

# Cloud IaaS Performance & Price-Performance

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Comparing Linux Compute Performance of Amazon EC2, Microsoft Azure, and SherWeb

Prepared for SherWeb  
Commercial Report

Published on 1/2015



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## EXECUTIVE SUMMARY

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Cloud Spectator was commissioned by SherWeb to gauge the performance of different virtual machine (VM) sizes on three public cloud providers. Amazon Web Services and Microsoft Azure were included in this study for comparison with SherWeb. Both performance and price-performance were examined to evaluate the value of each provider's VMs. The purpose of the study was to understand the disparity of performance and value (defined as price-performance) between cloud providers for similarly sized VMs. The primary components of virtual servers - vCPU, memory, storage and internal network - were evaluated for each of the VMs.

### vCPU PERFORMANCE SUMMARY

For this study, Cloud Spectator evaluated vCPU performance by benchmarking the VMs using Geekench 3, a suite of benchmark tests that simulate tasks such as cryptographic encoding and image processing. Testing occurred over the course of a 5-day testing period. Pricing was examined in conjunction with the performance tests.

#### vCPU Performance Key Findings:

- SherWeb exhibited on average 59% higher vCPU performance than Amazon and Microsoft Azure
- Microsoft Azure vCPU performance had the lowest variability
- SherWeb offered the highest price-performance value for vCPU

### MEMORY PERFORMANCE SUMMARY

Memory was evaluated using the Geekbench 3 benchmark suite over a 5-day testing period. Pricing was examined in conjunction with the performance tests.

#### Memory Performance Key Findings:

- SherWeb exhibited on average 24% higher memory performance than Amazon and Microsoft Azure
- Microsoft Azure's memory performance had the lowest variability
- SherWeb offered the highest price-performance value for memory

## STORAGE PERFORMANCE SUMMARY

Storage was evaluated using the FIO disk benchmark which tests the sequential read/write and random read/write operations of storage (block sizes of 4kb and 32kb were examined). Testing occurred over a 5-day test period. Persistent storage (offered as “block storage” or “redundant storage”) was used in all storage tests. Pricing was examined in conjunction with the performance tests.

### Storage Performance Key Findings:

- SherWeb exhibited on average 11x higher storage performance than Amazon and Microsoft Azure
- Amazon's storage performance had the lowest variability
- SherWeb offered the highest price-performance value for storage

## INTERNAL NETWORK PERFORMANCE SUMMARY

Internal network performance was measured as the throughput and latency between VMs within the internal environments of the cloud provider (measured using iperf and ping respectively) over the course of a 5-day test period. Pricing was examined in conjunction with the performance tests.

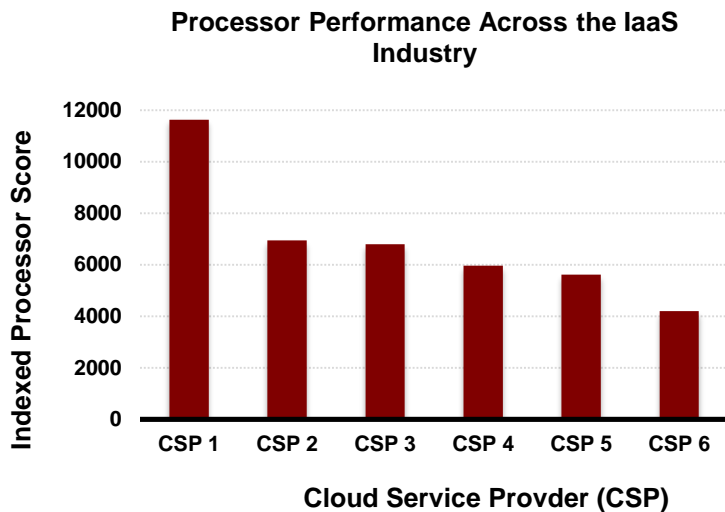
### Internal Network Performance Key Findings:

- Azure exhibited the highest throughput
- Amazon exhibited the lowest latency
- Amazon 's internal network performance had the lowest variability
- SherWeb offered the highest price-performance value for internal network on the majority of tests run across the 2,4,8 vCPU VMs

**WHY DOES PERFORMANCE MATTER?**

Cloud infrastructure performance is a key consideration that should not be overlooked. Differences in the performance outputs of virtual machines across the industry make it difficult to compare across IaaS providers in a standardized manner by simply examining features and/or pricing. Figure 1 on the left illustrates an example of the average processor performance from a sample of Cloud Service Providers (CSPs) as studied by Cloud Spectator. CSP 1 and CSP 6 (names removed) have a marked 3x difference in processor performance, giving CSP 1 a sizable advantage in many processor-intensive workloads. CSPs 2-5 exhibit a closer resemblance in processor performance, but also do not offer nearly as much processing power as CSP 1. Selecting the wrong provider to house an

application can result in unnecessary overspending and/or application performance problems.



Cloud Spectator examines infrastructure performance on both a hardware and an application layer. By examining the underlying hardware (in most cases, the virtualized hardware), Cloud Spectator can provide an understanding of the theoretical maximum and sustained performance of each component that comprises the server. Running application tests helps determine which hardware bottlenecks occur first on the server for different types of applications. This proactively addresses performance concerns in a test environment before it can affect a production environment.

Figure 1: Variance in VM performance across the industry means that simply comparing features or pricing cannot make an apples-to-apples

Table 1 below lists the 3 hardware components studied in this project, and each purpose as a function in the server.

CPU PERFORMANCE	MEMORY PERFORMANCE	STORAGE PERFORMANCE	NETWORK PERFORMANCE
The performance of all applications is highly dependent on the CPU. The CPU is responsible for the processing and orchestration of all applications.	While memory performance is not considered one of the key bottlenecks in performance for many applications, a subset of applications—particularly HPC and in-memory databases—is highly dependent on large sustained memory bandwidth.	Because most applications and all data reside on the disk, having fast disk performance is a key consideration for best application performance in many cases.	In a cloud environment, network performance is a critical piece. Scalability, in many cases, is dependent on the availability of additional VMs that must maintain a strong network backbone.

Table 1: A summary of each of the hardware components examined in this study and their functions within the server.

## PRICE-PERFORMANCE COMPARISONS

Cloud Spectator's price-performance calculation, the CloudSpecs Score, provides information on how much performance is realized 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 value is scaled; e.g., a Cloud Service Provider (CSP) with a score of 100 gives 4x the value of a CSP with a score of 25. The CloudSpecs Scores in this report can only be compared with equivalent configurations; e.g., a 1vCPU VM on Provider A can only be compared to a 1vCPU VM on Provider B.

The calculation of the CloudSpecs Score:

1.  $\text{provider\_value} = [\text{Provider Performance Score}] / [\text{Provider Cost}]$
2.  $\text{best\_provider\_value} = \max\{\text{provider\_values}\}$
3.  $\text{CSP's CloudSpecs Score} = 100 * \text{provider\_value} / \text{best\_provider\_value}$

## KEY CONSIDERATIONS

When examining the results of these tests, please keep the following in mind:

- Prices used in the price-performance comparisons are up to date effective December 31, 2014. Pricing may change for the specified VMs after the release of this report.
- Testing was conducted on specific VM types for each provider. Different VM configurations may yield different comparative results between the providers. Amazon and Microsoft offer fixed VM configurations with different resource allocations, while SherWeb offers independently customizable resource configuration.
- Users may experience different performance characteristics across different physical hosts. Factors such as user contention ("noisy neighbor") or malfunctions of the physical hardware can cause suboptimal performance. Cloud Spectator terminated and created new VMs for each test iteration to increase the likelihood of testing on different physical hosts.
- The VMs selected were the base offerings across the providers (with the exception of Provisioned IOPS on Amazon); greater performance may be obtained on certain providers by paying for additional features/services.

## TEST RESULTS

The following section displays the results of the benchmark tests conducted on Amazon, Microsoft Azure and SherWeb. The raw scores and rankings of the three different VM sizes examined across the three providers are shown below.

		AMAZON			AZURE			SHERWEB		
		2vCPU	4vCPU	8vCPU	2vCPU	4vCPU	8vCPU	2vCPU	4vCPU	8vCPU
VCPU	Integer	3RD	3RD	3RD	2ND	2ND	2ND	1ST	1ST	1ST
	Floating Point	3RD	3RD	3RD	2ND	2ND	2ND	1ST	1ST	1ST
Memory	Memory	3RD	2ND	2ND	2ND	3RD	3RD	1ST	1ST	1ST
Storage (4kb)	Sequential Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Sequential Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
Storage (32kb)	Sequential Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Sequential Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
Internal Network	Iperf	3RD	3RD	3RD	1ST	1ST	1ST	2ND	2ND	2ND
	Ping	3RD	1ST	1ST	2ND	3RD	3RD	1ST	2ND	3RD

### Observations:

#### vCPU –

The performance results were surprising because Azure slightly outperformed Amazon despite utilizing lower-grade CPUs. Azure uses the Intel Xeon E5-2660 processors, which outperformed the newer processors utilized by Amazon as shown in the results. A possible rationale for the performance disparities given the aforementioned processor types was that contention for vCPU resources between users on each VM varied between provider to provider. Also, in previous studies, Amazon has shown higher relative performance on single core tests compared to multicore tests. Amazon's single-core performance does not scale to multi-core as effectively as some other providers.

#### Storage –

Amazon remained relatively consistent due to the amount of Provisioned IOPS that were set for the storage volume. Azure's performance was also consistent across the tests, which could possibly be due to throttling in relation to the storage volume size. SherWeb had significantly higher levels of performance, but also higher performance variability (PV).

#### Internal Network –

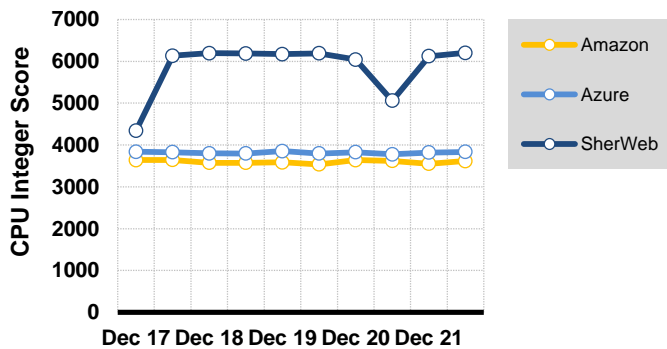
Throughput for Azure and SherWeb were relatively consistent across the different VM sizes. Amazon's throughput noticeably scaled as the machine sizes grew larger. While Azure and SherWeb displayed varying performance results, Amazon's results were very consistent, most likely due to throttling by the provider.

Latency is lower for the 2vCPU machines, but increases on the 4vCPU and 8vCPU machines. This may be due to heavier workloads on the more powerful machines increasing the network load and contention between users on the physical hosts.

## vCPU PERFORMANCE TESTING RESULTS: INTEGER TASKS

vCPU performance was evaluated by running benchmark tests from the Geekbench 3 suite (see *Methodology for details*). Integer tasks are one of the two categories of CPU operations that Geekbench tests in its benchmark. As stated by Geekbench<sup>7</sup>, “All software makes heavy use of integer instructions, meaning a high integer scores indicates good overall performance”. The results are normalized into an overall Integer Score where a higher score denotes better vCPU performance, as shown in the graphs below. Testing occurred on 2vCPU, 4vCPU and 8vCPU machines across the three providers included in this study.

