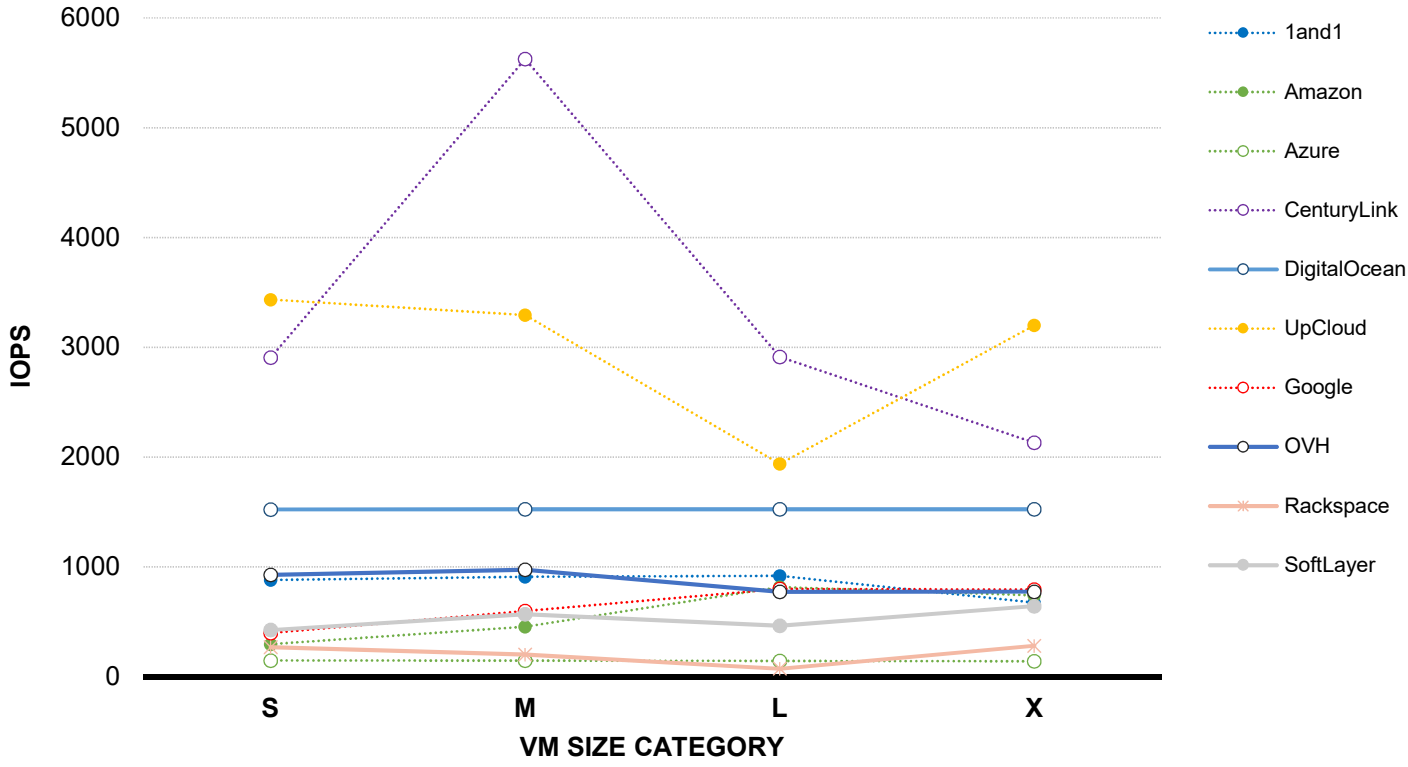


Chart 6E: Scenario Type 2 - Write (128K) Performance (Median Scores Displayed)



PRICING

This section outlines the cost of the VMs and block storage for each size examined in the study across all CSPs. Additional services, unless required (such as Rackspace Managed Services), are not included in the final cost of the VMs.

Only the cost of the VM and tested block storage were factored into the final cost. Please keep in mind that some providers may charge for add-on services such as support, while other providers include it into the cost of the VMs.

OVERALL PRICING

The final monthly cost of each VM category for each CSP is calculated as the cost of the VM and the cost of the attached block storage. 1&1, Digital Ocean, and OVH maintained top ranks as the least-expensive providers in the price ranking. The chart below displays the monthly costs of the providers' VMs and storage of the resources examined in the study.

Chart 7A: Monthly Cost of VMs Across CSPs

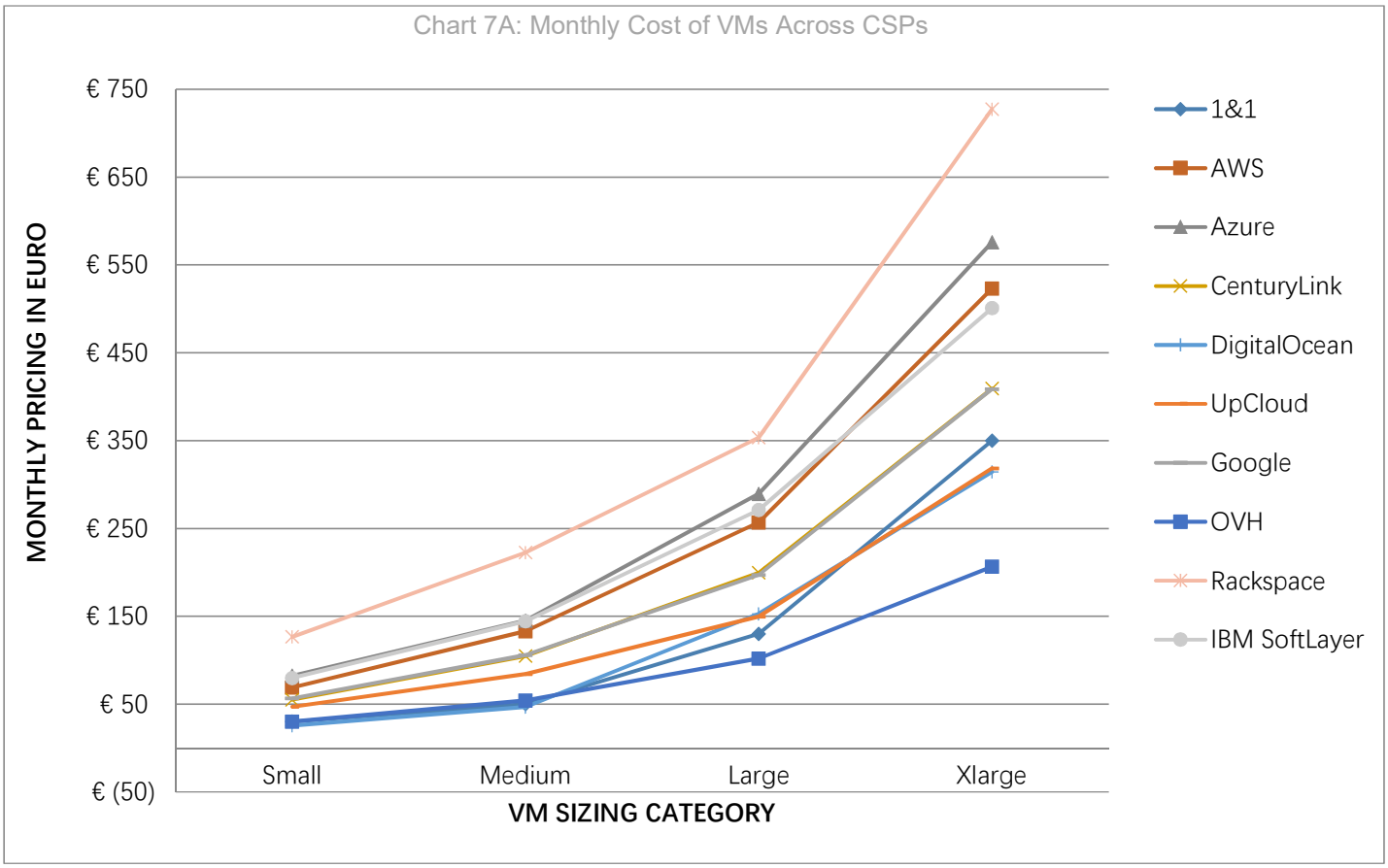


Table 7A: Monthly Cost of VMs Across CSPs

	Small	Medium	Large	Extra Large
1&1	€ 29.99	€ 49.99	€ 129.99	€ 349.99
Amazon	€ 68.92	€ 133.16	€ 256.97	€ 523.29
Azure	€ 82.34	€ 145.01	€ 289.33	€ 576.03
CenturyLink	€ 55.04	€ 104.90	€ 199.43	€ 409.22
Digital Ocean	€ 25.50	€ 46.75	€ 153.00	€ 314.50
UpCloud	€ 47.03	€ 84.45	€ 149.66	€ 318.56
Google	€ 56.51	€ 105.80	€ 197.15	€ 408.75
OVH	€ 30.09	€ 54.32	€ 102.00	€ 206.55
Rackspace	€ 126.56	€ 222.55	€ 353.45	€ 727.43
SoftLayer	€ 79.71	€ 144.53	€ 271.12	€ 500.84

PRICING BY VM CATEGORY

From small to large-sized VMs, the provider rankings remained the same from the least to most expensive provider. On the extra-large VMs, sizing allocation is less standardized, with differences in the amount of memory and local disk (if available) on the VM. The lack of standardization results in ranking changes on the extra-large VMs: OVH offers the least-expensive VM, and Google Compute Engine and CenturyLink Cloud swap rankings. Dimension Data does not have a VM that fits in the extra-large VM category.