**CPU Performance for Integer Tasks (2 vCPU - MultiCore)**

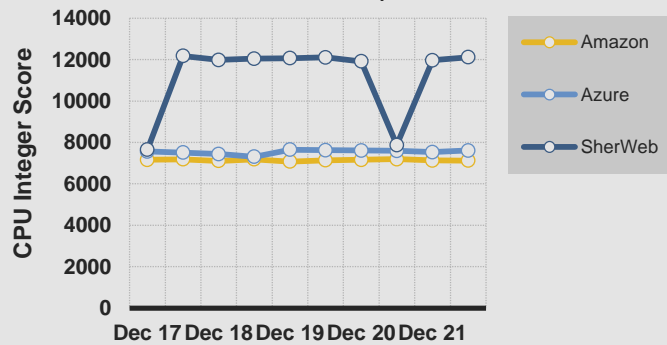


### vCPU Performance – Integer Tasks (Multicore): 2vCPU

SherWeb achieved between 54% to 63% higher performance on average than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 1%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	3598	39	1%	3643	3537
Azure	3817	24	1%	3853	3775
SherWeb	5862	639	11%	6202	4337

**CPU Performance for Integer Tasks (4 vCPU - MultiCore)**

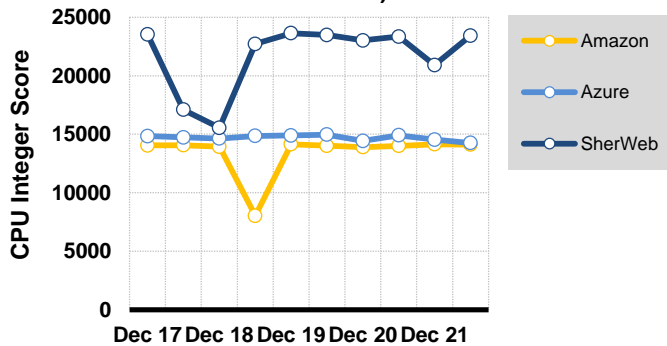


### vCPU Performance – Integer Tasks (Multicore): 4vCPU

SherWeb achieved between 48% to 57% higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 1%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	7146	38	1%	7193	7075
Azure	7546	104	1%	7652	7309
SherWeb	11195	1809	16%	12183	7661

**CPU Performance for Integer Tasks (8 vCPU - MultiCore)**



### vCPU Performance – Integer Tasks (Multicore): 8vCPU

SherWeb achieved between 47% to 61% higher performance than the other providers. Azure exhibited the lowest variability with a CV of 2%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	13435	1901	14%	14135	8029
Azure	14700	236	2%	14954	14243
SherWeb	21670	2953	14%	23633	15541

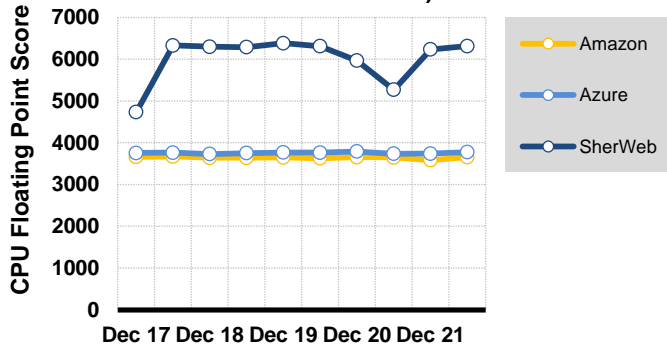
<sup>7</sup> <http://support.primatelabs.com/kb/geekbench/interpreting-geekbench-3-scores>



## vCPU PERFORMANCE TESTING RESULTS: FLOATING POINT TASKS

Floating Point tasks are the other category of CPU operations that Geekbench tests in its benchmark. As stated by Geekbench<sup>2</sup>, “Floating point performance is especially important in video games, digital content creation, and high-performance computing applications”. The results are normalized into an overall Floating Point Score where a higher score denotes better vCPU performance, as shown in the graphs below. Testing occurred on 2vCPU, 4vCPU and 8vCPU machines across the three providers included in this study.

**CPU Performance for Floating Point Tasks (2 vCPU - Multi Core)**

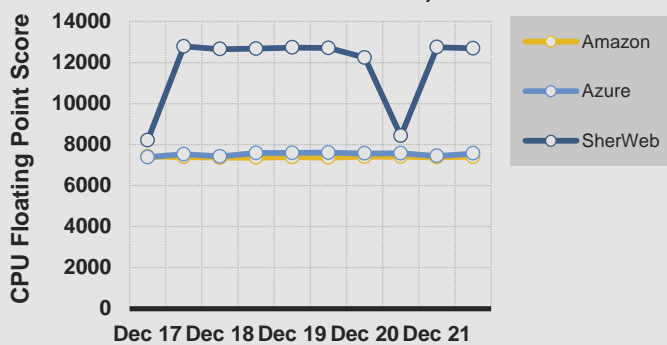


### vCPU Performance – FP Tasks (Multicore): 2vCPU

SherWeb achieved between 60% to 65% higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 1%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	3644	24	1%	3673	3583
Azure	3757	19	1%	3791	3729
SherWeb	6013	560	9%	6385	4731

**CPU Performance for Floating Point Tasks (4 vCPU - Multi Core)**

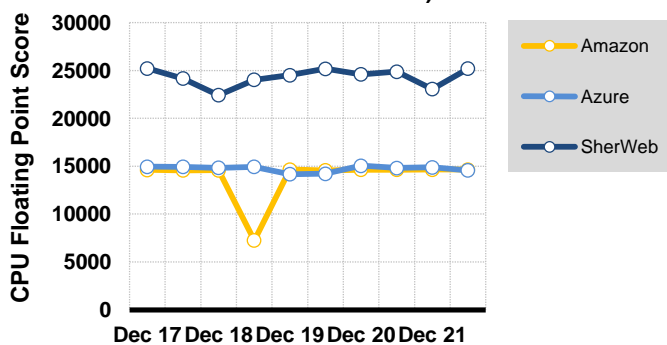


### vCPU Performance – FP Tasks (Multicore): 4vCPU

SherWeb achieved between 57% to 60% higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	7386	20	0%	7413	7356
Azure	7525	81	1%	7608	7385
SherWeb	11786	1836	16%	12782	8210

**CPU Performance for Floating Point Tasks (8 vCPU - Multi Core)**



### vCPU Performance – FP Tasks (Multicore): 8vCPU

SherWeb achieved between 65% to 75% higher performance than the other providers. Azure exhibited the lowest variability with a CV of 2%.

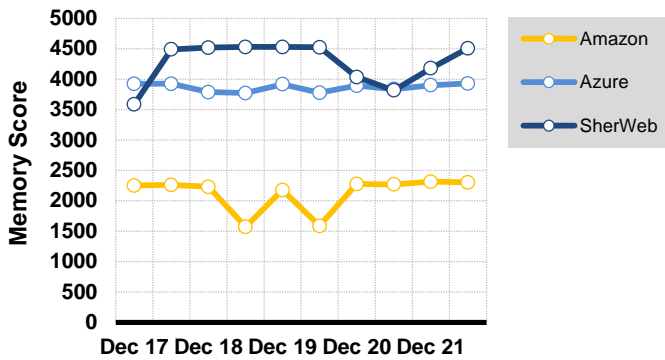
Ratio	Average	Stdev	CV	Max	Min
Amazon	13886	2333	17%	14661	7247
Azure	14743	314	2%	15062	14173
SherWeb	24334	947	4%	25231	22430

<sup>2</sup> <http://support.primatelabs.com/kb/geekbench/interpreting-geekbench-3-scores>

## MEMORY PERFORMANCE TESTING RESULTS

Memory performance was evaluated by running benchmark tests from the Geekbench 3 suite (see *Methodology for details*). Memory bandwidth is becoming increasingly important for modern high-performance applications and emerging in-memory databases, where the performance of applications is sensitive to the rate of data transactions between the processor and memory. Geekbench uses copy, scale, add and triad operations in its benchmark. The results are normalized into an overall Memory Score where a higher score denotes better memory performance, as shown in the graphs below. Testing occurred on 2vCPU, 4vCPU and 8vCPU machines across the three providers included in this study.

**Memory Performance (2 vCPU - Multi Core)**

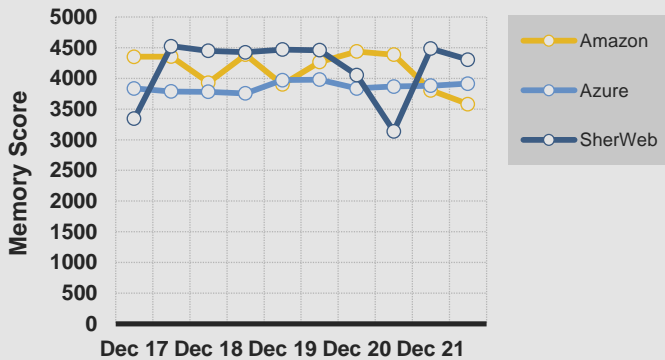


**Memory Performance (Multicore): 2vCPU**

SherWeb achieved between 10% to 101% higher performance than the other providers. Azure exhibited the lowest variability with a CV of 2%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	2122	290	14%	2311	1569
Azure	3865	66	2%	3929	3770
SherWeb	4270	350	8%	4527	3585

**Memory Performance (4 vCPU - Multi Core)**

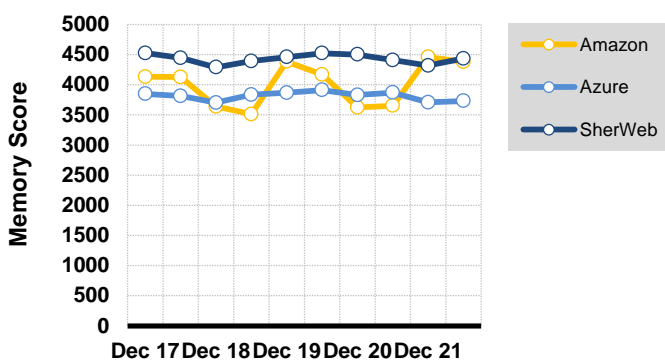


**Memory Performance (Multicore): 4vCPU**

SherWeb achieved between 1% to 8% higher performance than the other providers. Azure exhibited the lowest variability with a CV of 2%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	4141	306	7%	4440	3581
Azure	3861	77	2%	3979	3755
SherWeb	4166	509	12%	4524	3136

**Memory Performance (8 vCPU - Multi Core)**



**Memory Performance (Multicore): 8vCPU**

SherWeb achieved between 11% to 16% higher performance than the other providers. Azure and SherWeb exhibited the lowest variability with CVs of 2%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	4008	365	9%	4460	3510
Azure	3812	73	2%	3911	3702
SherWeb	4430	81	2%	4526	4288

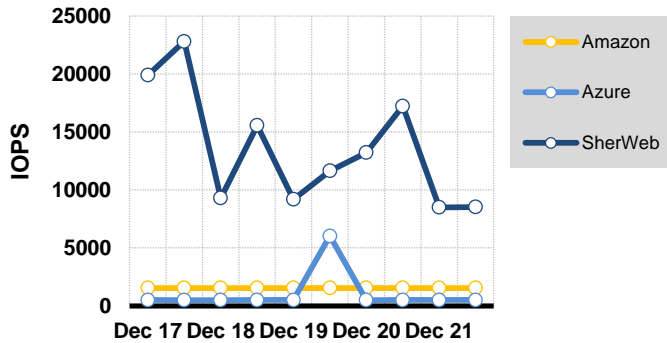
## STORAGE PERFORMANCE TESTING RESULTS

Storage performance was measured using the network storage offerings from each provider. Storage performance was evaluated by running tests with the FIO disk benchmark (see *Methodology for details*). FIO was configured to test sequential read/write and random read/write operations across different 4kb and 32kb block sizes. The results are the input/output per second (IOPS) of the storage device, where a higher value denotes better storage performance, as shown in the graphs below. Testing occurred on 2vCPU, 4vCPU and 8vCPU machines across the four providers included in this study. 4kb and 32kb block sizes were tested. A 2GB file was constructed by fio.

1500 provisioned IOPS were purchased for AWS to sustain high, guaranteed disk performance. While AWS guarantees provisioned IOPS performance for block sizes at 16kb or smaller, the tests showed sustained 1500 IOPS performance at 32kb block sizes. Microsoft Azure's block storage offering, which has no option to purchase guaranteed IOPS, fluctuated around 500 IOPS for the majority of iterations across all VMs. SherWeb's SSD-based SAN offering achieved higher IOPS by comparison, although stability of the performance is not guaranteed. Also unlike Azure and AWS, SherWeb's SAN offering delivered more IOPS on read than write operations. Smaller block size also correlated with higher IOPS, indicating strong performance for read-heavy operations in combination with small block sizes, such as web servers.

## STORAGE PERFORMANCE TESTING RESULTS: SEQUENTIAL READ (4KB BLOCK)

Storage Performance of Sequential Reads  
(2 vCPU - 4kb)

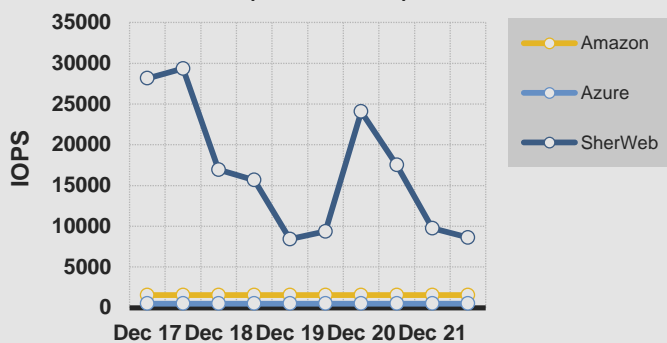


### Storage Performance – Sequential Read (4kb block): 2vCPU

SherWeb achieved between 7.9x to 12x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	1050	1747	166%	6021	494
SherWeb	13590	5114	38%	22819	8502

Storage Performance of Sequential Reads  
(4 vCPU - 4kb)

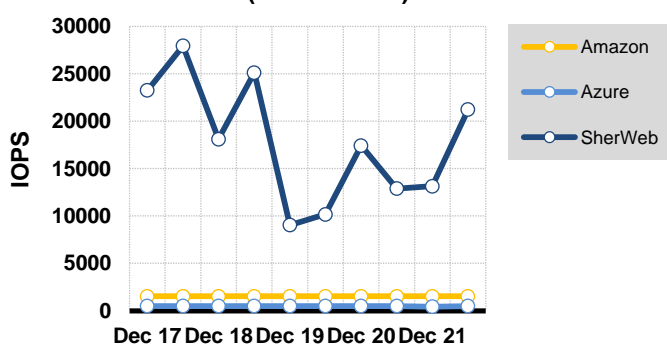


### Storage Performance – Sequential Read (4kb block): 4vCPU

SherWeb achieved between 10x to 33x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	499	2	0%	500	495
SherWeb	16781	8053	48%	29354	8406

Storage Performance of Sequential Reads  
(8 vCPU - 4kb)



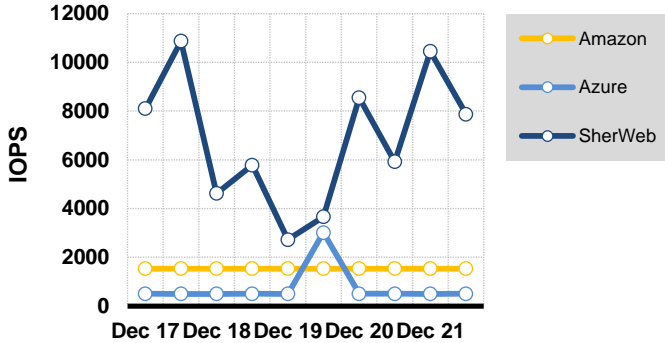
### Storage Performance – Sequential Read (4kb block): 8vCPU

SherWeb achieved between 10x to 35x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	493	21	4%	500	433
SherWeb	17830	6485	36%	27934	9046

## STORAGE PERFORMANCE TESTING RESULTS: SEQUENTIAL READ (32KB BLOCK)

Storage Performance of Sequential Reads (2 vCPU - 32kb)

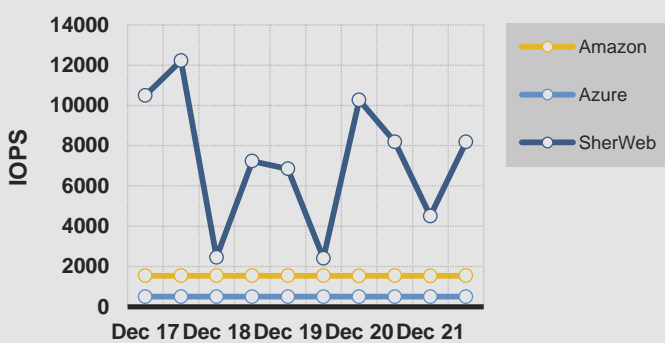


### Storage Performance – Sequential Read (32kb block): 2vCPU

SherWeb achieved between 3.5x to 8.1x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	750	795	106%	3012	497
SherWeb	6855	2765	40%	10870	2722

Storage Performance of Sequential Reads (4 vCPU - 32kb)

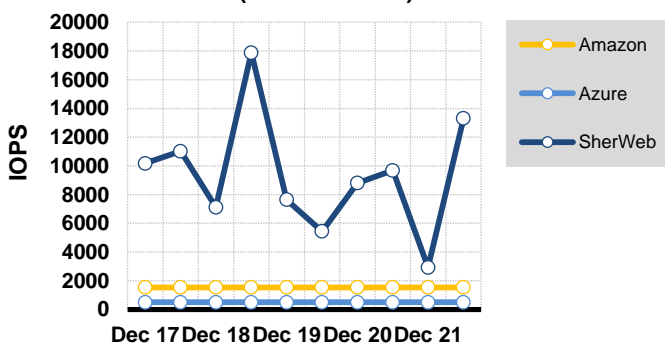


### Storage Performance – Sequential Read (32kb block): 4vCPU

SherWeb achieved between 3.7x to 13.5x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	1	0%	1536	1534
Azure	499	1	0%	500	496
SherWeb	7282	3338	46%	12225	2408

Storage Performance of Sequential Reads (8 vCPU - 32kb)



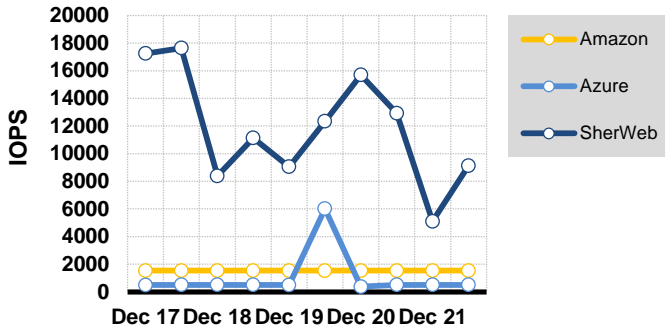
### Storage Performance – Sequential Read (32kb block): 8vCPU

SherWeb achieved between 5.1x to 17.8x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	499	1	0%	500	497
SherWeb	9398	4176	44%	17890	2926

## STORAGE PERFORMANCE TESTING RESULTS: SEQUENTIAL WRITE (4KB BLOCK)

Storage Performance of Sequential Writes  
(2 vCPU - 4kb)

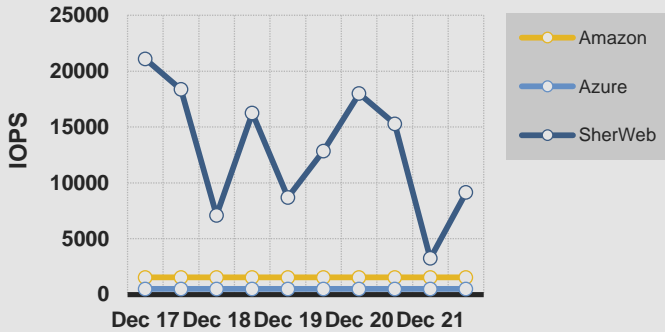


### Storage Performance – Sequential Write (4kb block): 2vCPU

SherWeb achieved between 6.7x to 10.4x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1534	1	0%	1534	1533
Azure	1039	1750	169%	6019	382
SherWeb	11864	4110	35%	17644	5098

Storage Performance of Sequential Writes  
(4 vCPU - 4kb)

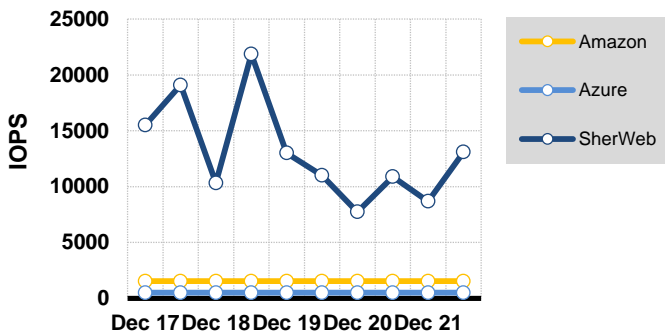


### Storage Performance – Sequential Write (4kb block): 4vCPU

SherWeb achieved between 7.5x to 25x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1534	0	0%	1534	1533
Azure	497	2	0%	500	494
SherWeb	13000	5765	44%	21097	3227

Storage Performance of Sequential Writes  
(8 vCPU - 4kb)



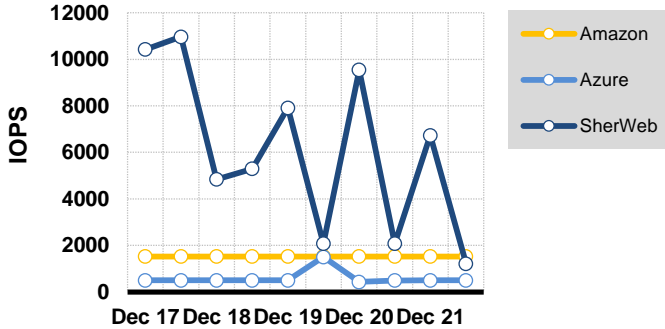
### Storage Performance – Sequential Write (4kb block): 8vCPU

SherWeb achieved between 7.6x to 25x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1534	0	0%	1534	1534
Azure	498	1	0%	499	497
SherWeb	13120	4520	34%	21860	7736

## STORAGE PERFORMANCE TESTING RESULTS: SEQUENTIAL WRITE (32KB BLOCK)

Storage Performance of Sequential Writes (2 vCPU - 32kb)

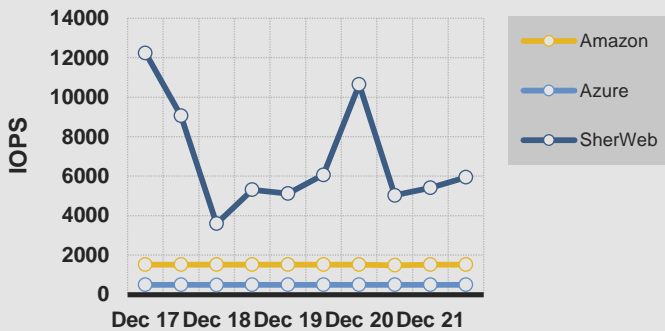


### Storage Performance – Sequential Write (32kb block): 2vCPU

SherWeb achieved between 3x to 9.3x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1523	0	0%	1523	1523
Azure	592	321	54%	1505	432
SherWeb	6110	3597	59%	10972	1218

Storage Performance of Sequential Writes (4 vCPU - 32kb)

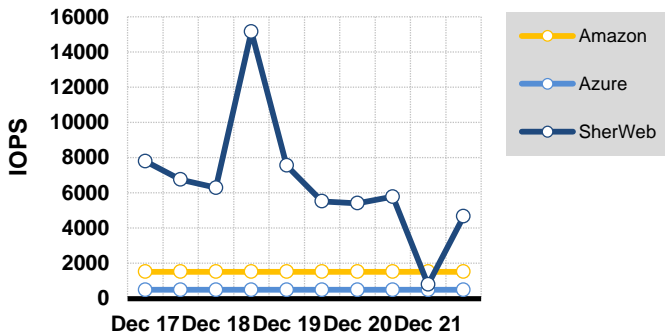


### Storage Performance – Sequential Write (32kb block): 4vCPU

SherWeb achieved between 3.5x to 12.7x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 1%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1520	10	1%	1523	1491
Azure	498	3	1%	499	491
SherWeb	6840	2810	41%	12240	3595

Storage Performance of Sequential Writes (8 vCPU - 32kb)



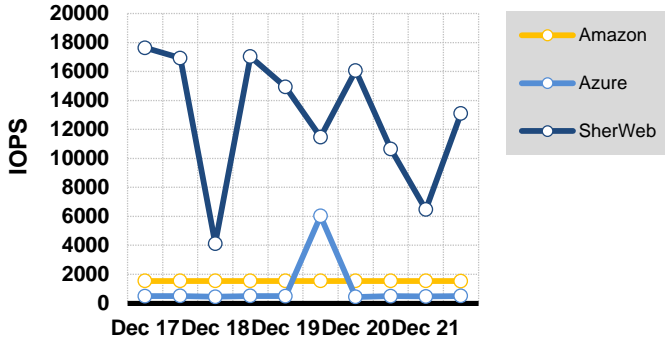
### Storage Performance – Sequential Write (32kb block): 8vCPU

SherWeb achieved between 3.3x to 17.6x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1523	0	0%	1523	1523
Azure	498	1	0%	500	496
SherWeb	6574	3598	55%	15164	795

## STORAGE PERFORMANCE TESTING RESULTS: RANDOM READ (4KB BLOCK)

Storage Performance of Random Reads  
(2 vCPU - 4kb)

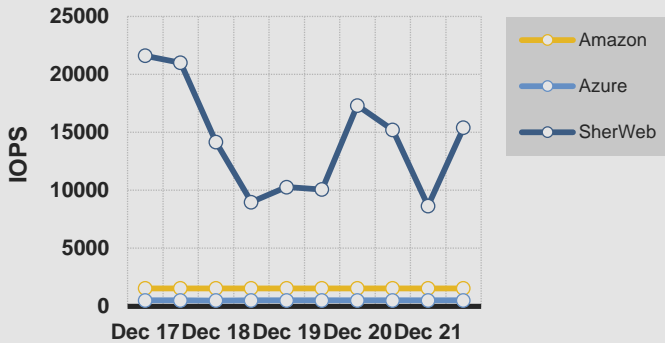


### Storage Performance – Random Read (4kb block): 2vCPU

SherWeb achieved between 7.4x to 11.4x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	1	0%	1536	1534
Azure	1036	1752	169%	6021	435
SherWeb	12836	4662	36%	17634	4110

Storage Performance of Random Reads  
(4 vCPU - 4kb)

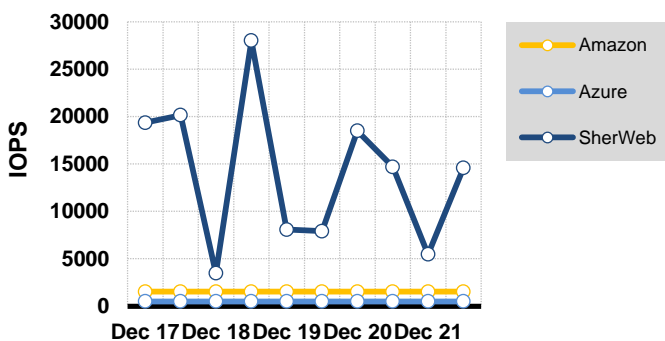


### Storage Performance – Random Read (4kb block): 4vCPU

SherWeb achieved between 8.3x to 28x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	498	3	1%	500	490
SherWeb	14273	4759	33%	21619	8651