Chart 7B: Monthly Cost of Small VMs

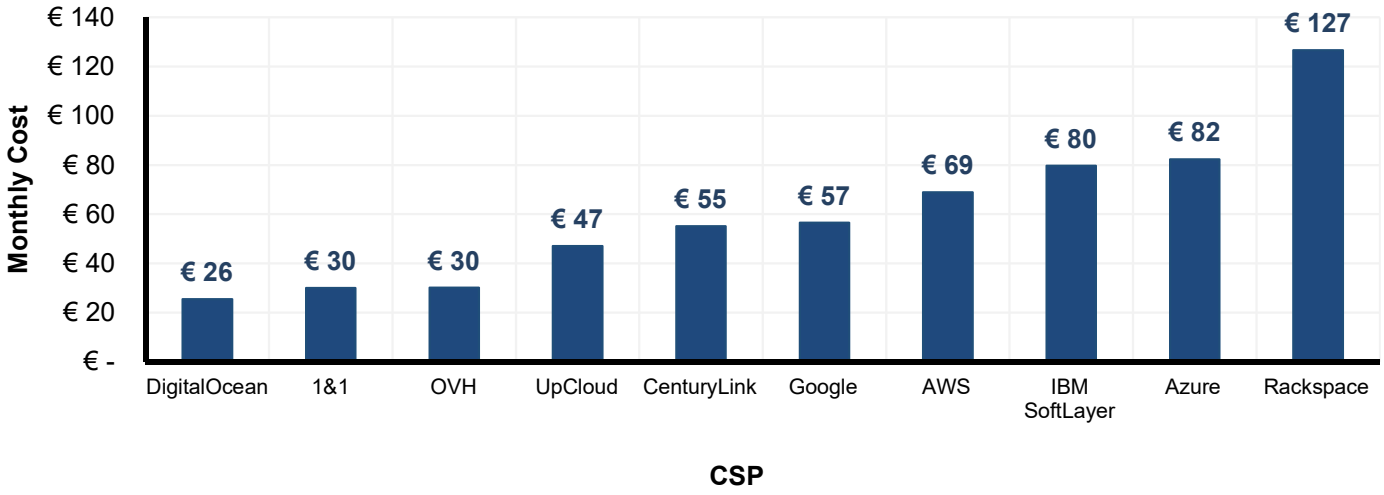


Chart 7C: Monthly Cost of Medium VMs

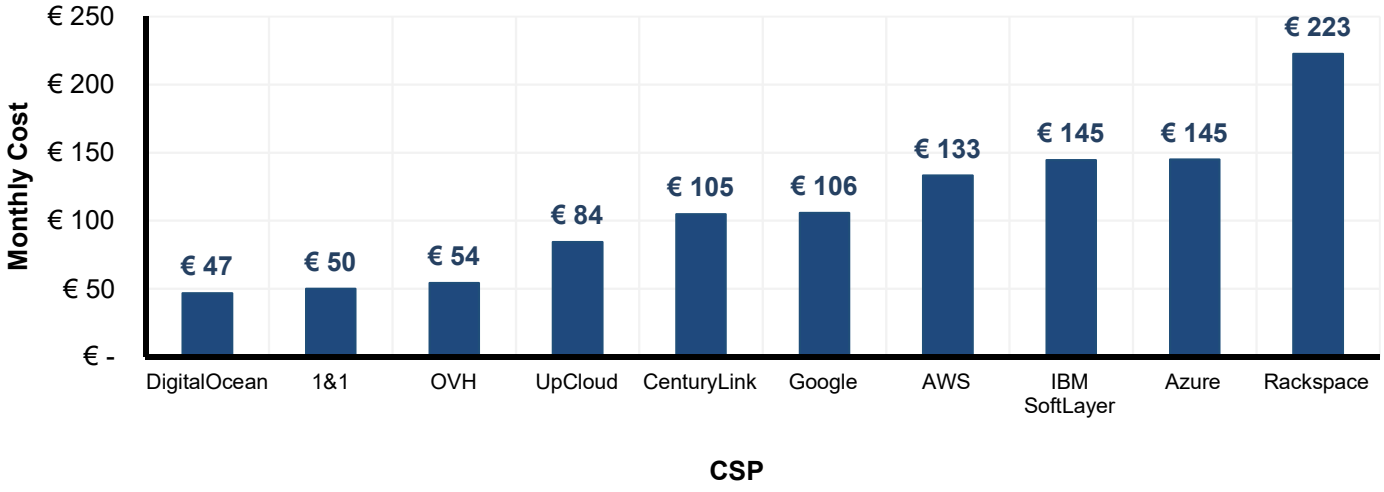


Chart 7D: Monthly Cost of Large VMs

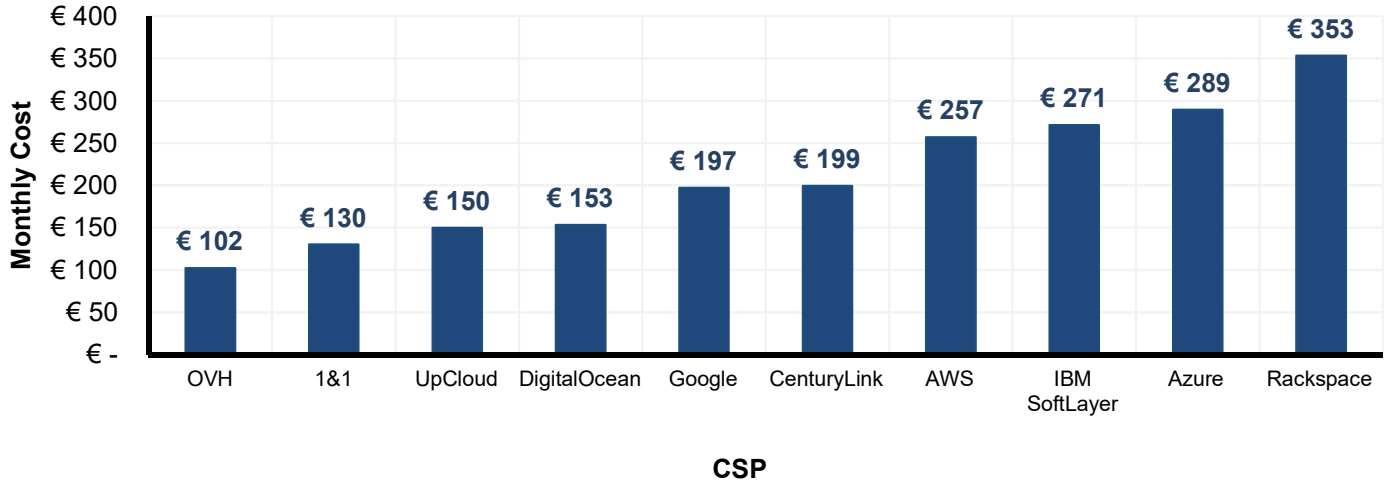
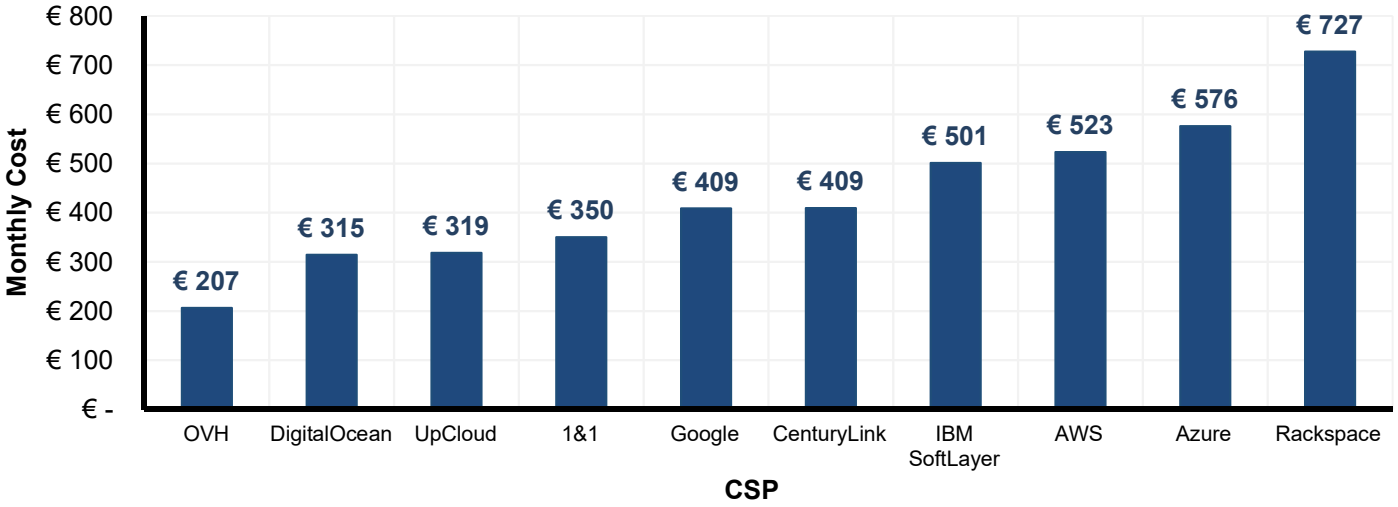


Chart 7E: Monthly Cost of Extra Large VMs



PERFORMANCE BY VM SIZE

UNDERSTANDING THE CHARTS

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

Maximum (MAX): The highest performance score(s) achieved on the VM over the course of the study.

95TH Percentile (95TH): 95% of all scores on the VM achieved this performance score or lower.

Median (MED): The number separating the higher and lower half of scores. If the median is closer to the 95TH percentile, then more high-performance scores were observed than low performance scores (and vice versa).

5TH Percentile (5TH): 5% of all scores on the VM achieved this performance score or lower.

Minimum (MIN): The lowest performance score(s) achieved on the VM over the course of the study.

SMALL VMs

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

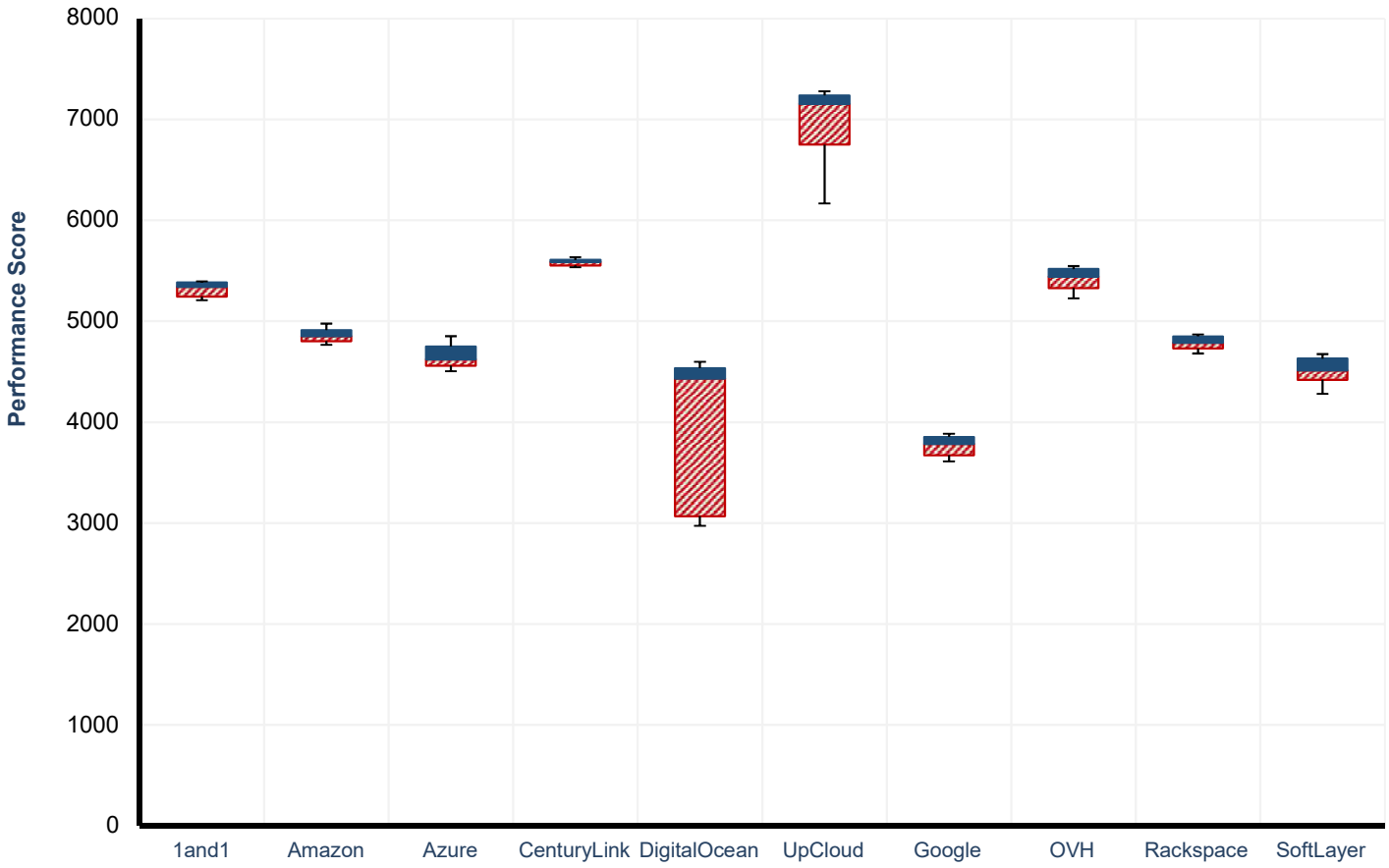


Table 8A.1: VM Performance (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1&1	5,208	5,245	5,341	5,383	5,396	43	1%
Amazon	4,765	4,803	4,853	4,912	4,976	36	1%
Azure	4,506	4,560	4,622	4,750	4,852	59	1%
CenturyLink	5,536	5,553	5,588	5,608	5,636	15	0%
Digital Ocean	2,972	3,068	4,431	4,536	4,598	589	15%
UpCloud	6,169	6,750	7,154	7,238	7,279	199	3%
Google	3,612	3,673	3,783	3,852	3,886	55	1%
OVH	5,226	5,329	5,440	5,518	5,547	59	1%
Rackspace	4,680	4,730	4,787	4,849	4,869	39	1%
SoftLayer	4,280	4,420	4,512	4,630	4,674	69	2%

Chart 8A.2: Read (4K) Block Disk Performance Type 1 (Small VM)

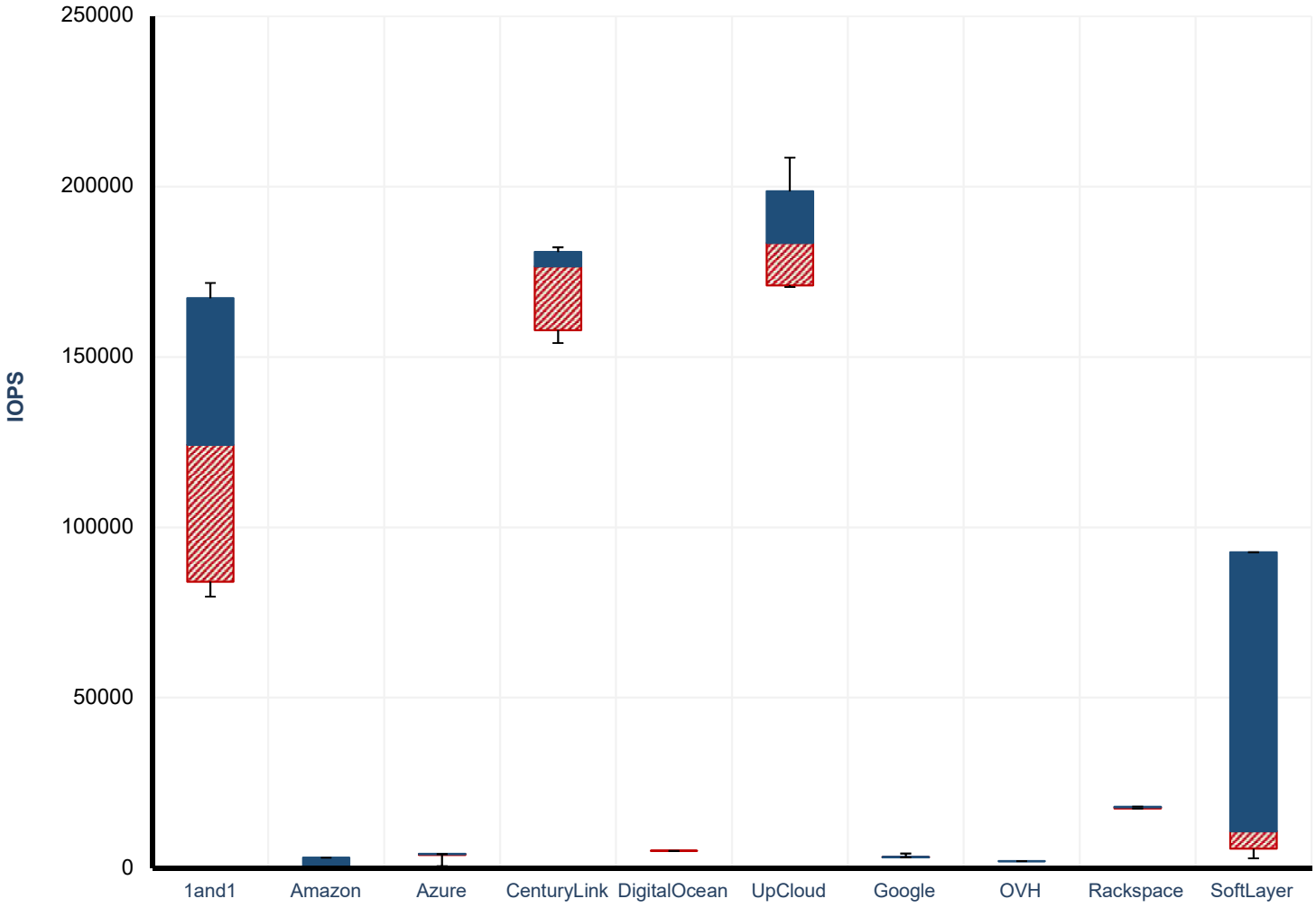


Table 8A.2: Read Block Disk Performance Type 1 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1&1	79,683	84,050	124,228	167,255	171,740	39,375	31%
Amazon	311	312	313	3,048	3,048	855	139%
Azure	513	3,838	4,081	4,083	4,083	366	9%
CenturyLink	154,077	157,905	176,650	180,822	182,221	6,513	4%
Digital Ocean	4,994	5,006	5,008	5,008	5,009	2	0%
UpCloud	170,531	171,041	183,479	198,644	208,511	9,316	5%
Google	3,124	3,126	3,140	3,143	4,247	78	2%
OVH	2,002	2,002	2,002	2,002	2,003	0	0%
Rackspace	17,412	17,478	17,807	18,001	18,052	145	1%
SoftLayer	2,866	5,661	10,793	92,646	92,675	40,787	112%

Chart 8A.3: Write (4K) Block Disk Performance Type 1 (Small VM)