Storage Performance of Random Reads  
(8 vCPU - 4kb)



### Storage Performance – Random Read (4kb block): 8vCPU

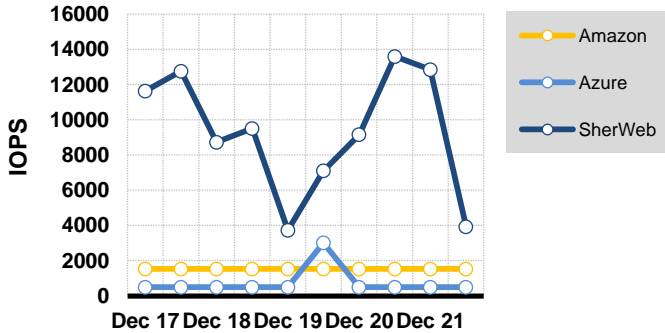
SherWeb achieved between 8.1x to 27x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1536
Azure	499	0	0%	499	498
SherWeb	14018	7742	55%	28007	3464



## STORAGE PERFORMANCE TESTING RESULTS: RANDOM READ (32KB BLOCK)

Storage Performance of Random Reads  
(2 vCPU - 32kb)

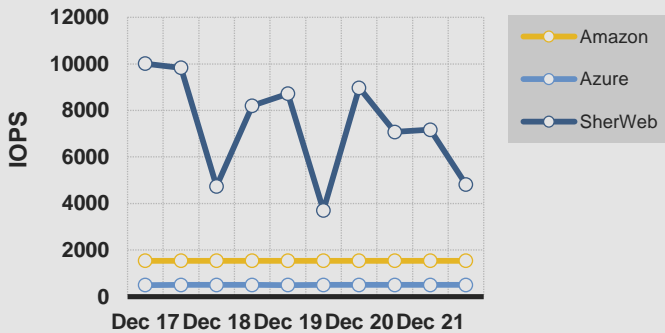


### Storage Performance – Random Read (32kb block): 2vCPU

SherWeb achieved between 5.1x to 11.4x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1535
Azure	748	795	106%	3012	494
SherWeb	9301	3553	38%	13602	3733

Storage Performance of Random Reads  
(4 vCPU - 32kb)

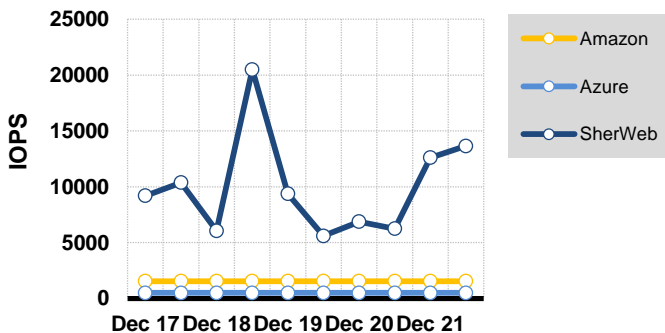


### Storage Performance – Random Read (32kb block): 4vCPU

SherWeb achieved between 3.8x to 13.8x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1535
Azure	497	2	0%	499	493
SherWeb	7325	2240	31%	10014	3705

Storage Performance of Random Reads  
(8 vCPU - 32kb)



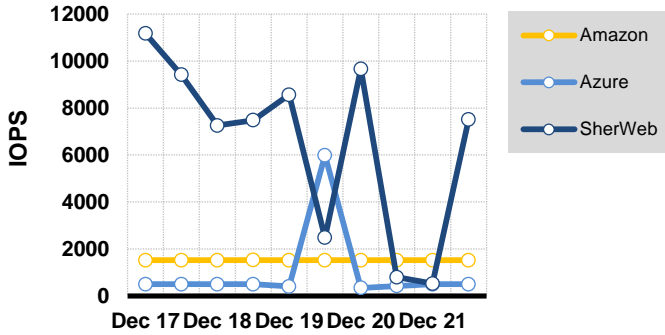
### Storage Performance – Random Read (32kb block): 8vCPU

SherWeb achieved between 5.5x to 19.2x higher performance than the other providers. Amazon and Azure exhibited the lowest variability with CVs of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1536	0	0%	1536	1535
Azure	498	2	0%	500	492
SherWeb	10045	4599	46%	20502	5600

## STORAGE PERFORMANCE TESTING RESULTS: RANDOM WRITE (4KB BLOCK)

Storage Performance of Random Writes  
(2 vCPU - 4kb)

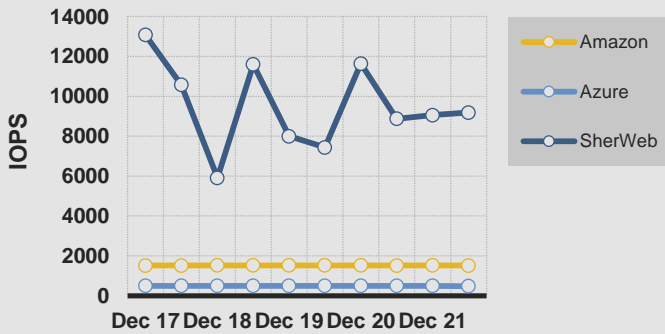


### Storage Performance – Random Write (4kb block): 2vCPU

SherWeb achieved between 3.3x to 5.4x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1520	1	0%	1521	1518
Azure	1011	1750	173%	5989	335
SherWeb	6486	3826	59%	11175	519

Storage Performance of Random Writes  
(4 vCPU - 4kb)

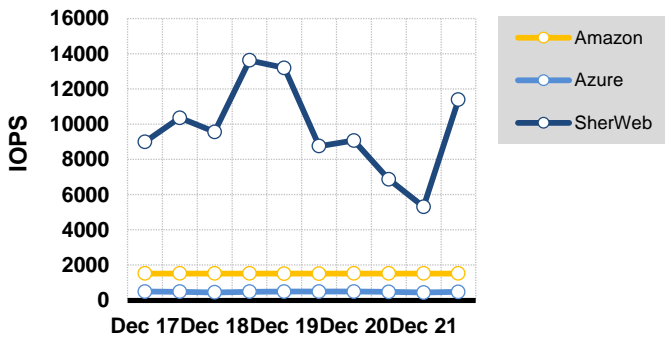


### Storage Performance – Random Write (4kb block): 4vCPU

SherWeb achieved between 5.3x to 18.4x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1518	2	0%	1522	1517
Azure	492	5	1%	496	478
SherWeb	9536	2188	23%	13082	5908

Storage Performance of Random Writes  
(8 vCPU - 4kb)



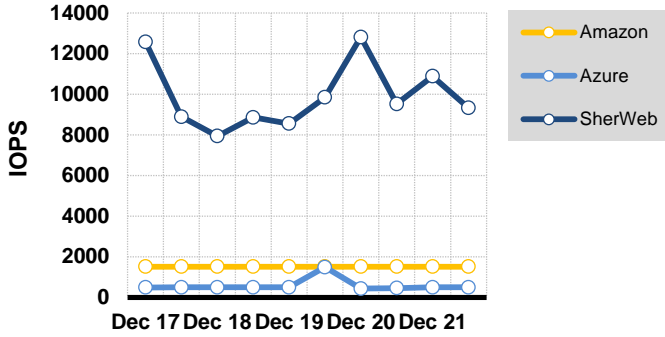
### Storage Performance – Random Write (4kb block): 8vCPU

SherWeb achieved between 5.4x to 19.3x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1519	2	0%	1521	1515
Azure	480	19	4%	494	441
SherWeb	9716	2581	27%	13629	5315

## STORAGE PERFORMANCE TESTING RESULTS: RANDOM WRITE (32KB BLOCK)

Storage Performance of Random Writes  
(2 vCPU - 32kb)

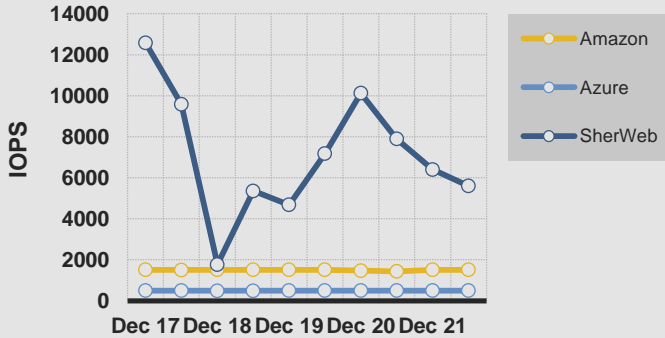


### Storage Performance – Random Write (32kb block): 2vCPU

SherWeb achieved between 5.6x to 16.1x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1510	1	0%	1511	1508
Azure	581	318	55%	1483	430
SherWeb	9918	1662	17%	12811	7938

Storage Performance of Random Writes  
(4 vCPU - 32kb)

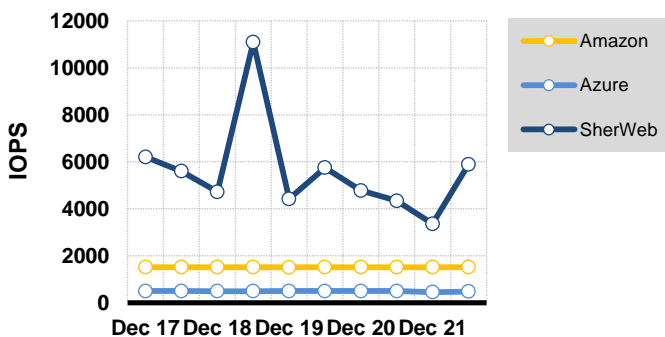


### Storage Performance – Random Write (32kb block): 4vCPU

SherWeb achieved between 3.8x to 13.4x higher performance than the other providers. Azure exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1497	27	2%	1511	1429
Azure	493	2	0%	495	489
SherWeb	7116	3093	43%	12581	1767

Storage Performance of Random Writes  
(8 vCPU - 32kb)



### Storage Performance – Random Write (32kb block): 8vCPU

SherWeb achieved between 2.7x to 10.6x higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

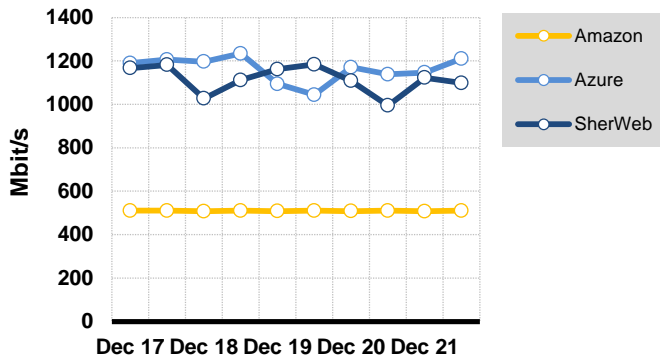
Ratio	Average	Stdev	CV	Max	Min
Amazon	1509	2	0%	1512	1506
Azure	486	15	3%	495	446
SherWeb	5616	2114	38%	11101	3359

## INTERNAL NETWORK PERFORMANCE TESTING RESULTS: THROUGHPUT

Internal network performance was evaluated by running tests measuring the throughput and latency of the network using iperf and ping commands (see *Methodology for details*). Iperf measures the network throughput between machines. Network throughput is a critical component of public cloud systems, where scalability depends on quickly increasing or decreasing the number of virtual machines that must maintain a strong network backbone. In-memory databases, distributed file systems, and high-performance application clusters require a large and fast connection across VMs within the cluster.

The results are reported in megabits per second (Mbit/s) where a higher value denotes better network performance, as shown in the graphs below. Testing occurred on 2vCPU, 4vCPU and 8vCPU machines across the four providers included in this study.