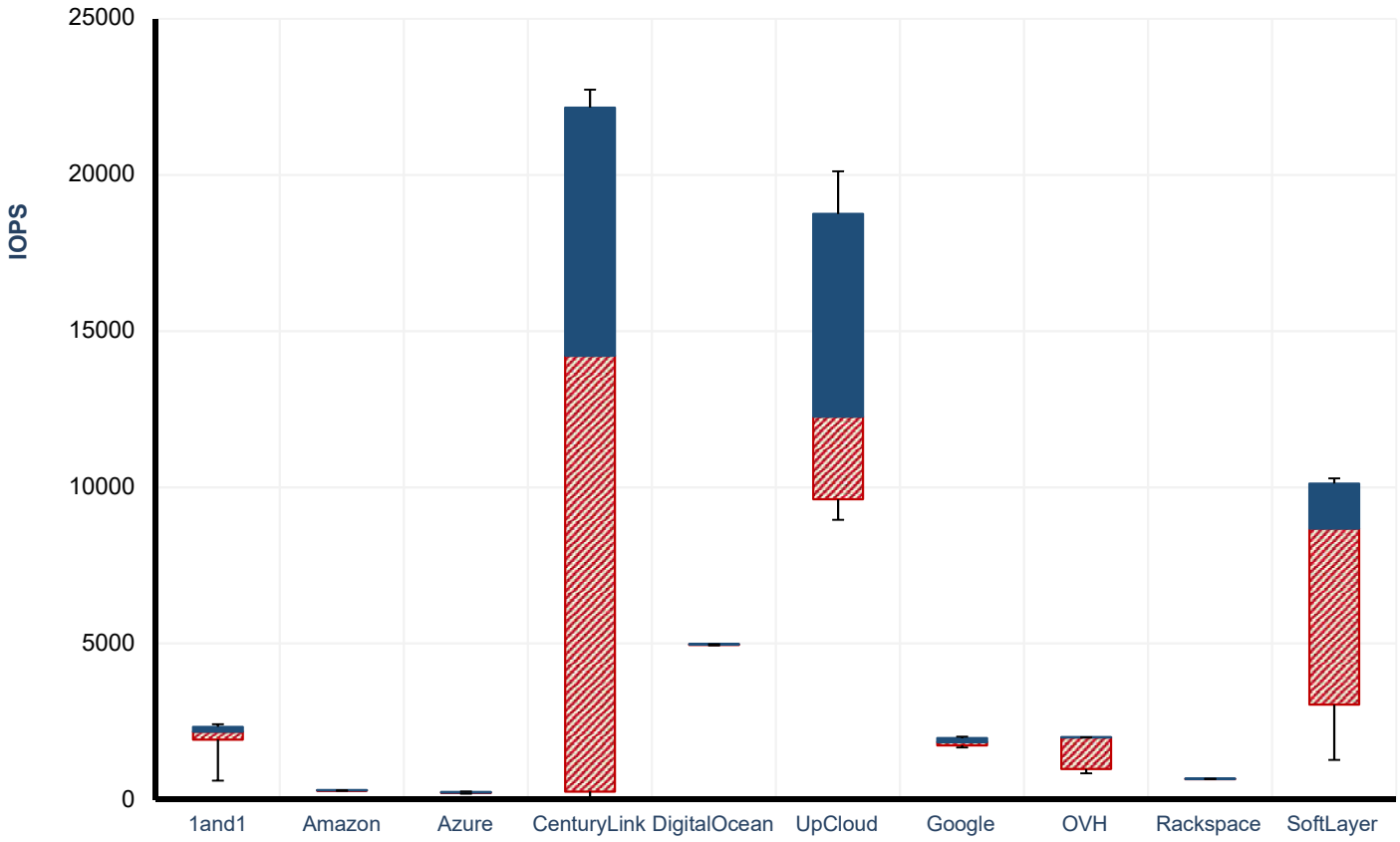


Table 8A.3: Write Block Disk Performance Type 1 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	608	1,921	2,180	2,332	2,419	239	11%
Amazon	284	286	293	297	300	4	1%
Azure	190	214	231	246	256	9	4%
CenturyLink	44	258	14,212	22,157	22,734	8,375	81%
Digital Ocean	4,943	4,956	4,969	4,977	4,978	7	0%
UpCloud	8,962	9,617	12,266	18,754	20,121	3,181	24%
Google	1,671	1,737	1,835	1,968	2,018	77	4%
OVH	841	977	1,994	1,999	2,000	369	21%
Rackspace	656	660	664	670	671	3	0%
SoftLayer	1,276	3,044	8,683	10,119	10,285	2,512	31%

Chart 8A.4: Read (128K) Block Disk Performance Type 2 (Small VM)

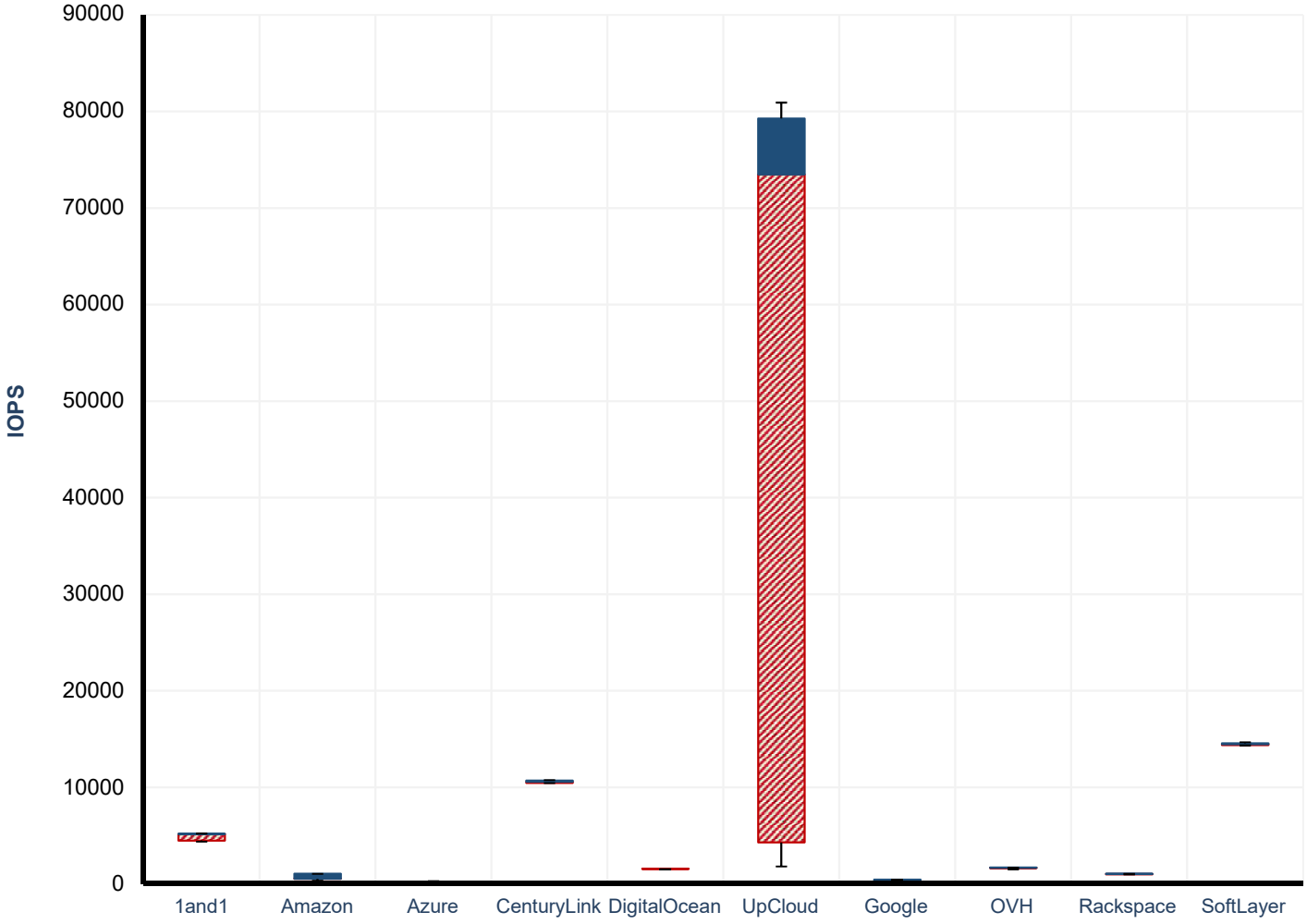


Table 8A.4: Read Block Disk Performance Type 2 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	4,371	4,485	5,142	5,186	5,208	303	6%
Amazon	311	520	523	1,041	1,041	269	35%
Azure	254	255	255	255	255	0	0%
CenturyLink	10,431	10,449	10,581	10,705	10,739	88	1%
Digital Ocean	1,527	1,528	1,528	1,528	1,528	0	0%
UpCloud	1,803	4,286	73,464	79,265	80,920	29560	58%
Google	400	400	400	401	401	0	0%
OVH	1,504	1,619	1,648	1,674	1,683	31	2%
Rackspace	983	991	1,003	1,011	1,021	7	1%
SoftLayer	14,334	14,370	14,453	14,555	14,658	62	0%

Chart 8A.5: Write (128K) Block Disk Performance Type 2 (Small VM)

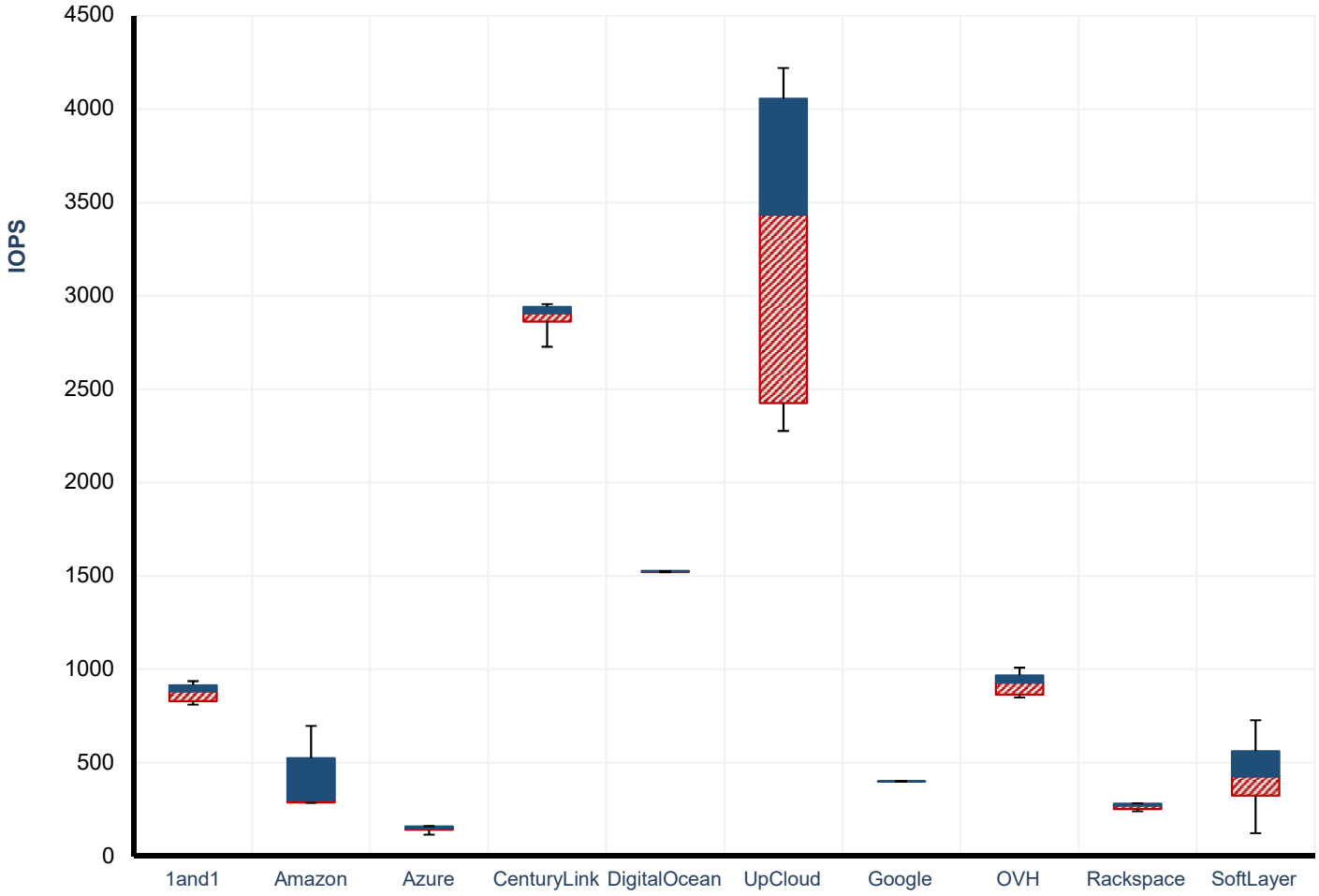


Table 8A.5: Write Block Disk Performance Type 2 (Small VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	810	829	882	914	936	29	3%
Amazon	284	286	297	523	696	115	30%
Azure	113	140	148	157	159	6	4%
CenturyLink	2,727	2,862	2,907	2,941	2,956	37	1%
Digital Ocean	1,519	1,520	1,524	1,527	1,527	3	0%
UpCloud	2,276	2,425	3,436	4,056	4,221	486	14%
Google	399	399	399	400	400	0	0%
OVH	848	864	928	967	1,008	33	4%
Rackspace	238	251	270	280	282	10	4%
SoftLayer	121	323	426	561	726	85	20%