**Network Throughput Performance (2 vCPU)**

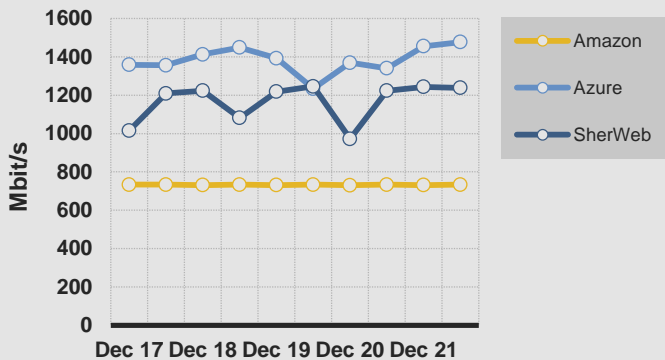


**Internal Network Performance – Throughput: 2vCPU**

Azure achieved between 4% to 128% higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	509	1	0%	510.5	507
Azure	1163	59	5%	1234	1043.5
SherWeb	1116	64	6%	1184	994.5

**Network Throughput Performance (4 vCPU)**

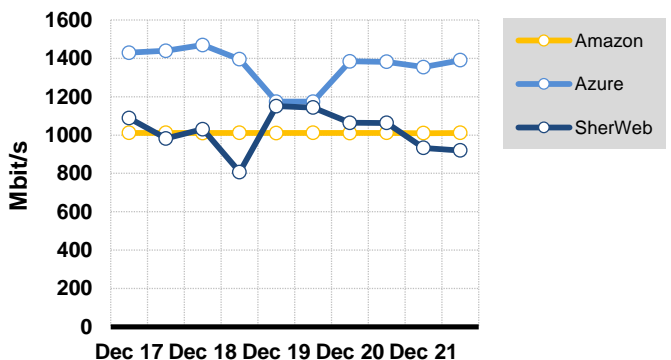


**Internal Network Performance – Throughput: 4vCPU**

Azure achieved between 19% to 89% higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	732	1	0%	733.5	730
Azure	1385	71	5%	1477	1234.5
SherWeb	1167	103	9%	1246	972

**Network Throughput Performance (8 vCPU)**



**Internal Network Performance – Throughput: 8vCPU**

Azure achieved 34% higher performance than the other providers. Amazon exhibited the lowest variability with a CV of 0%.

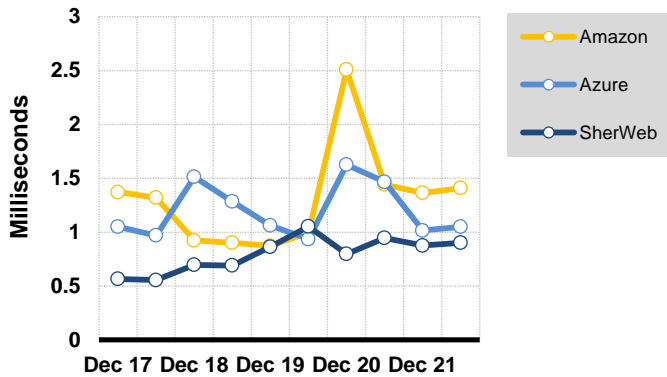
Ratio	Average	Stdev	CV	Max	Min
Amazon	1011	1	0%	1011.5	1010
Azure	1359	103	8%	1470	1174
SherWeb	1018	108	11%	1151	807

## INTERNAL NETWORK PERFORMANCE TESTING RESULTS: LATENCY

Ping measures the latency over the network between machines. The results are reported in milliseconds where a lower value denotes better network performance, as shown in the graphs below.

Network latency is a separate piece in diagnosing the network backbone of a cloud environment. Network latency is dependent on a variety of factors that are out of the control of the user, such as the physical proximity of the virtual machines, and one which physical hosts those machines are provisioned. Low network latency is crucial to cluster environments that demand high performance, such as distributed file systems (e.g., Hadoop).

**Network Latency Performance (2 vCPU)**

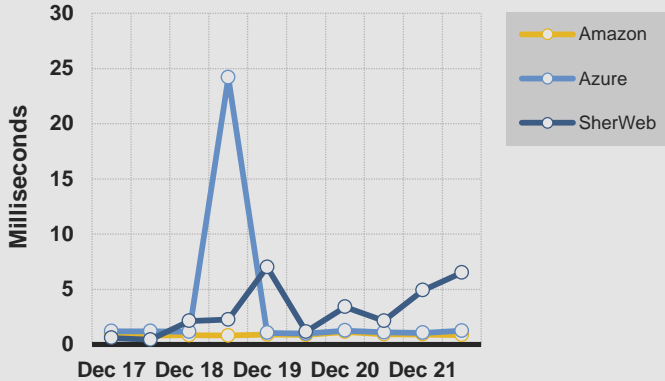


**Internal Network Performance – Latency: 2vCPU**

SherWeb achieved between 34% to 39% better performance than the other providers. Azure and SherWeb exhibited the lowest variability with CVs of 21%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	1.3	0.5	37%	2.5	0.9
Azure	1.2	0.3	21%	1.6	0.9
SherWeb	0.8	0.2	21%	1.1	0.6

**Network Latency Performance (4 vCPU)**

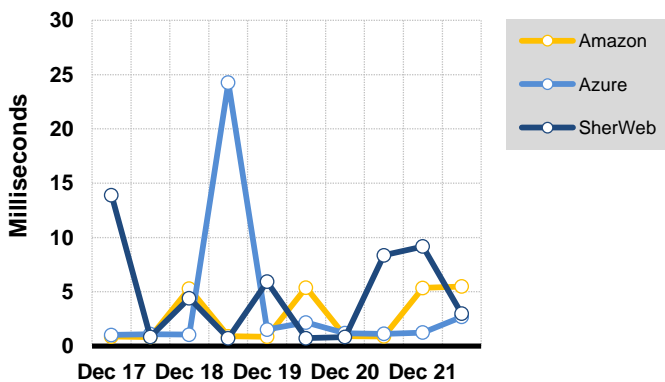


**Internal Network Performance – Latency: 4vCPU**

Amazon achieved between 71% to 74% better performance than the other providers. Amazon exhibited the lowest variability with a CV of 11%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	0.9	0.1	11%	1.1	0.8
Azure	3.4	7.3	211%	24.2	1.0
SherWeb	3.1	2.4	77%	7.0	0.4

**Network Latency Performance (8 vCPU)**



**Internal Network Performance – Latency: 8vCPU**

Amazon achieved between 28% to 44% better performance than the other providers. Amazon exhibited the lowest variability with a CV of 87%.

Ratio	Average	Stdev	CV	Max	Min
Amazon	2.7	2.3	87%	5.5	0.8
Azure	3.7	7.2	193%	24.3	1.0
SherWeb	4.8	4.5	94%	13.9	0.7

## VALUE ANALYSIS RESULTS

The following section provides the price-performance comparisons of the VMs tested in the performance analysis section above. The values used in the comparison are taken from the raw performance scores shown in the preceding section and the pricing for the VMs being examined (see *Methodology: About the VMs*).

TESTING RESULTS - PRICE:PERFORMANCE RANKINGS										
		AMAZON			AZURE			SHERWEB		
		2vCPU	4vCPU	8vCPU	2vCPU	4vCPU	8vCPU	2vCPU	4vCPU	8vCPU
VCPU	Integer	3RD	3RD	2ND	2ND	2ND	3RD	1ST	1ST	1ST
	Floating Point	3RD	3RD	2ND	2ND	2ND	3RD	1ST	1ST	1ST
Memory	Memory	3RD	2ND	2ND	2ND	3RD	3RD	1ST	1ST	1ST
Storage (4kb)	Sequential Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Sequential Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
Storage (32kb)	Sequential Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Sequential Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Read	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
	Random Write	2ND	2ND	2ND	3RD	3RD	3RD	1ST	1ST	1ST
Internal Network	Iperf	3RD	3RD	3RD	2ND	2ND	2ND	1ST	1ST	1ST
	Ping	3RD	1ST	1ST	2ND	3RD	3RD	1ST	2ND	2ND

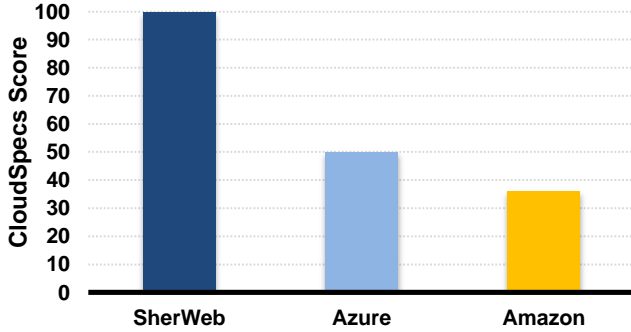
VALUE ANALYSIS - PROVIDER PRICING										
		AMAZON			AZURE			SHERWEB		
		2vCPU	4vCPU	8vCPU	2vCPU	4vCPU	8vCPU	2vCPU	4vCPU	8vCPU
Hourly Prices	VM	\$0.105	\$0.210	\$0.420	\$0.188	\$0.376	\$0.752	\$0.119	\$0.239	\$0.478
	Storage	\$0.142*	\$0.162*	\$0.192*	\$0.002**	\$0.002**	\$0.002**	\$0.027	\$0.027	\$0.027
	Total	\$0.247	\$0.372	\$0.612	\$0.190	\$0.378	\$0.754	\$0.146	\$0.266	\$0.505

\*Includes price for EBS-optimized Instance Pricing and 1500 provisioned IOPS

\*\*Price of Block Blob storage

## vCPU VALUE ANALYSIS RESULTS

**CPU Value for Integer Tasks  
(2 vCPU - MultiCore)**

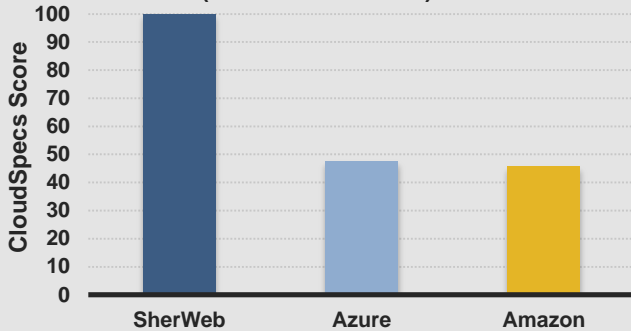


### vCPU Value – Integer Tasks (Multicore): 2vCPU

SherWeb offered between 99% to 175% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	36	50	100

**CPU Value for Integer Tasks  
(4 vCPU - MultiCore)**

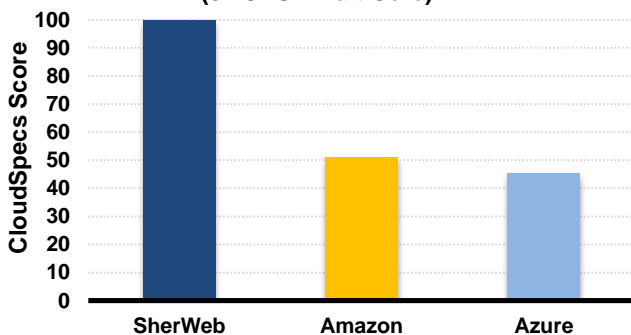


### vCPU Value – Integer Tasks (Multicore): 4vCPU

SherWeb offered between 111% to 119% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	46	47	100

**CPU Value for Integer Tasks  
(8 vCPU - MultiCore)**



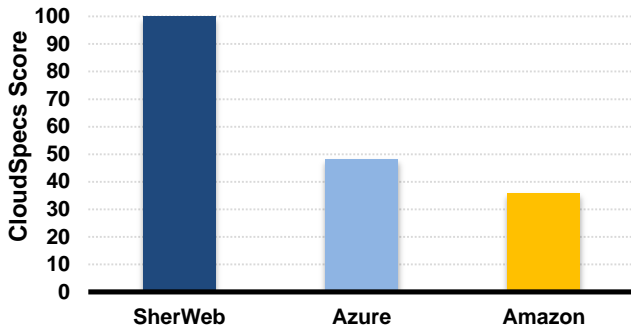
### vCPU Value – Integer Tasks (Multicore): 8vCPU

SherWeb offered between 96% to 120% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	51	45	100

## vCPU VALUE ANALYSIS RESULTS

**CPU Value for Floating Point Tasks  
(2 vCPU - MultiCore)**

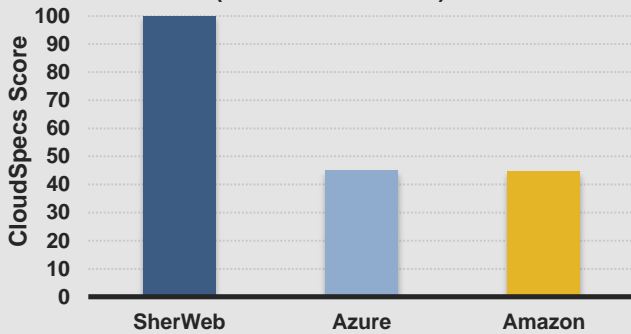


### vCPU Value – Floating Point Tasks (Multicore): 2vCPU

SherWeb offered between 108% to 179% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	36	48	100

**CPU Value for Floating Point Tasks  
(4 vCPU - MultiCore)**

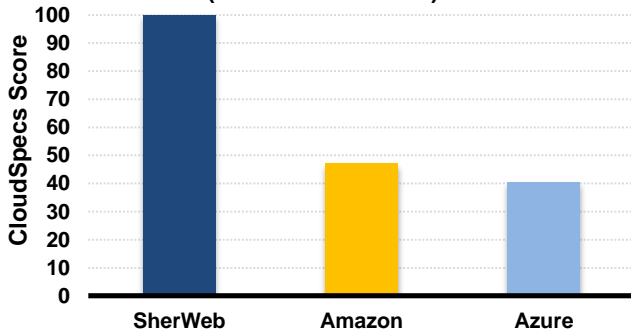


### vCPU Value – Floating Point Tasks (Multicore): 4vCPU

SherWeb offered between 123% to 124% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	45	45	100

**CPU Value for Floating Point Tasks  
(8 vCPU - MultiCore)**



### vCPU Value – Floating Point Tasks (Multicore): 8vCPU

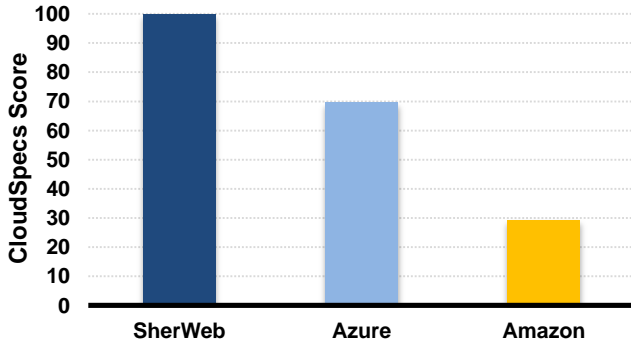
SherWeb offered between 113% to 147% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	47	41	100



## MEMORY VALUE ANALYSIS RESULTS

Memory Value (2 vCPU - MultiCore)

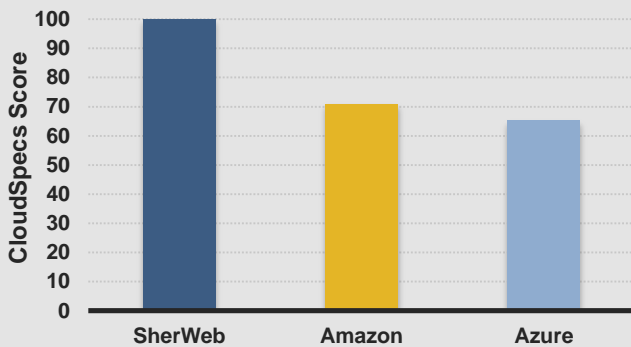


### Memory Value (Multicore): 2vCPU

SherWeb offered between 43% to 240% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	29	70	100

Memory Value (4 vCPU - MultiCore)

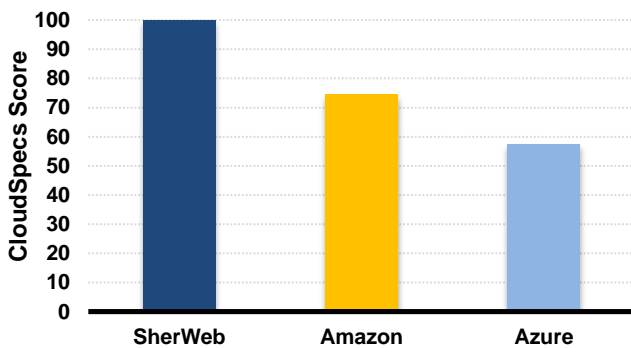


### Memory Value (Multicore): 4vCPU

SherWeb offered between 41% to 53% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	71	65	100

Memory Value (8 vCPU - MultiCore)

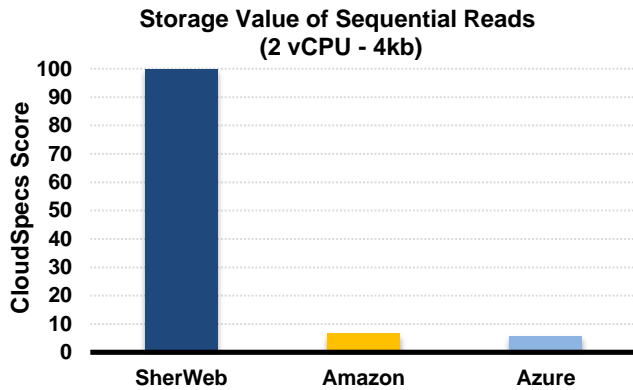


### Memory Value (Multicore): 8vCPU

SherWeb offered between 34% to 74% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	75	58	100

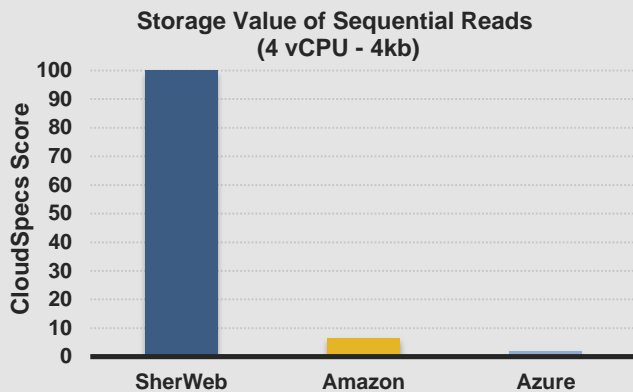
## STORAGE VALUE ANALYSIS RESULTS: SEQUENTIAL READS – 4KB BLOCK SIZE



### Storage Value – Sequential Read (4kb block): 2vCPU

SherWeb offered between 14x to 15.8x greater value than the other providers.

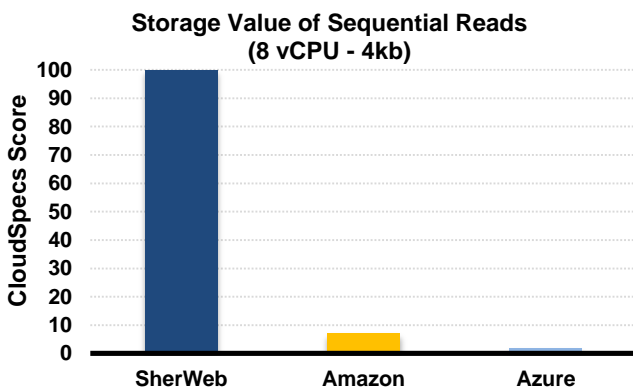
	Amazon	Azure	SherWeb
CloudSpecs Score	7	6	100



### Storage Value – Sequential Read (4kb block): 4vCPU

SherWeb offered between 14.3x to 47x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	7	2	100



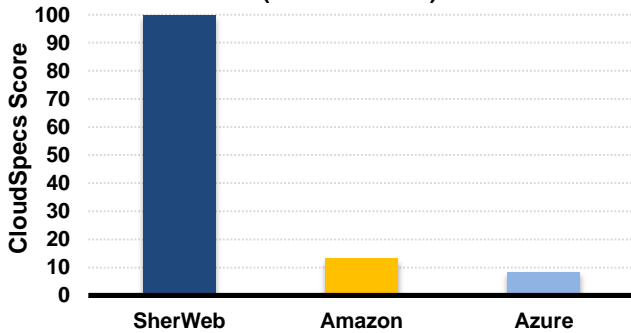
### Storage Value – Sequential Read (4kb block): 8vCPU

SherWeb offered between 13.1x to 53x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	7	2	100

## STORAGE VALUE ANALYSIS RESULTS: SEQUENTIAL READS – 32KB BLOCK SIZE

**Storage Value of Sequential Reads  
(2 vCPU - 32kb)**

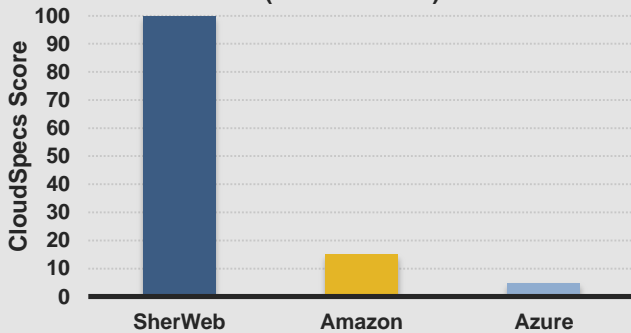


### Storage Value – Sequential Read (32kb block): 2vCPU

SherWeb offered between 6.5x to 10.9x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	13	8	100

**Storage Value of Sequential Reads  
(4 vCPU - 32kb)**

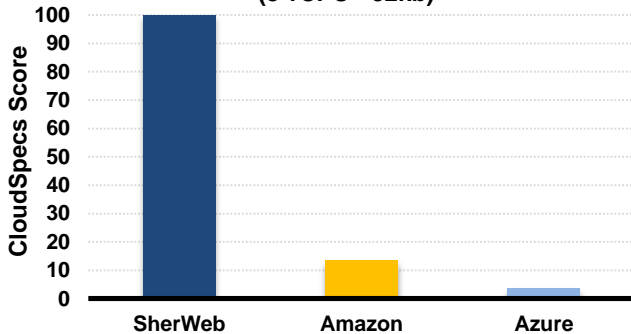


### Storage Value – Sequential Read (32kb block): 4vCPU

SherWeb offered between 5.6x to 19.7x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	15	5	100

**Storage Value of Sequential Reads  
(8 vCPU - 32kb)**

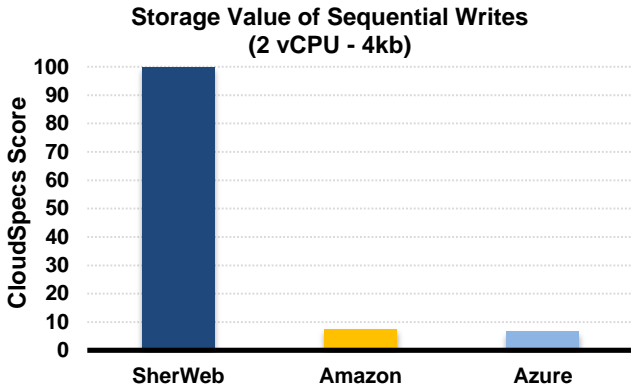


### Storage Value – Sequential Read (32kb block): 8vCPU

SherWeb offered between 6.4x to 27x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	13	4	100

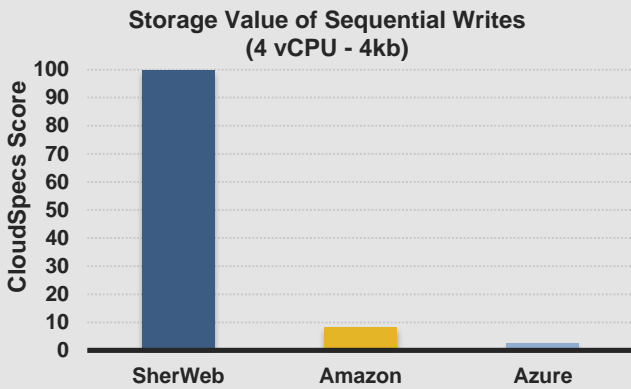
## STORAGE VALUE ANALYSIS RESULTS: SEQUENTIAL WRITES – 4KB BLOCK SIZE



### Storage Value – Sequential Write (4kb block): 2vCPU

SherWeb offered between 12.1x to 13.8x greater value than the other providers.

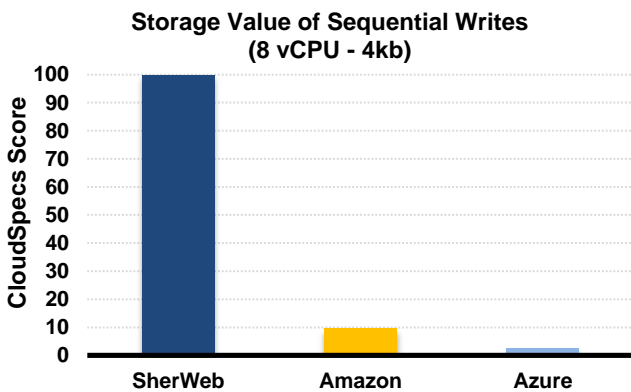
	Amazon	Azure	SherWeb
CloudSpecs Score	8	7	100



### Storage Value – Sequential Write (4kb block): 4vCPU

SherWeb offered between 10.9x to 36x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	8	3	100

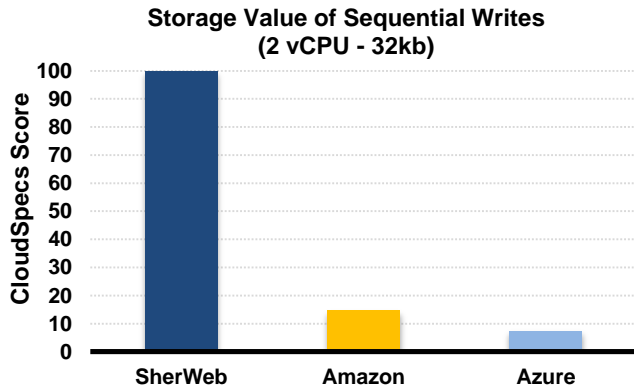


### Storage Value – Sequential Write (4kb block): 8vCPU

SherWeb offered between 9.4x to 38x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	10	3	100

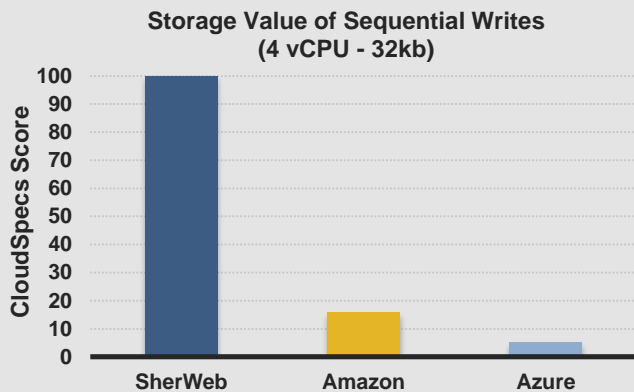
## STORAGE VALUE ANALYSIS RESULTS: SEQUENTIAL WRITES – 32KB BLOCK SIZE



### Storage Value – Sequential Write (32kb block): 2vCPU

SherWeb offered between 5.8x to 12.4x greater value than the other providers.