MEDIUM VMs

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

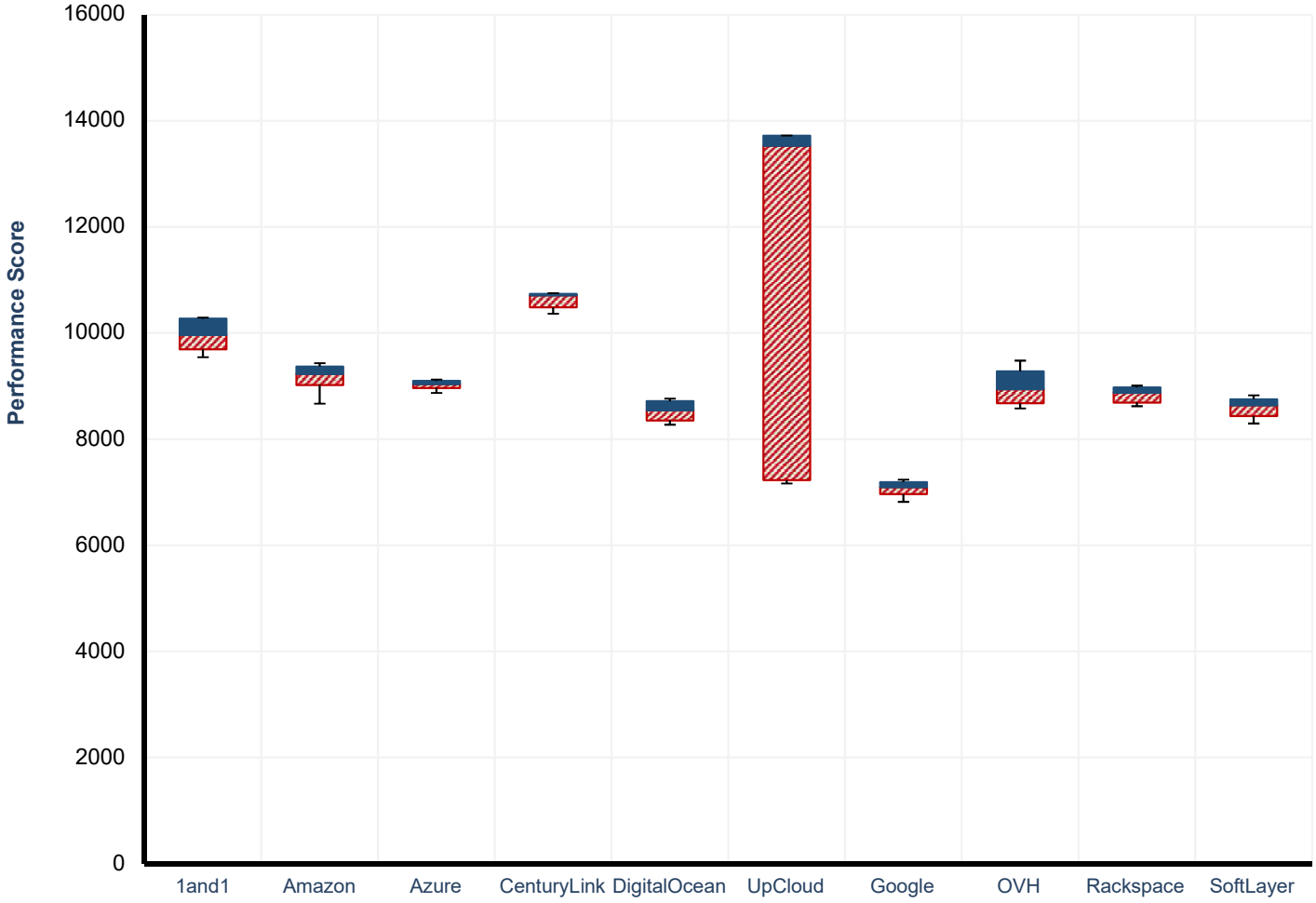


Table 8B.1: VM Performance (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	9,544	9,693	9,966	10,272	10,291	185	2%
Amazon	8,668	9,022	9,227	9,371	9,431	121	1%
Azure	8,871	8,965	9,039	9,097	9,122	43	0%
CenturyLink	10,363	10,483	10,708	10,736	10,750	76	1%
Digital Ocean	8,273	8,354	8,540	8,714	8,766	120	1%
UpCloud	7,163	7,227	13,530	13,722	13,726	2,372	19%
Google	6,818	6,964	7,093	7,189	7,234	72	1%
OVH	8,577	8,676	8,941	9,280	9,481	179	2%
Rackspace	8,621	8,691	8,875	8,976	9,008	88	1%
SoftLayer	8,294	8,437	8,640	8,750	8,826	99	1%

Chart 8B.2: Read (4K) Block Disk Performance Type 1 (Medium VM)

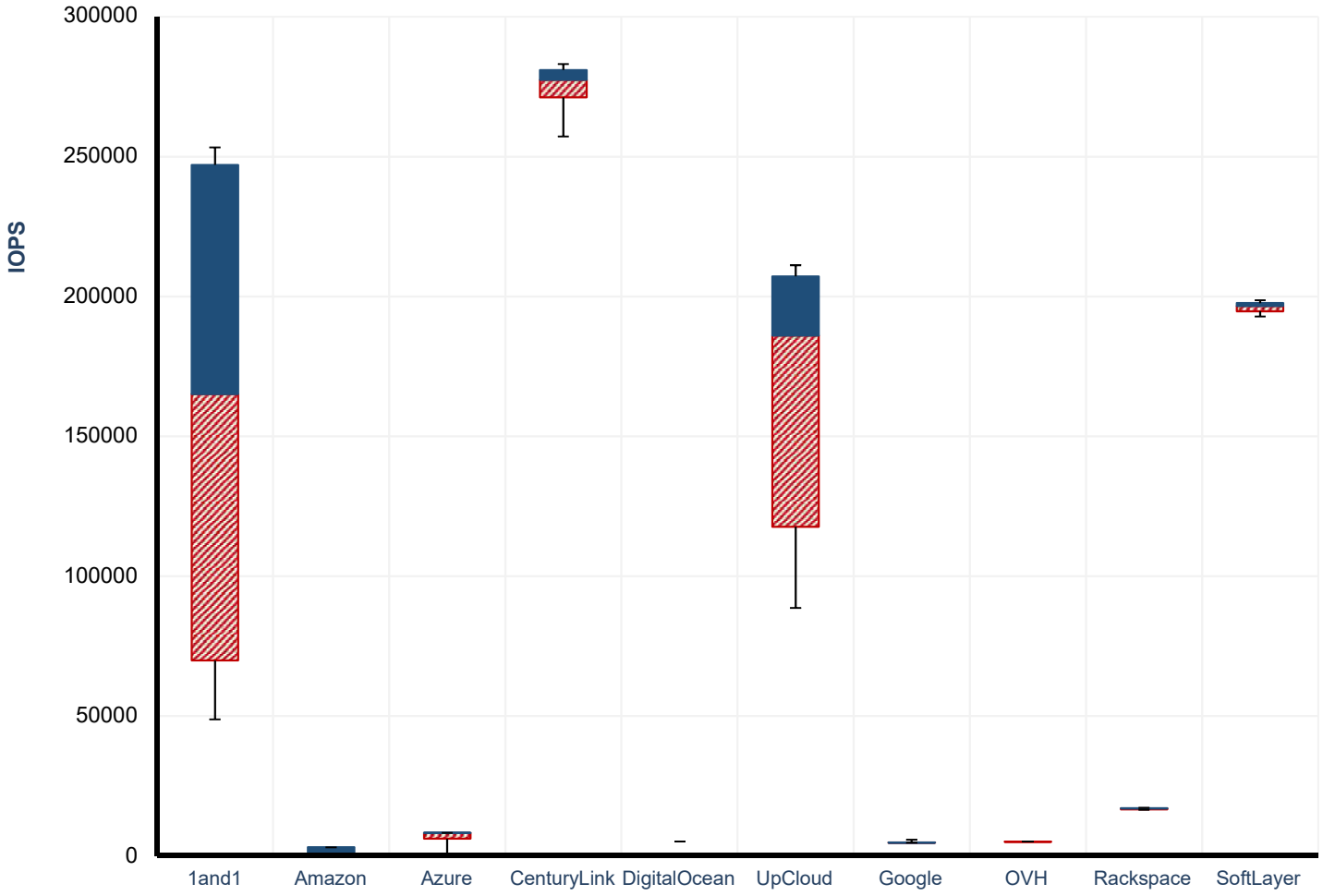


Table 8B.2: Read Block Disk Performance Type 1 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	48,811	69,833	165,043	247,006	253,264	78,208	48%
Amazon	456	469	469	3,048	3,048	827	107%
Azure	514	6,141	8,162	8,167	8,167	1,052	13%
CenturyLink	257,206	271,195	277,475	280,965	283,075	4,048	1%
Digital Ocean	5,008	5,008	5,008	5,008	5,008	0	0%
UpCloud	88,652	117,674	185,978	207,185	211,171	28,914	16%
Google	4,688	4,690	4,712	4,716	5,746	73	2%
OVH	5,007	5,007	5,008	5,008	5,008	0	0%
Rackspace	16,502	16,648	16,906	17,071	17,160	135	1%
SoftLayer	192,862	194,707	196,588	197,636	198,627	1,011	1%

Chart 8B.3: Write (4K) Block Disk Performance Type 1 (Medium VM)

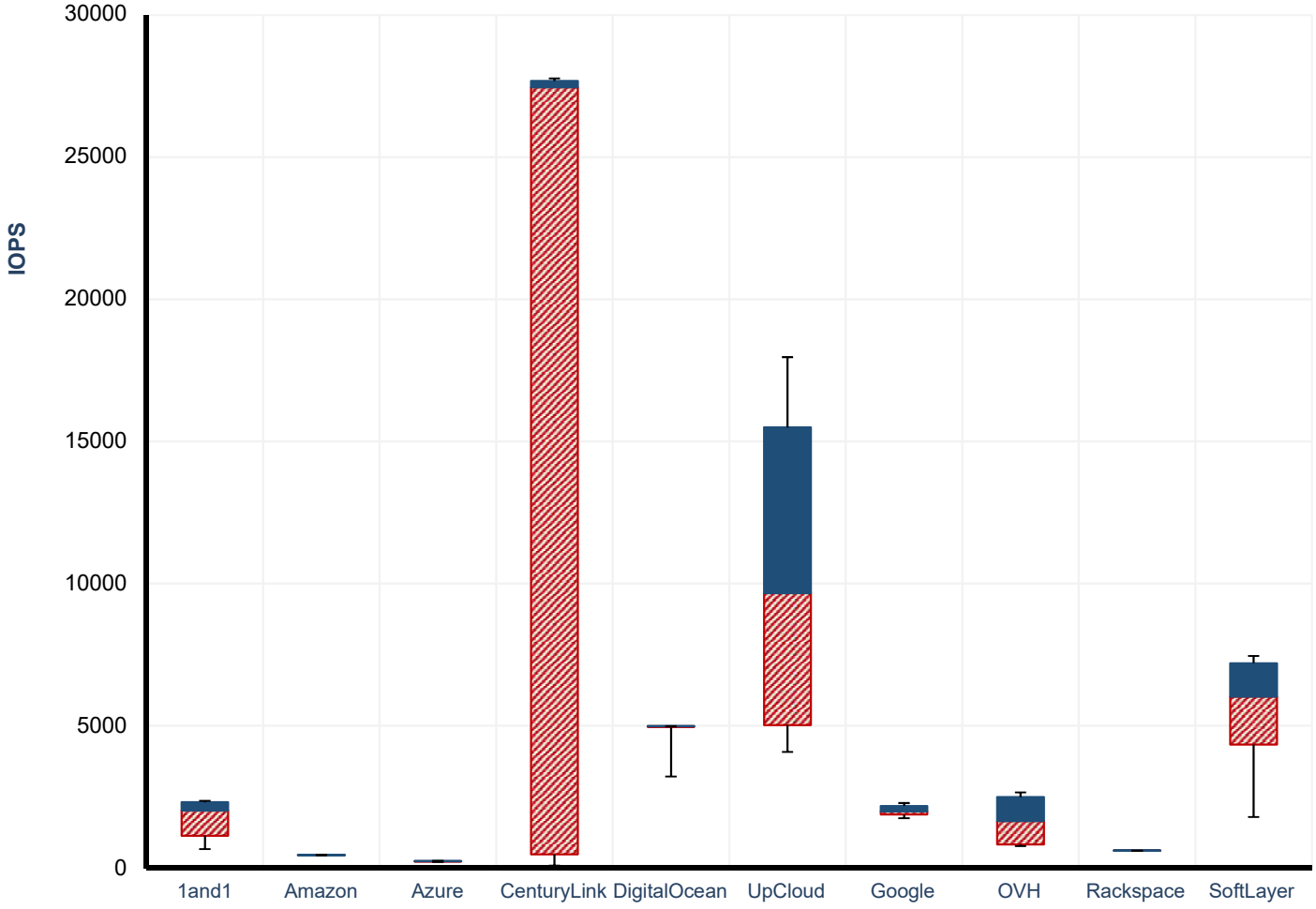


Table 8B.3: Write Block Disk Performance Type 1 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	664	1,132	2,017	2,309	2,357	323	17%
Amazon	439	442	446	452	456	3	1%
Azure	213	221	231	243	250	7	3%
CenturyLink	75	479	27,459	27,683	27,776	12,119	66%
Digital Ocean	3,216	4,962	4,976	4,979	4,981	249	5%
UpCloud	4,079	5,024	9,662	15,497	17,967	3,895	40%
Google	1,747	1,877	1,983	2,176	2,279	89	4%
OVH	765	821	1,646	2,488	2,656	567	34%
Rackspace	599	602	605	608	611	2	0%
SoftLayer	1,789	4,338	6,030	7,197	7,455	1,028	18%

Chart 8B.4: Read (128K) Block Disk Performance Type 2 (Medium VM)

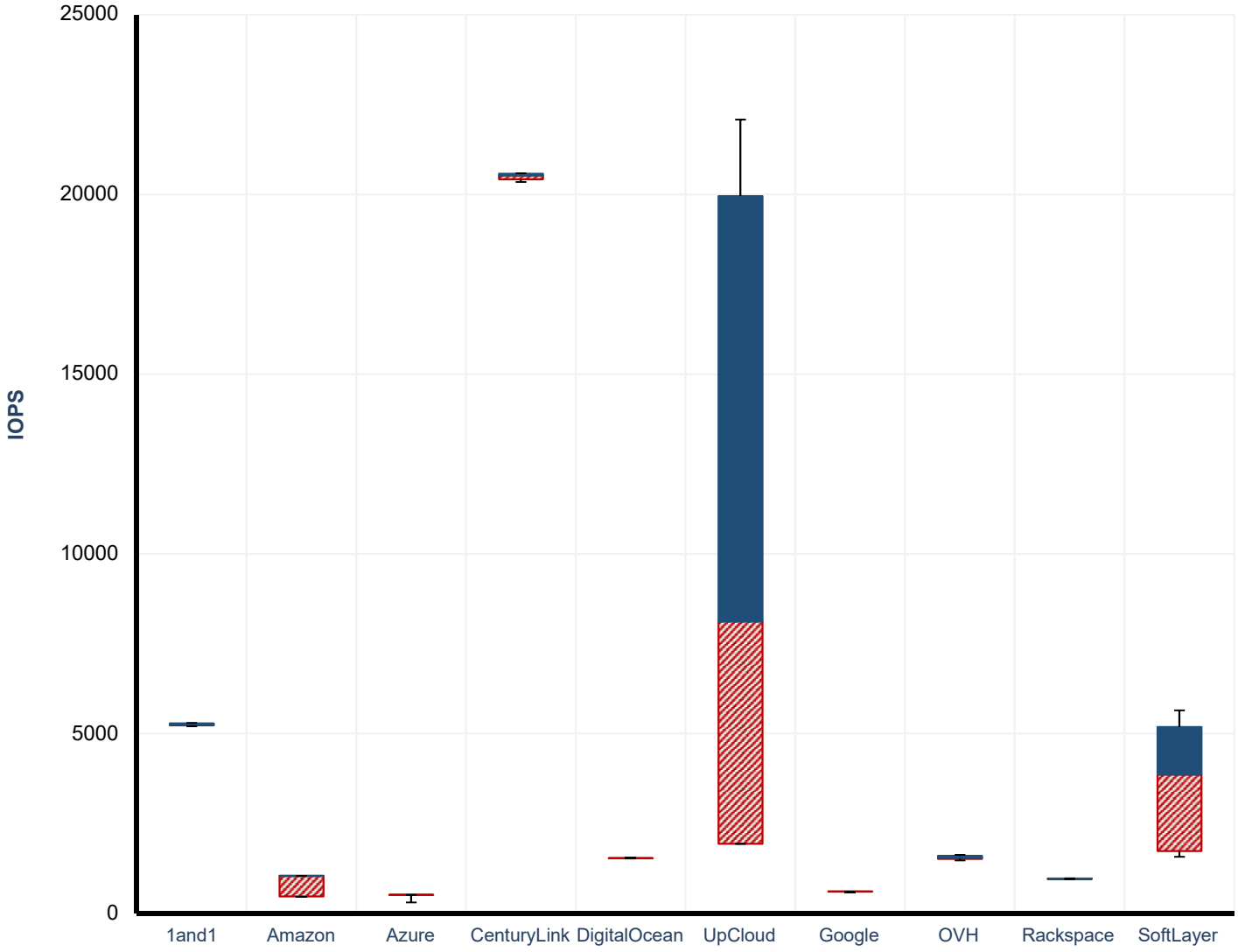


Table 8B.4: Read Block Disk Performance Type 2 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	5,203	5,230	5,250	5,287	5,294	19	0%
Amazon	466	466	1,039	1,041	1,041	288	38%
Azure	300	508	510	510	510	23	4%
CenturyLink	20,350	20,421	20,531	20,579	20,589	54	0%
Digital Ocean	1,524	1,525	1,528	1,528	1,528	1	0%
UpCloud	1,933	1,934	8,123	19,958	22,086	5439	61%
Google	600	600	601	601	601	0	0%
OVH	1,467	1,513	1,540	1,596	1,623	26	2%
Rackspace	951	955	962	965	967	3	0%
SoftLayer	1,568	1,730	3,862	5,185	5,648	1076	29%

Chart 8B.5: Write (128K) Block Disk Performance Type 2 (Medium VM)

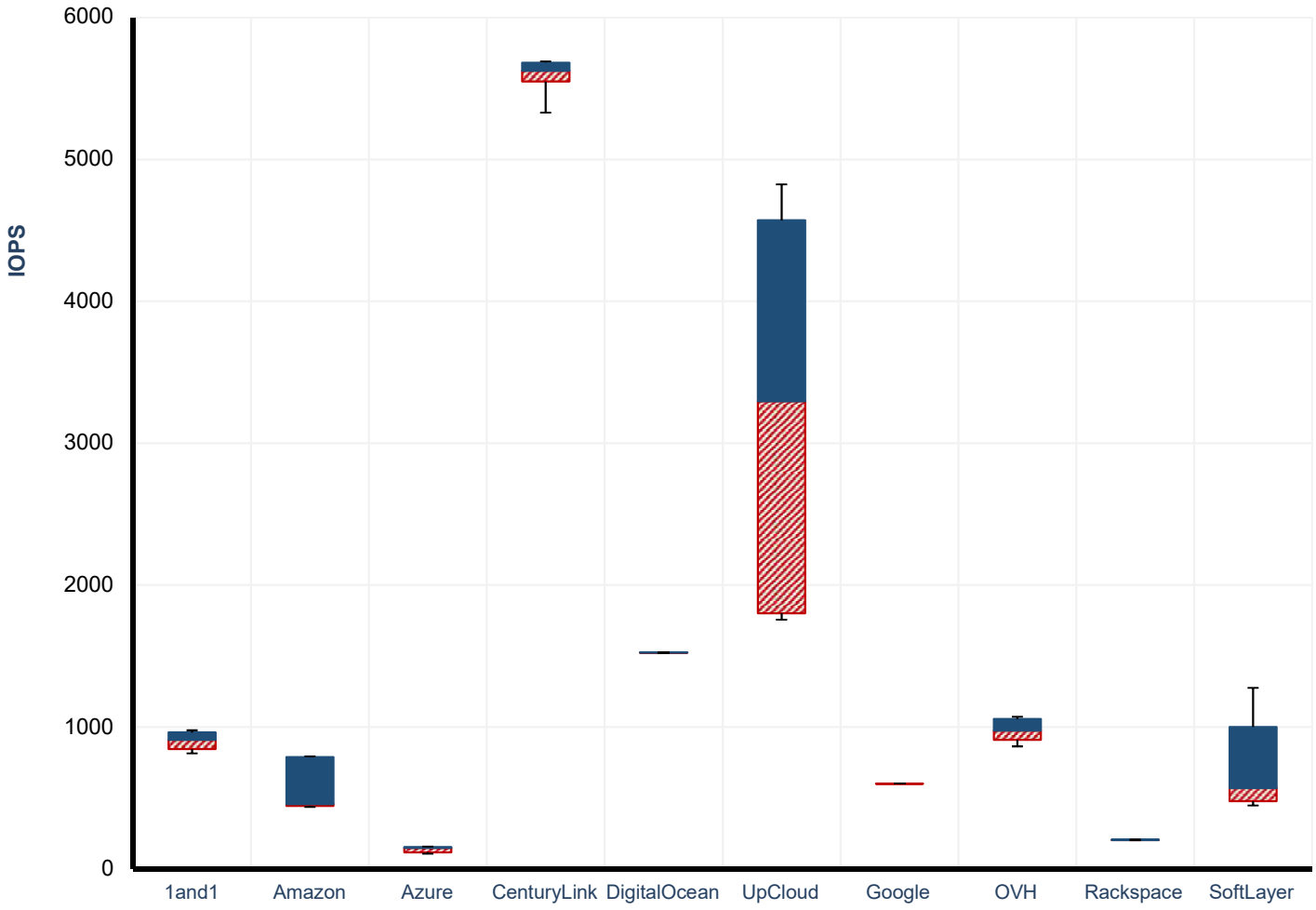


Table 8B.5: Write Block Disk Performance Type 2 (Medium VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	813	843	910	961	976	37	4%
Amazon	436	444	455	787	792	164	27%
Azure	107	116	147	154	156	10	7%
CenturyLink	5,331	5,549	5,626	5,683	5,691	57	1%
Digital Ocean	1,521	1,521	1,525	1,527	1,527	2	0%
UpCloud	4,079	5,024	9,662	15,497	17,967	3895	40%
Google	599	599	600	600	600	0	0%
OVH	863	910	975	1,055	1,071	45	5%
Rackspace	200	201	203	204	206	1	1%
SoftLayer	447	477	570	1,000	1,276	147	24%

LARGE VMs

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

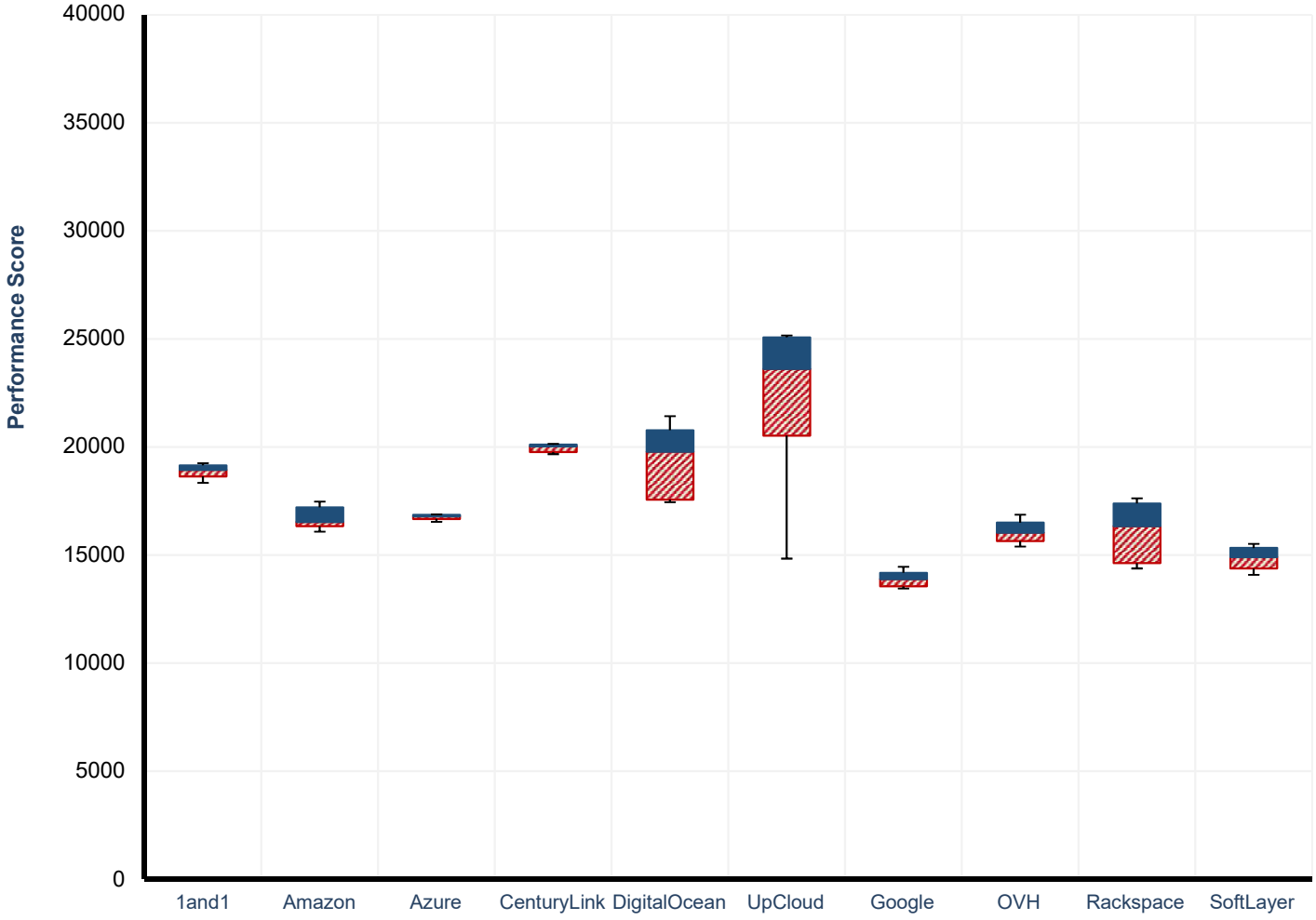


Table 8C.1: VM Performance (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	18,336	18,641	18,945	19,147	19,247	169	1%
Amazon	16,080	16,333	16,529	17,206	17,477	276	2%
Azure	16,540	16,673	16,786	16,859	16,882	62	0%
CenturyLink	19,670	19,760	20,028	20,108	20,141	91	0%
Digital Ocean	17,443	17,566	19,782	20,779	21,424	1,069	6%
UpCloud	14,835	20,528	23,613	25,071	25,159	1,974	9%
Google	13,453	13,550	13,878	14,173	14,455	199	1%
OVH	15,388	15,646	16,035	16,499	16,865	273	2%
Rackspace	14,379	14,623	16,330	17,390	17,629	816	5%
SoftLayer	14,088	14,378	14,899	15,328	15,517	275	2%

Chart 8C.2: Read (4K) Block Disk Performance Type 1 (Large VM)

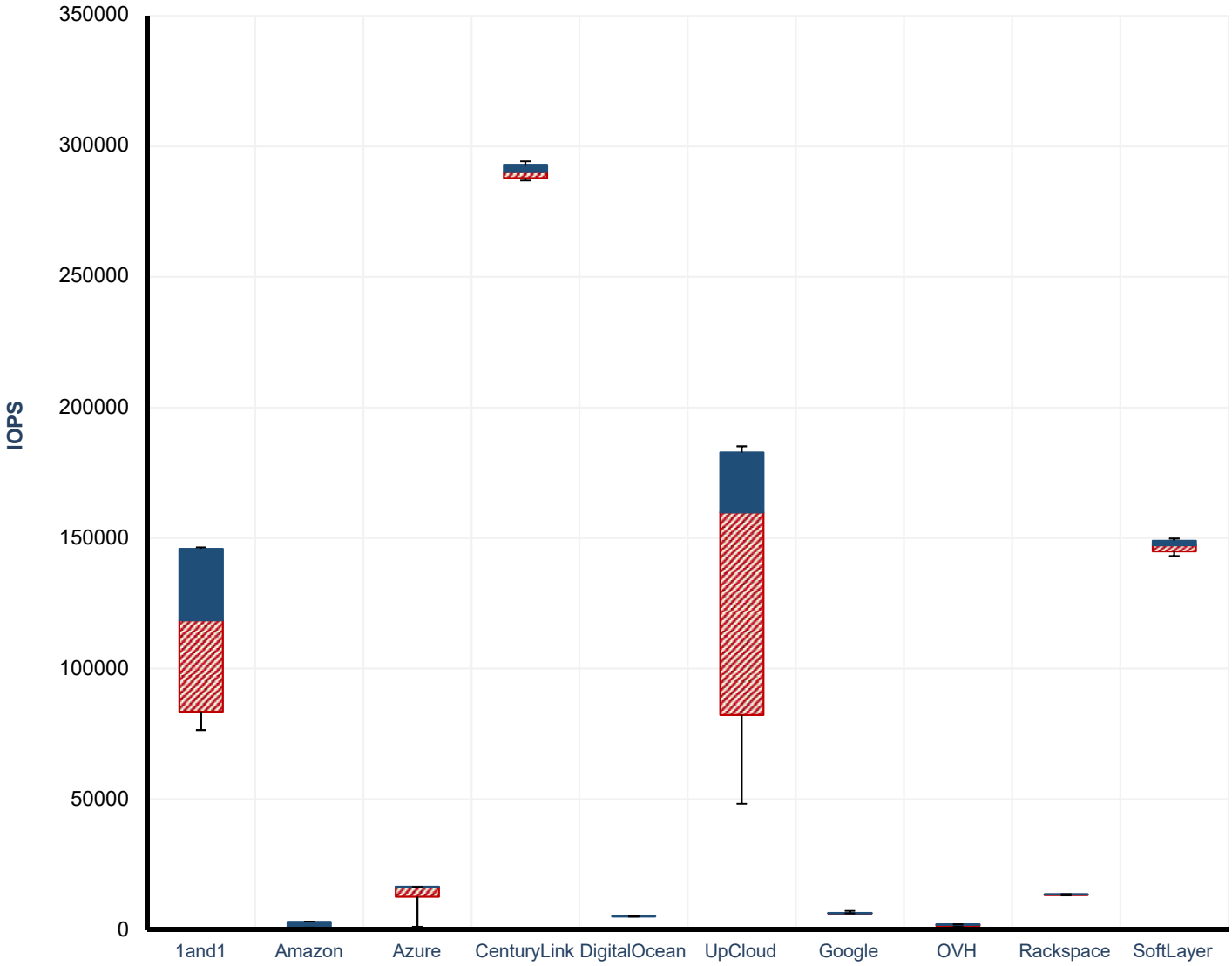


Table 8C.2: Read Block Disk Performance Type 1 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	76,440	83,543	118,509	145,853	146,412	27,634	23%
Amazon	781	782	783	3,048	3,048	766	71%
Azure	1,127	12,631	16,325	16,333	16,335	2,037	13%
CenturyLink	286,902	287,821	290,193	292,888	294,293	1,590	1%
Digital Ocean	5,004	5,008	5,008	5,009	5,009	1	0%
UpCloud	48,249	82,261	159,869	182,761	185,110	31,827	21%
Google	6,251	6,255	6,284	6,290	7,245	69	1%
OVH	1,262	1,443	1,965	2,025	2,062	176	9%
Rackspace	13,122	13,237	13,513	13,597	13,643	104	1%
SoftLayer	143,093	144,855	147,265	148,934	149,776	1,326	1%