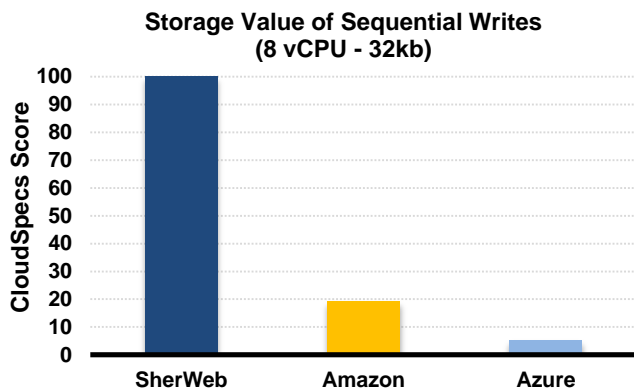
	Amazon	Azure	SherWeb
CloudSpecs Score	15	7	100



### Storage Value – Sequential Write (32kb block): 4vCPU

SherWeb offered between 5.3x to 18.5x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	16	5	100

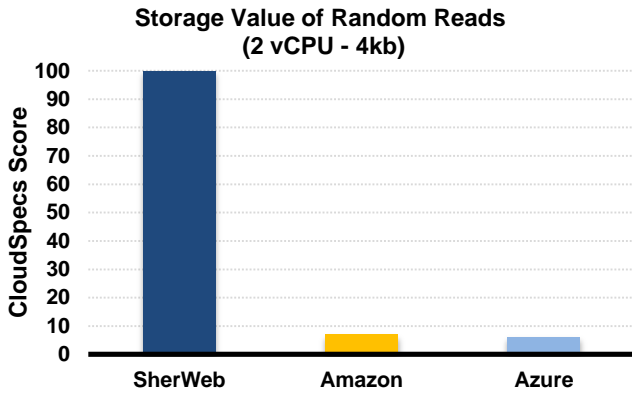


### Storage Value – Sequential Write (32kb block): 8vCPU

SherWeb offered between 4.2x to 18.7x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	19	5	100

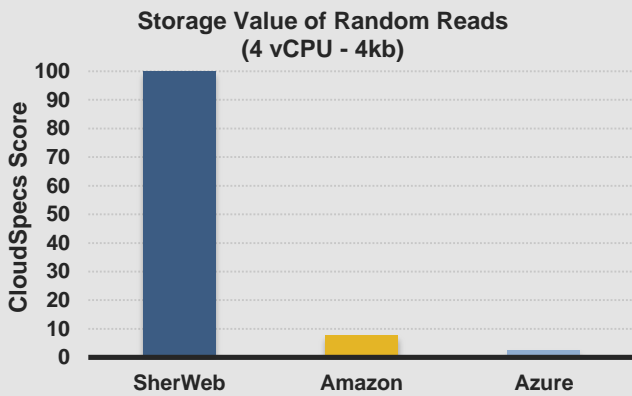
## STORAGE VALUE ANALYSIS RESULTS: RANDOM READS – 4KB BLOCK SIZE



### Storage Value – Random Read (4kb block): 2vCPU

SherWeb offered between 13.1x to 15.1x greater value than the other providers.

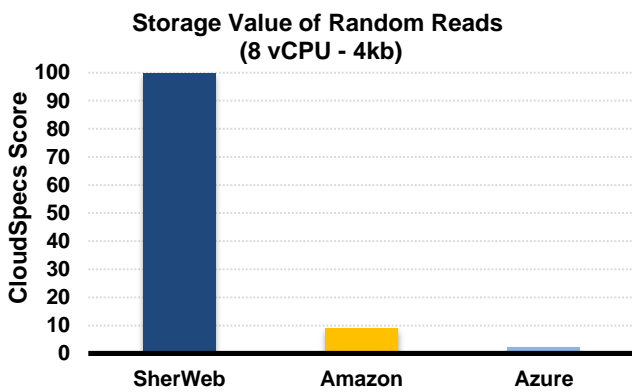
	Amazon	Azure	SherWeb
CloudSpecs Score	7	6	100



### Storage Value – Random Read (4kb block): 4vCPU

SherWeb offered between 12x to 40x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	8	2	100



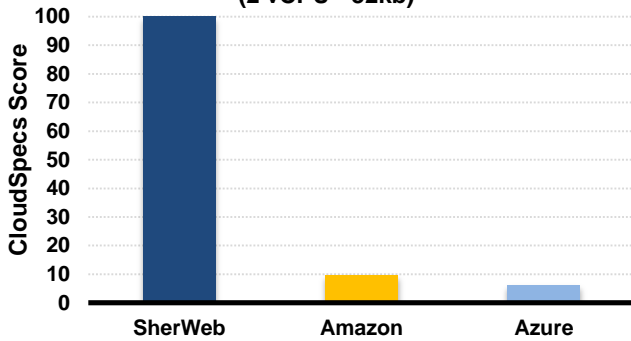
### Storage Value – Random Read (4kb block): 8vCPU

SherWeb offered between 10.1x to 41x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	9	2	100

## STORAGE VALUE ANALYSIS RESULTS: RANDOM READS – 32KB BLOCK SIZE

**Storage Value of Random Reads  
(2 vCPU - 32kb)**

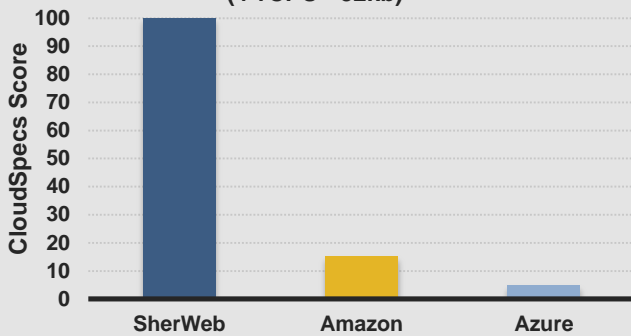


### Storage Value – Random Read (32kb block): 2vCPU

SherWeb offered between 9.2x to 15.1x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	10	6	100

**Storage Value of Random Reads  
(4 vCPU - 32kb)**

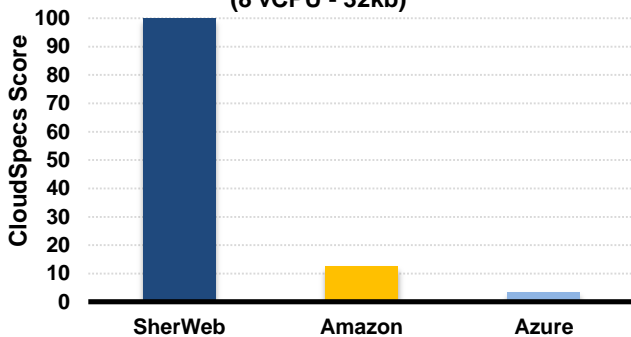


### Storage Value – Random Read (32kb block): 4vCPU

SherWeb offered between 5.7x to 20x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	15	5	100

**Storage Value of Random Reads  
(8 vCPU - 32kb)**



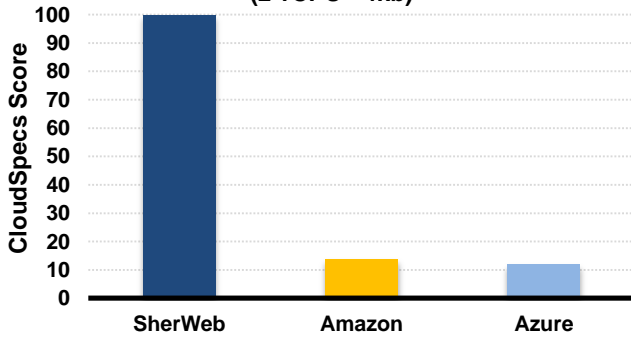
### Storage Value – Random Read (32kb block): 8vCPU

SherWeb offered between 6.9x to 29x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	13	3	100

## STORAGE VALUE ANALYSIS RESULTS: RANDOM WRITES – 4KB BLOCK SIZE

**Storage Value of Random Writes  
(2 vCPU - 4kb)**

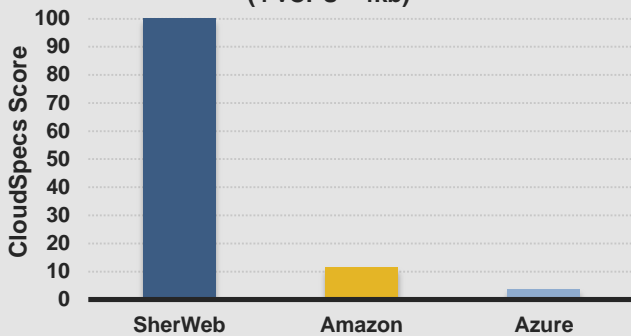


### Storage Value – Random Write (4kb block): 2vCPU

SherWeb offered between 6.2x to 7.3x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	14	12	100

**Storage Value of Random Writes  
(4 vCPU - 4kb)**

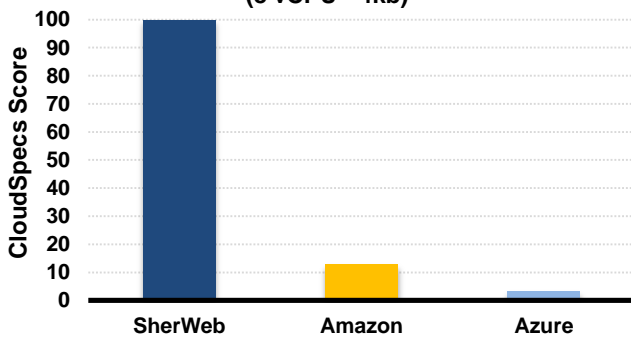


### Storage Value – Random Write (4kb block): 4vCPU

SherWeb offered between 7.8x to 27x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	11	4	100

**Storage Value of Random Writes  
(8 vCPU - 4kb)**



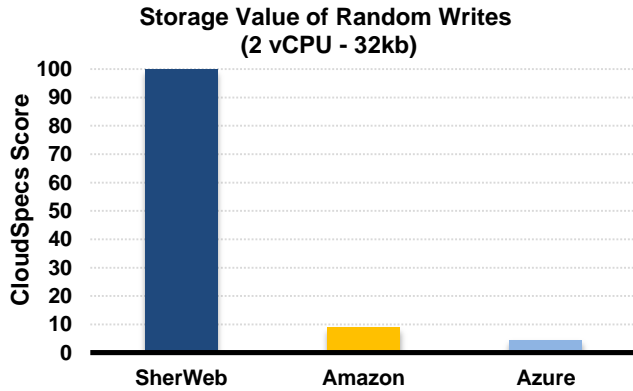
### Storage Value – Random Write (4kb block): 8vCPU

SherWeb offered between 6.8x to 29x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	13	3	100



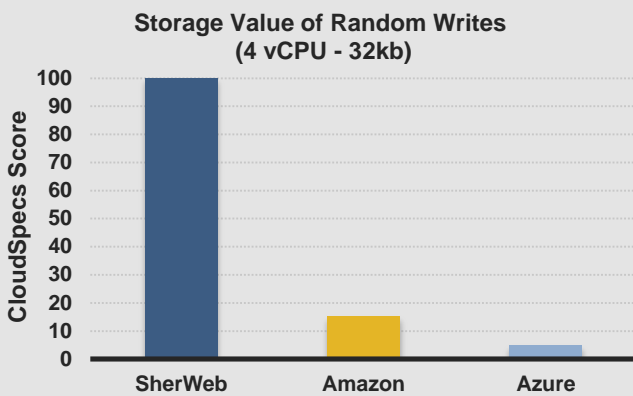
## STORAGE VALUE ANALYSIS RESULTS: RANDOM WRITES – 32KB BLOCK SIZE



### Storage Value – Random Write (32kb block): 2vCPU

SherWeb offered between 10.1x to 21x greater value than the other providers.