Chart 8C.3: Write (4K) Block Disk Performance Type 1 (Large VM)

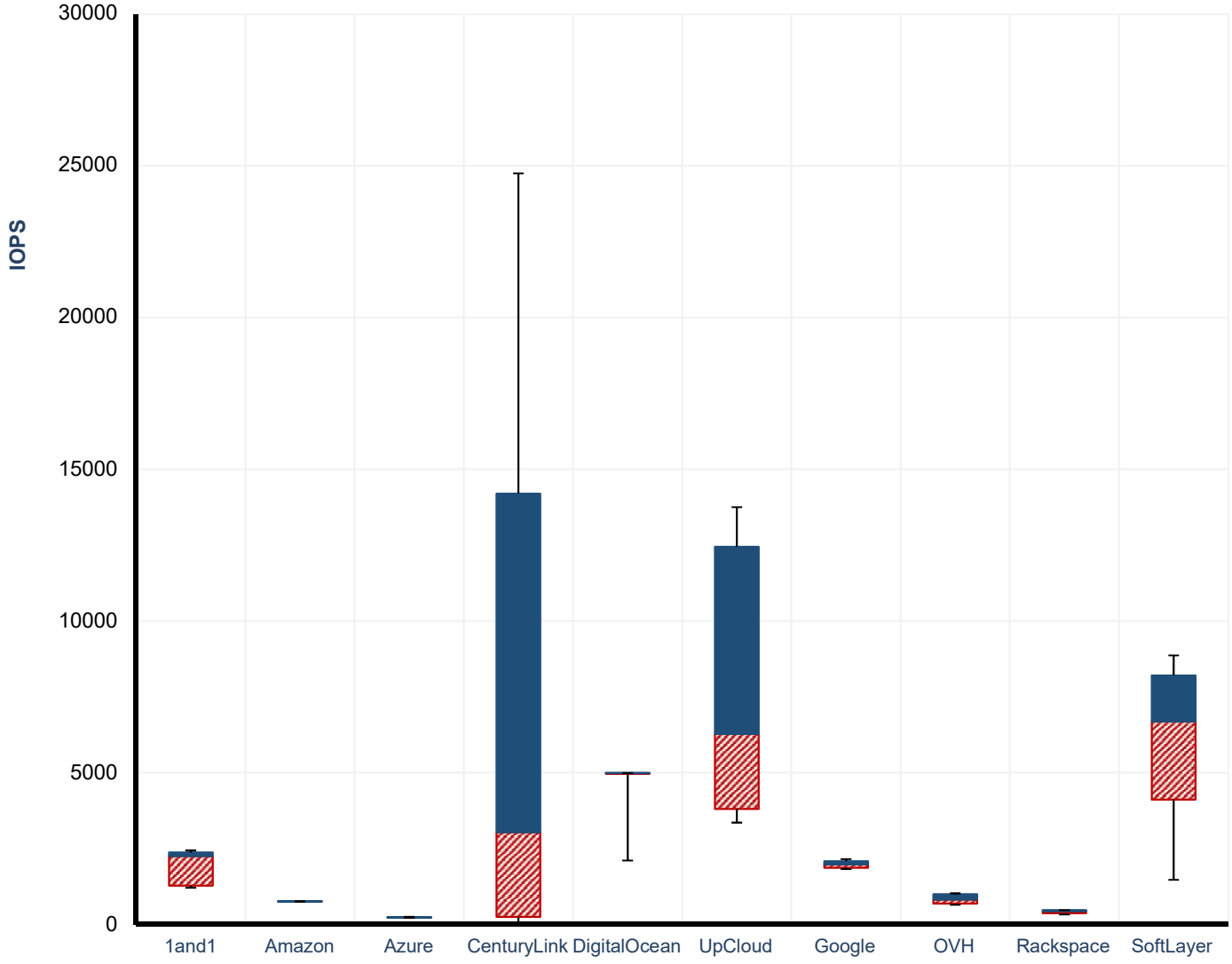


Table 8C.3: Write Block Disk Performance Type 1 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	1,202	1,277	2,252	2,369	2,437	273	13%
Amazon	744	747	753	758	763	3	0%
Azure	213	217	228	240	247	7	3%
CenturyLink	40	243	3,034	14,198	24,756	5,495	99%
Digital Ocean	2,105	4,967	4,985	4,989	4,990	407	8%
UpCloud	3,353	3,805	6,279	12,448	13,753	3,004	41%
Google	1,819	1,865	1,975	2,084	2,151	66	3%
OVH	642	683	819	993	1,022	105	13%
Rackspace	326	363	432	465	466	36	8%
SoftLayer	1,465	4,115	6,692	8,205	8,863	1,430	22%

Chart 8C.4: Read (128K) Block Disk Performance Type 2 (Large VM)

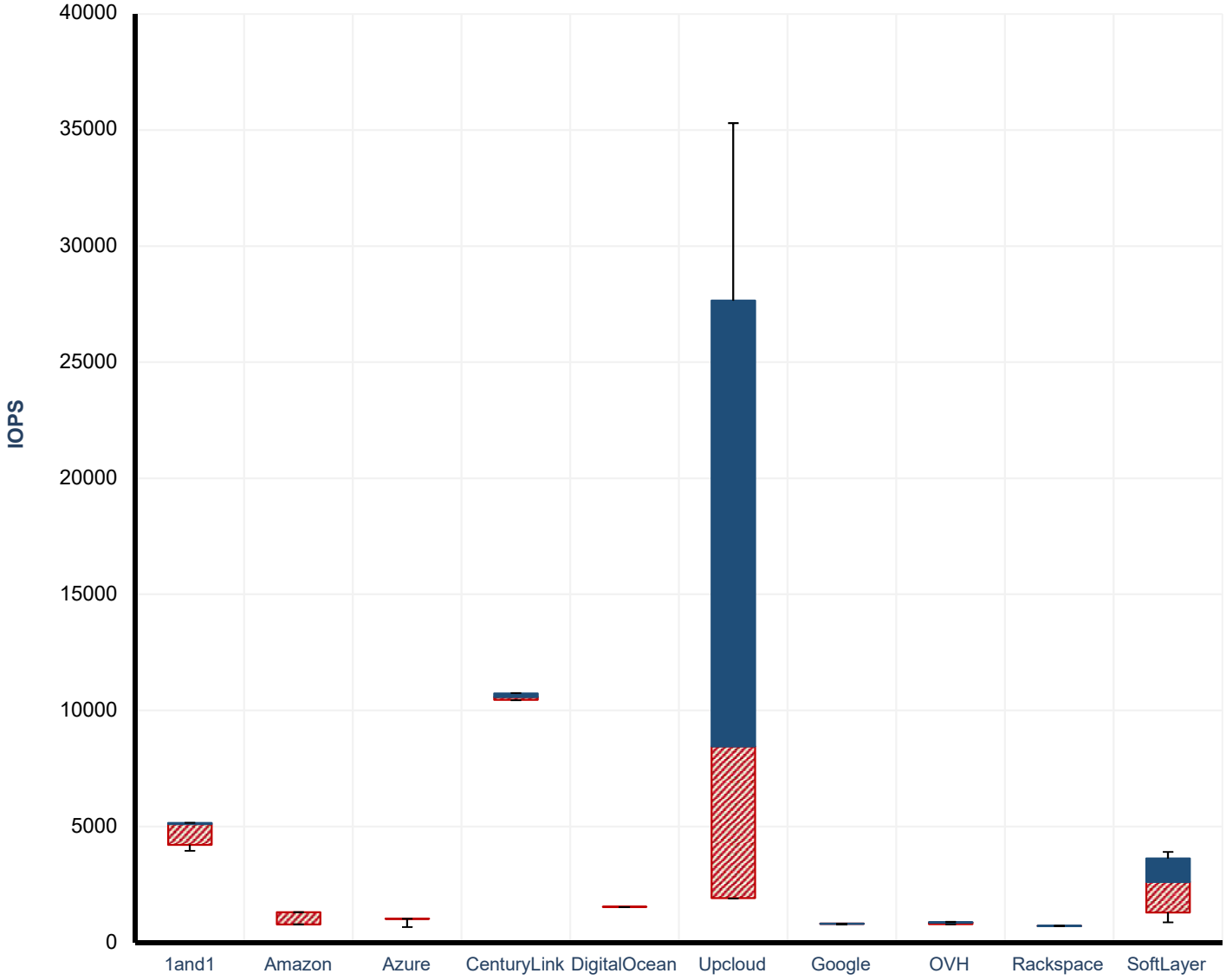


Table 8C.4: Read Block Disk Performance Type 2 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	3,951	4,210	5,103	5,152	5,159	397	8%
Amazon	777	778	1,303	1,303	1,303	263	25%
Azure	666	1,019	1,020	1,020	1,020	37	4%
CenturyLink	10,432	10,453	10,575	10,724	10,748	91	1%
Digital Ocean	1,525	1,527	1,528	1,528	1,528	1	0%
UpCloud	1,895	1,912	8,447	27,654	35,298	7925	80%
Google	800	801	801	802	802	0	0%
OVH	781	794	860	878	886	24	3%
Rackspace	705	708	712	717	718	3	0%
SoftLayer	864	1,296	2,610	3,620	3,898	733	29%

Chart 8C.5: Write (128K) Block Disk Performance Type 2 (Large VM)

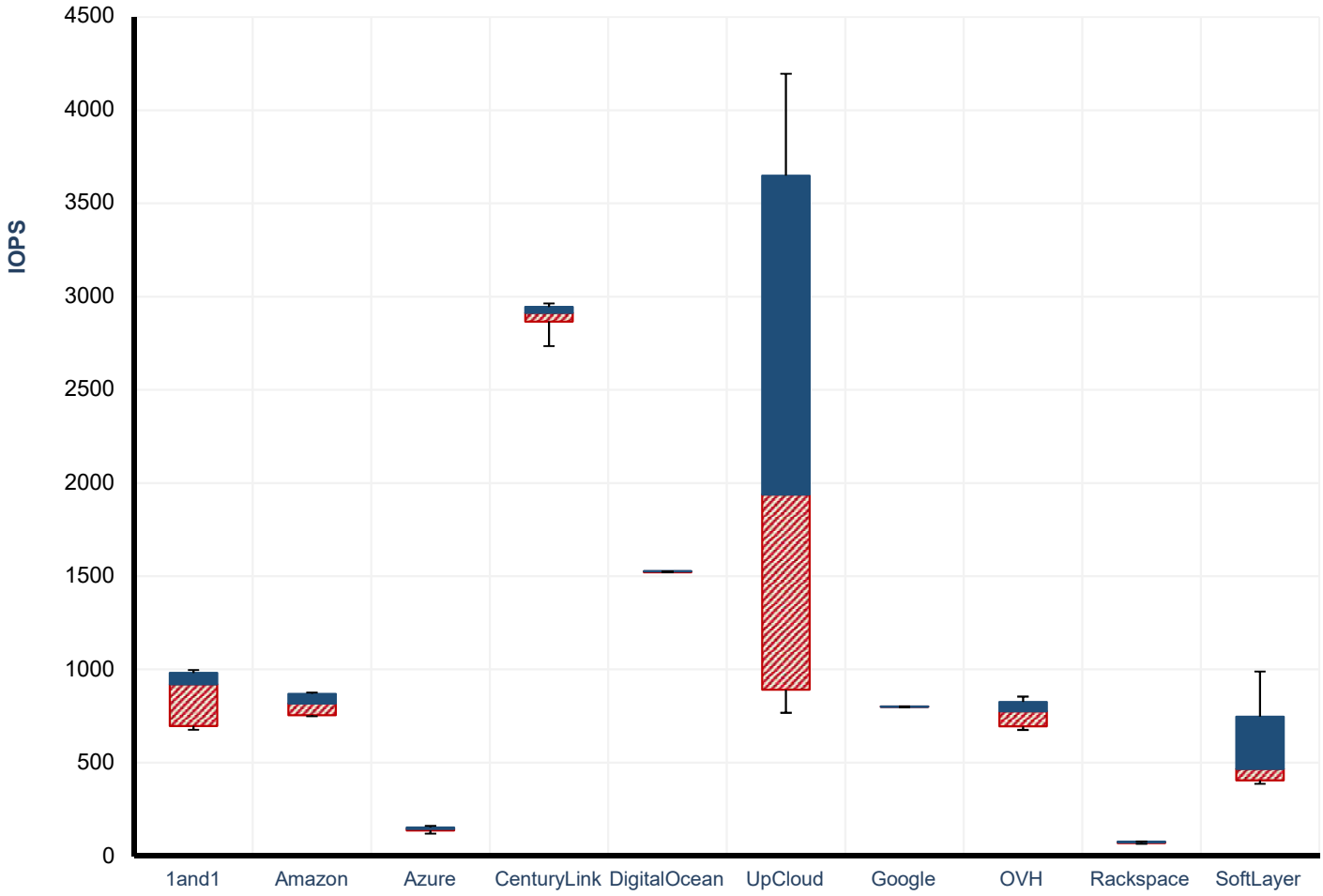


Table 8C.5: Write Block Disk Performance Type 2 (Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	676	697	920	981	996	89	10%
Amazon	749	754	817	869	876	50	6%
Azure	119	136	144	152	160	6	4%
CenturyLink	2,734	2,866	2,913	2,944	2,963	37	1%
Digital Ocean	1,521	1,521	1,526	1,527	1,527	2	0%
UpCloud	3,353	3,805	6,279	12,448	13,753	3004	41%
Google	799	799	800	801	802	1	0%
OVH	675	694	775	825	854	44	6%
Rackspace	64	68	73	76	77	3	4%
SoftLayer	386	404	466	746	989	99	20%

EXTRA LARGE VMs

Chart 8D.1: VM Performance (Extra Large VMs)

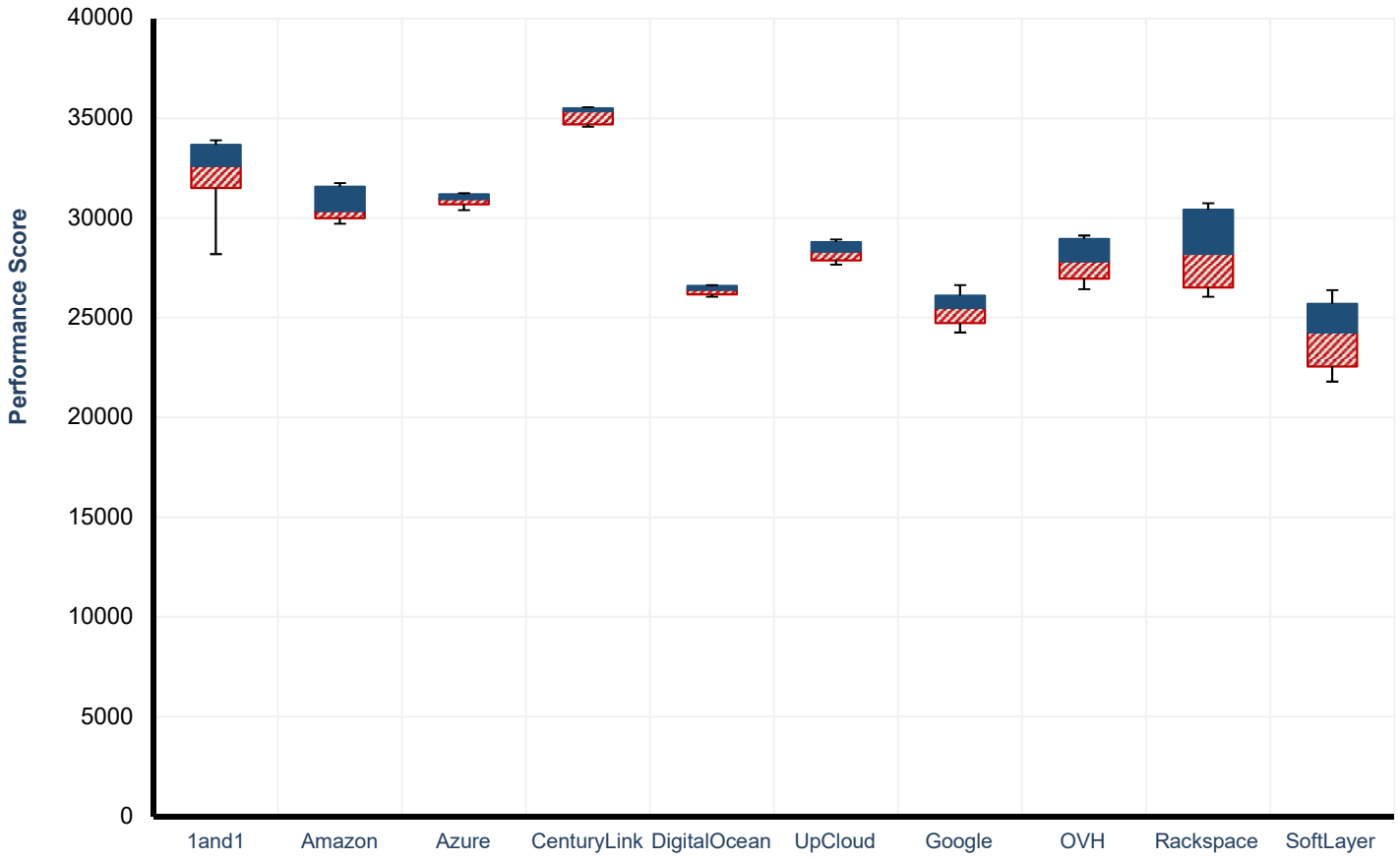


Table 8D.1: VM Performance (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	28,194	31,507	32,609	33,667	33,906	781	2%
Amazon	29,718	29,992	30,356	31,567	31,754	450	1%
Azure	30,401	30,690	30,954	31,192	31,253	153	0%
CenturyLink	34,577	34,700	35,355	35,506	35,559	251	1%
Digital Ocean	26,051	26,181	26,410	26,593	26,637	133	1%
UpCloud	27,659	27,881	28,322	28,800	28,925	286	1%
Google	24,261	24,735	25,492	26,107	26,633	426	2%
OVH	26,434	26,964	27,827	28,944	29,125	600	2%
Rackspace	26,060	26,522	28,215	30,419	30,738	1,288	5%
SoftLayer	21,802	22,560	24,261	25,694	26,384	1,000	4%

Chart 8D.2: Read (4K) Block Disk Performance Type 1 (Extra Large VM)

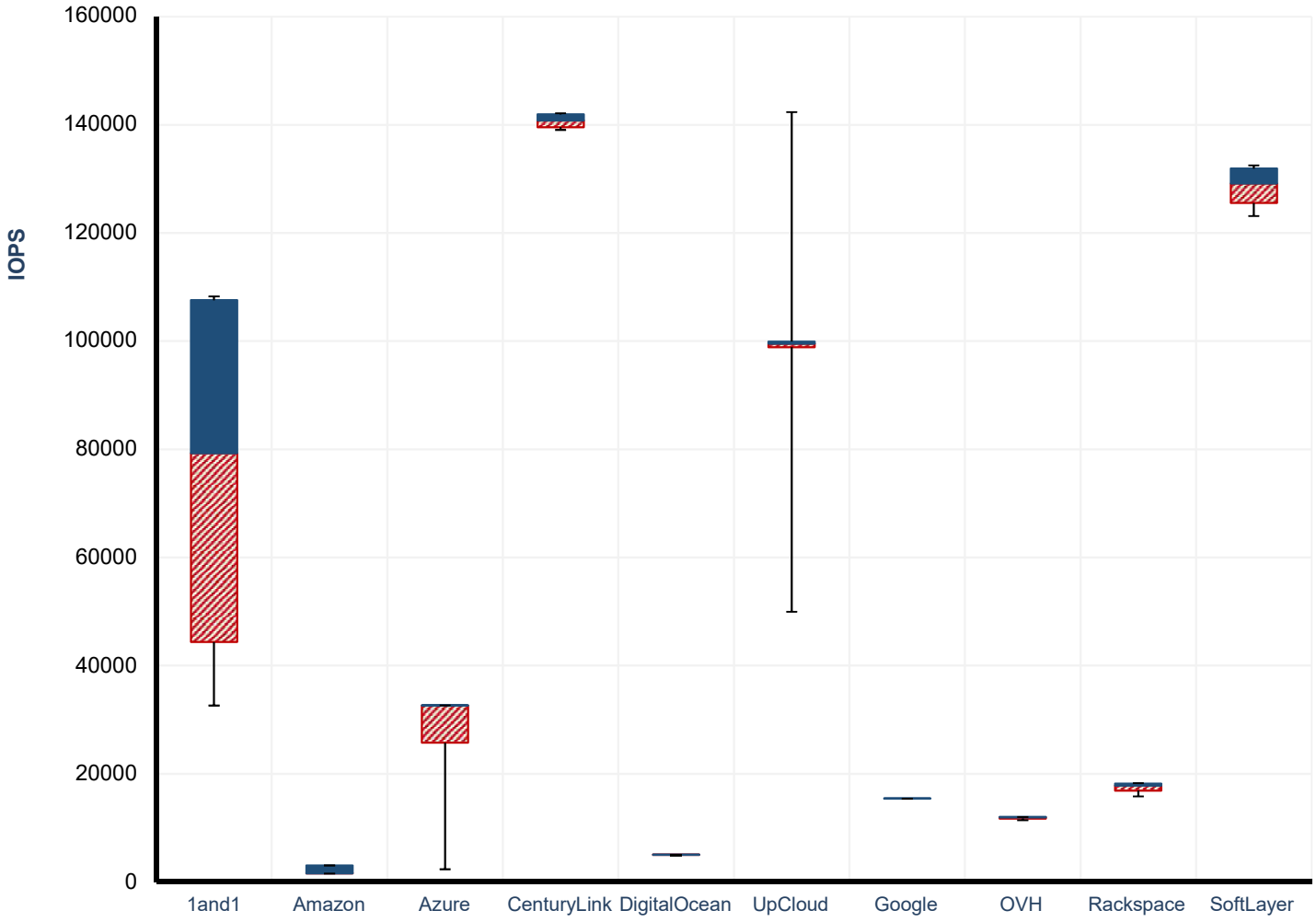


Table 8D.2: Read Block Disk Performance Type 1 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	32,623	44,369	79,304	107,582	108,264	28,873	37%
Amazon	1,566	1,567	1,569	3,048	3,049	594	32%
Azure	2,352	25,748	32,648	32,662	32,664	3,988	13%
CenturyLink	139,069	139,576	140,799	141,944	142,147	674	0%
Digital Ocean	4,997	5,007	5,008	5,010	5,010	2	0%
UpCloud	49,978	98,896	99,537	99,943	142,357	8,619	9%
Google	15,376	15,429	15,429	15,430	15,430	3	0%
OVH	11,432	11,734	11,953	12,022	12,025	107	1%
Rackspace	15,842	16,911	17,802	18,181	18,288	459	3%
SoftLayer	123,129	125,536	129,131	131,921	132,495	2,139	2%

Chart 8D.3: Write (4K) Block Disk Performance Type 1 (Extra Large VM)

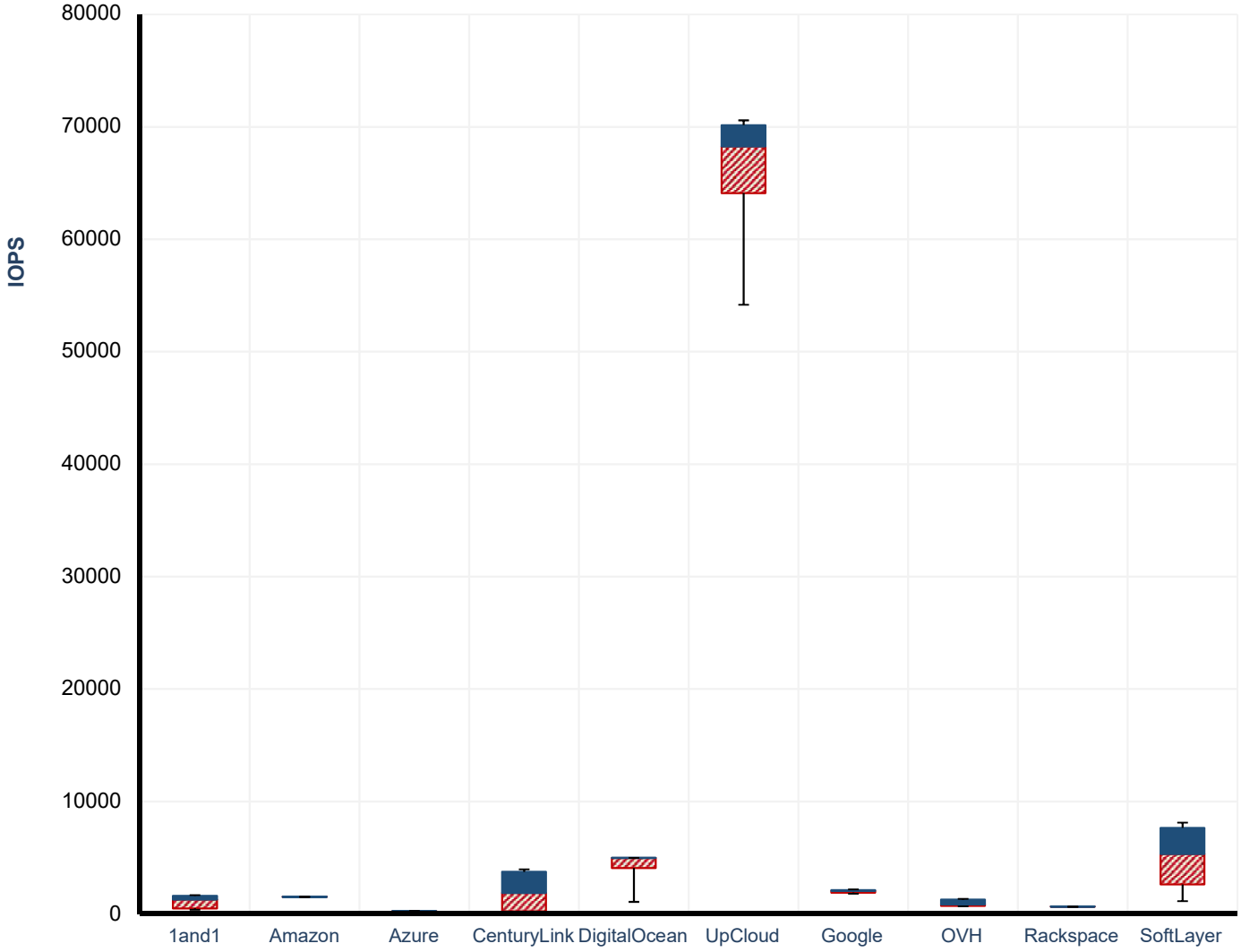


Table 8D.3: Write Block Disk Performance Type 1 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	370	498	1,278	1,612	1,664	367	32%
Amazon	1,501	1,507	1,518	1,525	1,537	6	0%
Azure	209	224	235	248	260	8	3%
CenturyLink	75	242	1,867	3,741	3,976	1,159	60%
Digital Ocean	1,073	4,084	4,983	4,988	4,989	720	15%
UpCloud	54,182	64,119	68,254	70,153	70,578	2,486	4%
Google	1,808	1,891	2,045	2,125	2,177	72	4%
OVH	681	711	848	1,271	1,343	158	18%
Rackspace	634	644	651	658	662	4	1%
SoftLayer	1,143	2,626	5,333	7,650	8,125	1,704	32%