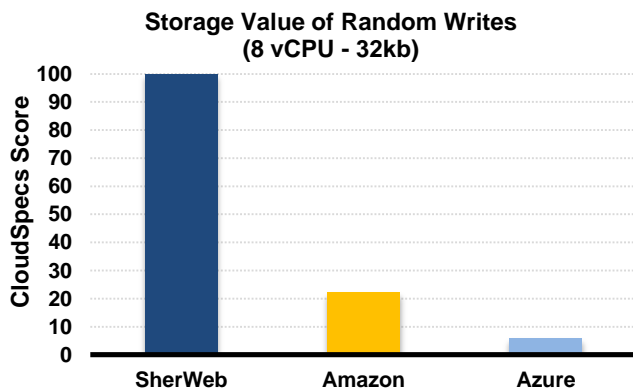
	Amazon	Azure	SherWeb
CloudSpecs Score	9	5	100



### Storage Value – Random Write (32kb block): 4vCPU

SherWeb offered between 5.7x to 19.5x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	15	5	100



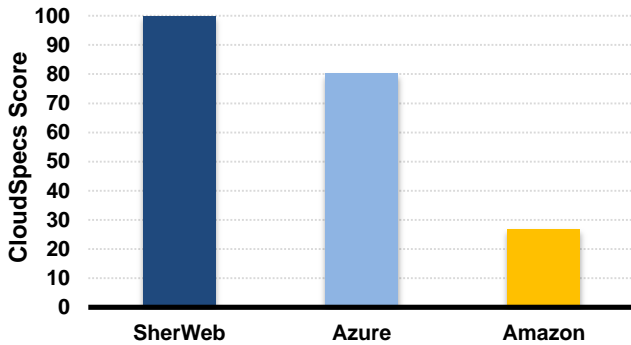
### Storage Value – Random Write (32kb block): 8vCPU

SherWeb offered between 3.5x to 16.3x greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	22	6	100

## INTERNAL NETWORK VALUE ANALYSIS RESULTS: THROUGHPUT

Network Throughput Performance (2 vCPU)

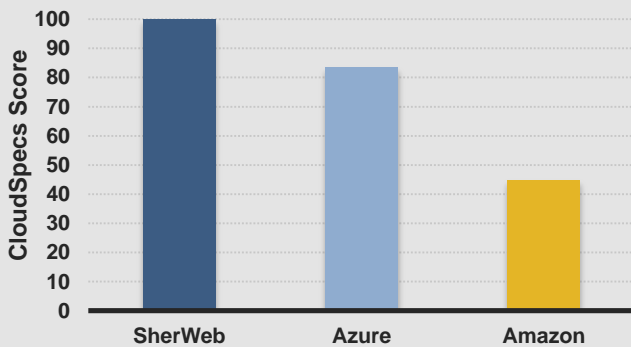


### Internal Network Value – Throughput: 2vCPU

SherWeb offered between 24% to 270% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	27	80	100

Network Throughput Performance (4 vCPU)

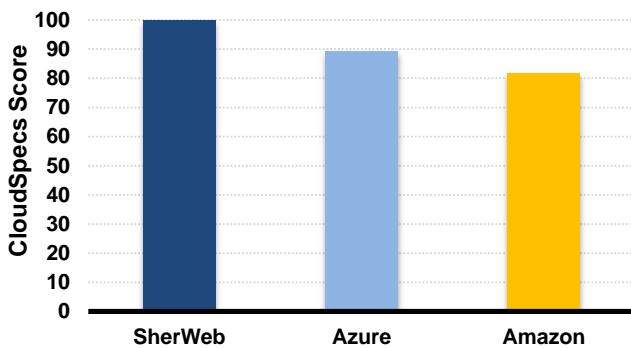


### Internal Network Value – Throughput: 4vCPU

SherWeb offered between 20% to 123% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	45	83	100

Network Throughput Performance (8 vCPU)



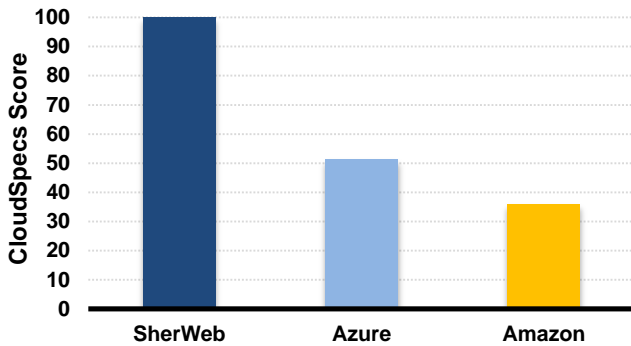
### Internal Network Value – Throughput: 8vCPU

SherWeb offered between 12% to 22% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	82	89	100

## INTERNAL NETWORK VALUE ANALYSIS RESULTS: LATENCY

Network Latency Value (2 vCPU)

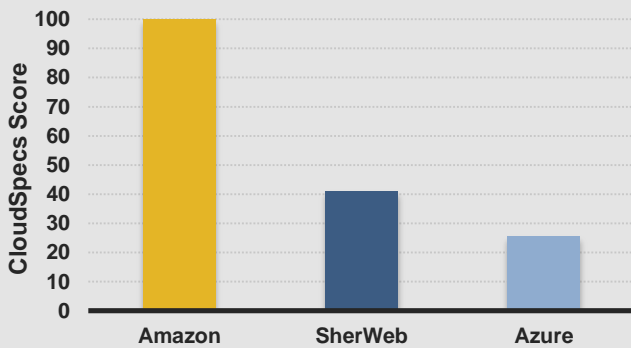


### Internal Network Value – Latency: 2vCPU

SherWeb offered between 95% to 179% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	36	51	100

Network Latency Value (4 vCPU)

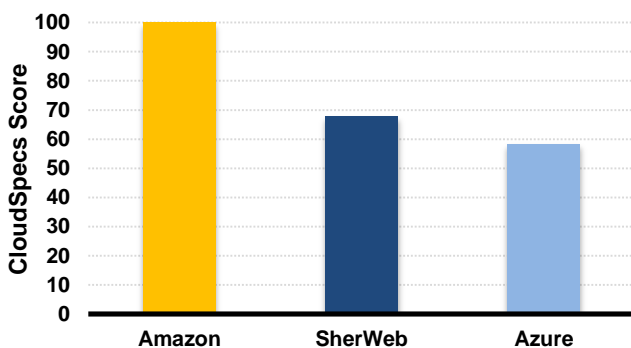


### Internal Network Value – Latency: 4vCPU

Amazon offered between 144% to 292% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	100	26	41

Network Latency Value (8 vCPU)



### Internal Network Value – Latency: 8vCPU

Amazon offered between 47% to 72% greater value than the other providers.

	Amazon	Azure	SherWeb
CloudSpecs Score	100	58	68

## CONCLUSION

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The purpose of this study was to examine the differences in performance and value of the cloud infrastructure offerings across various public cloud providers. Performance and price-performance of the servers were examined to determine the value offered, as determined by the price-performance ratios, albeit standardized into a general score for easier comparison (CloudSpecs Score). Performance must be examined first to determine the baseline amount of performance that will be offered by each provider. Pricing is then factored in to understand the performance levels of each provider machine per unit of cost spent. The price-performance value of cloud offerings is important for users to consider because higher price-performance ratios may mean less infrastructure is needed to run an application, thereby saving cost.

The study revealed that SherWeb offered the highest overall performance and price-performance value in the majority of tests that were performed. SherWeb exhibited the highest performance in vCPU, memory, and storage tests, while being second overall in the internal network tests. Only in the internal network tests did SherWeb not offer both the highest value and best performance. Amazon offered the lowest latency and highest value for the 4vCPU and 8vCPU machines. Microsoft Azure provided the highest throughput, but SherWeb's lower cost allowed for a higher price-performance ratio. On average, variability in performance was lowest on Azure for the vCPU and memory tests, while Amazon was lowest for the storage and internal network tests.

The study showed that smaller providers such as SherWeb are able to offer performance at the level of, or greater than, the large-scale providers in the IaaS market. While smaller providers may not offer as many features as a more mature offering, more competitive pricing of their services can offer greater value to users who do not require as complex of a solution. At the same time, providers with more customizable offerings may allow you to purchase additional resources or performance services to better tailor to an application's needs. There is a balance between finding a solution that offers the best performance with the solution that offers the best value.

### **FURTHER STUDY**

Further studies may include more VM sizes and varying configurations across the providers. Some providers throttle performance based on the amount of resources allocated. As a result, performance may scale differently on certain providers based on different vCPU to memory ratios or size of the storage volumes.

Many providers allow you to pay for additional features and/or services that increase performance of the VMs. Users may be able to provision faster storage hardware, additional IOPS, larger network bandwidth, isolated physical environments, etc.

Further studies may also include specific application tests that more closely simulate common use cases.

## **ABOUT CLOUD SPECTATOR**

Cloud Spectator is a cloud analyst agency focused on cloud Infrastructure-as-a-Service (IaaS) performance. The company actively monitors 20+ 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 businesses 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.

## TESTING SETUP

Cloud Spectator identified and provisioned equivalent sized VMs across each provider. All VMs were provisioned anonymously on each provider to ensure a fair comparison and most closely simulate an average user's experience. The locations of the VMs were all in North America. The chosen benchmarking software was then installed on each VM and run twice per day for a period of 5 days.

## TESTS USED

Test	Category	Description
Geekbench 3	CPU	Separate CPU tests that are all aggregated into a final score. <ul style="list-style-type: none"> <li>Subtests include: Integer Math, Floating Point Math</li> </ul>
Geekbench 3	Memory	Four separate memory tests that are all aggregated into a final score. <ul style="list-style-type: none"> <li>Subtests include: Add, Copy, Triad, Scale</li> </ul>
FIO	Disk	Combination of Sequential Read, Sequential Write, Random Read and Random Write operations <ul style="list-style-type: none"> <li>4kb and 32kb block sizes were used</li> </ul>
Iperf	Network	Transfers data bi-directionally between 2 nodes within 60 seconds, measured in megabits per second.
TCP Ping	Network	Sends a signal back and forth between 2 nodes to measure roundtrip delay, measured in milliseconds.

Geekbench 3 test details and benchmark software can be found at: <http://www.primatelabs.com/geekbench/>

## ABOUT THE VMS

All VM sizes were selected by Cloud Spectator, standardized as closely as possible with vCPUs. All VMs ran Ubuntu 14.04 operating systems. Two VMs of identical configurations were provisioned on each provider, one VM is used for the CPU, memory and disk tests, while the second VM is used in testing the internal network performance.

### 2 vCPU

SAMPLE SIZE	SherWeb	Amazon	Microsoft
OFFERING NAME	2C	c3.large	D2
vCPUs	2	2	2
MEMORY IN GB	8	3.5	7
BLOCK STORAGE	50GB	50GB	50GB
VM PRICE (\$/HR)	\$0.119	\$0.105	\$0.188
STORAGE (\$/HR)	\$0.027	\$0.142*	\$0.002**
DATA CENTER	Montreal	US East	East US

### 4 vCPU

SAMPLE SIZE	SherWeb	Amazon	Microsoft
OFFERING NAME	4C	c3.xlarge	D3
vCPUs	4	4	4
MEMORY IN GB	8	7.5	14
BLOCK STORAGE	50GB	50GB	50GB
VM PRICE (\$/HR)	\$0.239	\$0.210	\$0.376
STORAGE (\$/HR)	\$0.027	\$0.162*	\$0.002**
DATA CENTER	Montreal	US East	East US

## 8 vCPU

SAMPLE SIZE	SherWeb	Amazon	Microsoft
OFFERING NAME	8C	c3.2xlarge	D4
vCPUs	8	8	8
MEMORY IN GB	16	15	28
BLOCK STORAGE	50GB	50GB	50GB
VM PRICE (\$/HR)	\$0.478	\$0.420	\$0.752
STORAGE (\$/HR)	\$0.027	\$0.192*	\$0.002**
DATA CENTER	Montreal	US East	East US

\*Includes price for EBS-optimized Instance Pricing and 1500 provisioned IOPS

\*\*Price of Block Blob storage

## TESTING NOTES

- Testing was conducted for a period of 5 days.
  - The testing spanned from 12/17/14 to 12/21/14.
  - Tests were conducted twice per day for each day of testing.
- The average performance values from the entire testing period were used in the price-performance calculations as the [Provider Performance Score].
- The performance variability was measured using the coefficient of variation (standard deviation / average) of values from the entire testing period.
- Persistent storage (also known as block storage) was tested instead of ephemeral storage (also known as local storage) due to the greater dependability of the data volume as well as the common user need to retain data regardless of the on/off state of the VM.
- The storage volume of Amazon was an EBS SSD Provisioned IOPS device with 1500 provisioned IOPS
  - 1500 provisioned IOPS is the maximum number of IOPS that can be provisioned from a 50GB storage volume. The maximum number of IOPS allocated scales with the size of the storage volume.
  - Provisioned IOPS was chosen over General Purpose SSD because the latter offering can achieve 3000 IOPS on burst, but only ~150 IOPS for overall use, resulting in variable performance. Provisioned IOPS EBS offers consistent performance to the tune of the number of IOPS provisioned.