Chart 8D.4: Read (128K) Block Disk Performance Type 2 (Extra Large VM)

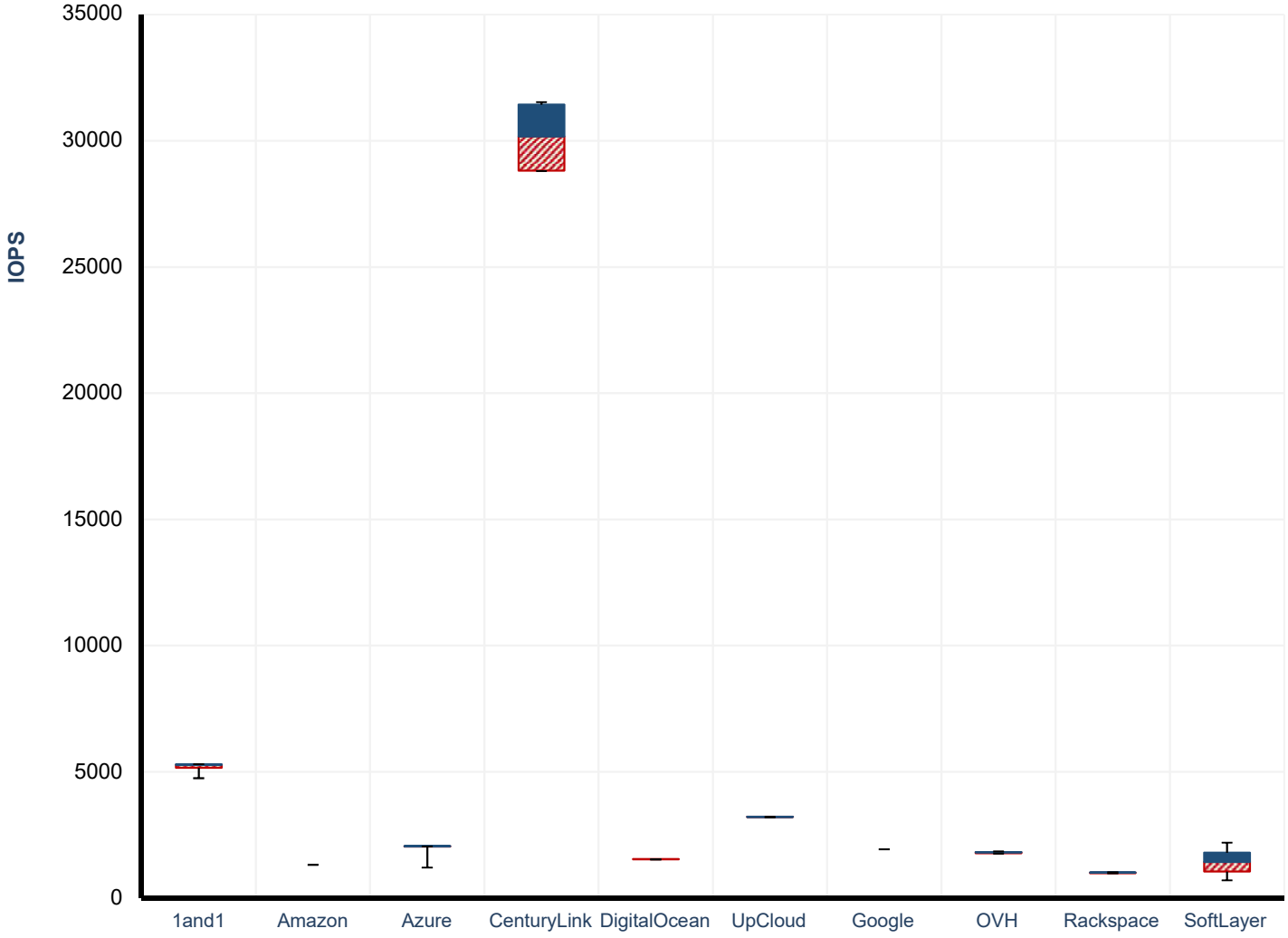


Table 8D.4: Read Block Disk Performance Type 2 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	4,742	5,151	5,273	5,294	5,299	101	2%
Amazon	1,303	1,303	1,303	1,303	1,303	0	0%
Azure	1,200	2,032	2,040	2,041	2,041	91	4%
CenturyLink	28,804	28,817	30,172	31,431	31,529	1014	3%
Digital Ocean	1,526	1,528	1,528	1,528	1,528	0	0%
UpCloud	3,200	3,200	3,203	3,204	3,204	1	0%
Google	1,921	1,921	1,921	1,921	1,921	0	0%
OVH	1,757	1,768	1,799	1,819	1,840	17	1%
Rackspace	971	981	998	1,007	1,012	8	1%
SoftLayer	692	1,044	1,430	1,788	2,190	236	17%

Chart 8D.5: Write (128K) Block Disk Performance Type 2 (Extra Large VM)

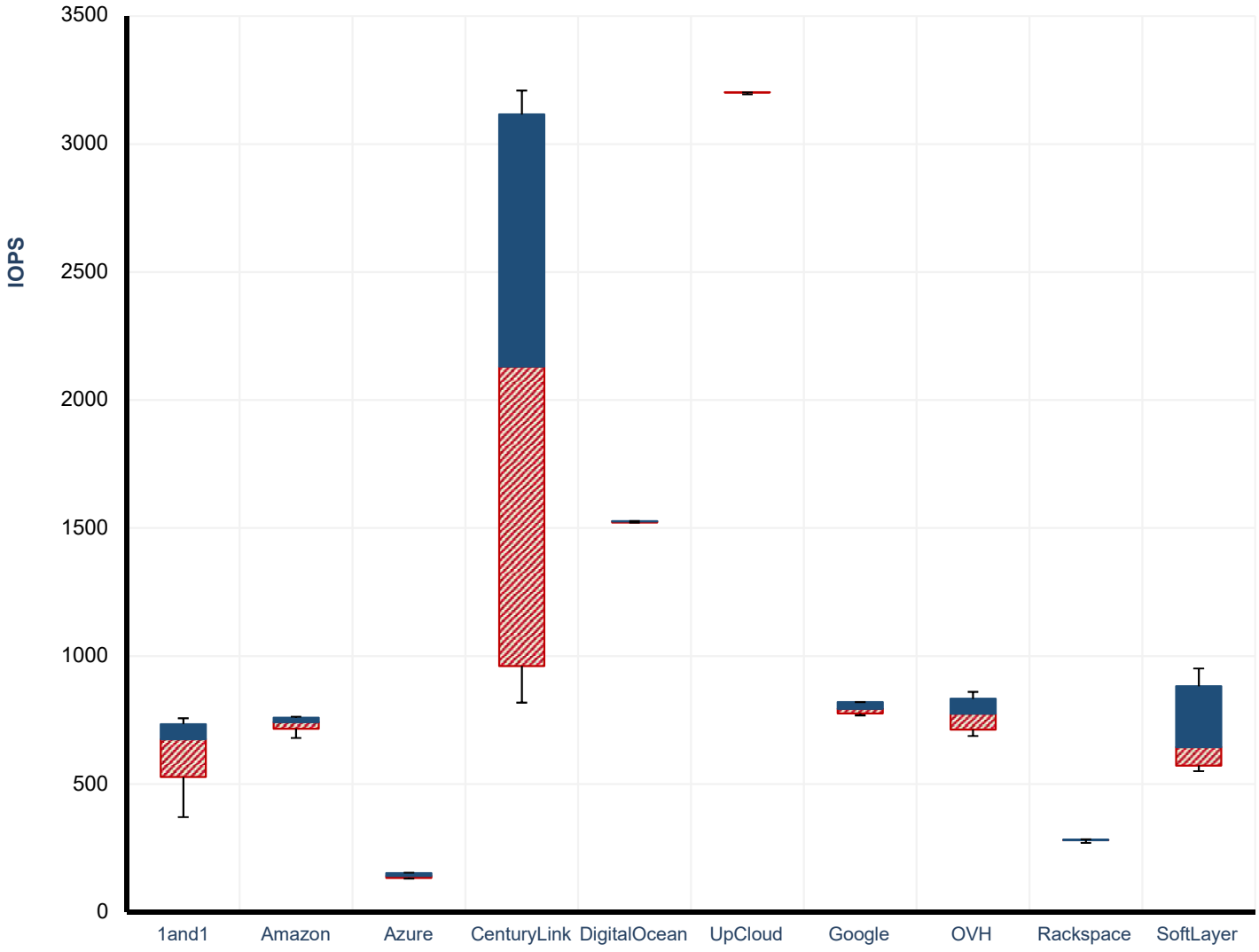


Table 8D.5: Write Block Disk Performance Type 2 (Extra Large VMs)

PROVIDER	MIN	5TH	MEDIAN	95TH	MAX	STDEV	CV
1and1	371	527	676	734	757	76	12%
Amazon	680	716	741	759	763	15	2%
Azure	130	133	141	152	154	5	4%
CenturyLink	818	961	2,132	3,116	3,209	727	35%
Digital Ocean	1,521	1,522	1,526	1,527	1,527	2	0%
UpCloud	3,194	3,201	3,202	3,202	3,202	1	0%
Google	768	776	793	820	820	14	2%
OVH	688	712	775	833	860	39	5%
Rackspace	270	280	282	283	284	2	1%
SoftLayer	550	572	644	882	951	86	13%

ABOUT CLOUD SPECTATOR

Cloud Spectator is a data-driven cloud consultancy specializing in cloud performance, price-performance analysis, and cloud consulting.

Cloud Spectator actively monitors many of the largest cloud Infrastructure as a Service (IaaS) providers in the world to evaluate and compare Cloud service performance (i.e., CPU, RAM, disk, internal network, external network and workloads) and pricing to achieve transparency in the cloud market.

Cloud Spectator provides full spectrum cloud consulting services including strategy and planning, architecture and technology selection, deployment and implementation, as well as cloud migration services. In addition, Cloud Spectator also helps cloud providers understand their market position within a competitive landscape.

The firm was founded in early 2011 and is located in Boston, MA.

For questions about this report, to request a custom report, or if you have general inquiries about our products and services, please contact Cloud Spectator (www.cloudspectator.com) at +1 (617) 300-0711 or contact@cloudspectator.com.

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APPENDIX

Tested VM & Storage Configurations

The table below summarizes the virtual machine configurations and data centers that were tested in this report. (The table is on the following page.)

VM Size	Provider	Instance	Storage Type	vCPU	RAM	Storage	Data Center
Small	1and1	Cloud Server XL	SSD Storage	2	4	120	Germany
	Amazon	c5.large	SSD EBS	2	3.75	100	EU (Ireland)
	Azure	F2s v2	Premium Storage P10 (128GB)	2	4	128	North Europe
	CenturyLink	Customized	Block Storage	2	4	100	GB3
	Digital Ocean	4GB	SSD Block Storage	2	4	100	London 1
	UpCloud	Customized	Max IOPs Block Storage	2	4	100	Frankfurt 1
	Google	Customized	SSD Persistent Disk	2	4	100	Europe-West1
	OVH	B2-7	High Speed Volume	2	7	200	SBG3
	Rackspace	Compute1-4	SSD Block Storage	2	3.75	100	London
	SoftLayer	Customized	Portable Storage	2	4	100	AMS01
Medium	1and1	Cloud Server XXL	SSD Storage	4	8	160	Germany
	Amazon	c5.xlarge	SSD EBS	4	7.5	150	EU (Ireland)
	Azure	F4s v2	Premium Storage P10 (128GB)	4	8	128	North Europe
	CenturyLink	Customized	Block Storage	4	8	150	GB3
	Digital Ocean	8GB	SSD Block Storage	4	8	150	London 1
	UpCloud	Customized	Max IOPs Block Storage	4	8	150	Frankfurt 1
	Google	Customized	SSD Persistent Disk	4	8	150	Europe-West1
	OVH	B2-15	High Speed Volume	4	15	400	SBG3
	Rackspace	Compute1-8	SSD Block Storage	4	7.5	150	London
	SoftLayer	Customized	Portable Storage	4	8	150	AMS01
Large	1and1	Cloud Server 3XL	SSD Storage	8	16	240	Germany
	Amazon	c5.2xlarge	SSD EBS	8	15	200	EU (Ireland)
	Azure	F8s v2	Premium Storage P15 (256GB)	8	16	128	North Europe
	CenturyLink	Customized	Block Storage	8	16	200	GB3
	Digital Ocean	16GB	SSD Block Storage	8	16	200	London 1
	UpCloud	Customized	Max IOPs Block Storage	8	16	200	Frankfurt 1
	Google	Customized	SSD Persistent Disk	8	16	200	Europe-West1
	OVH	B2-30	High Speed Volume	8	30	800	SBG3
	Rackspace	Compute1-15	SSD Block Storage	8	15	200	London
	SoftLayer	Customized	Portable Storage	8	16	200	AMS01
Extra Large	1and1	Cloud Server 5XL	SSD Storage	16	48	500	Germany
	Amazon	c5.4xlarge	SSD EBS	16	30	500	EU (Ireland)
	Azure	F16s v2	Premium Storage P20 (512GB)	16	32	512	North Europe
	CenturyLink	Customized	Block Storage	16	32	500	GB3
	Digital Ocean	32GB	SSD Block Storage	16	32	500	London 1
	UpCloud	Customized	Max IOPs Block Storage	16	32	500	Frankfurt 1
	Google	Customized	SSD Persistent Disk	16	32	500	Europe-West1
	OVH	B2-60	High Speed Volume	16	60	1600	SBG3
	Rackspace	Compute1-30	SSD Block Storage	16	30	500	London
	SoftLayer	Customized	Portable Storage	16	32	500	AMS01