

Cloud IaaS Performance & Price-Performance

Comparing Linux Compute Performance of Amazon EC2, NxtGen ECS, Rackspace Cloud Servers and SoftLayer Virtual Servers

Prepared for NxtGen
Commercial Report

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EXECUTIVE SUMMARY

NxtGen commissioned Cloud Spectator to measure the performance of virtual machines (VMs) across:

1. AWS Elastic Cloud Compute (EC2)
2. Rackspace Cloud Servers
3. SoftLayer Virtual Servers
4. NxtGen's Enterprise Cloud Services (ECS)

NxtGen wanted to compare performance and value (defined as price-performance) across the different cloud providers. To measure performance and value, Cloud Spectator benchmarked vCPU, memory, storage, and internal network performance. To measure value, Cloud Spectator compared performance in relation to pricing.

Table A (*shown below*) lists the VMs that were examined in this study. Amazon and Rackspace designate specific instance names to the tiered VM sizes that they offer. NxtGen and SoftLayer VMs were assigned names for the purpose of simplifying identification of specific VMs in this study.

	vCPU	NxtGen Memory	Storage
c2m2	2	2GB	100GB
c2m4	2	4GB	100GB
c2m8	2	8GB	100GB
c4m4	4	4GB	500GB
c4m8	4	8GB	500GB
c4m15	4	15GB	500GB
c8m8	8	8GB	1000GB
c8m15	8	15GB	1000GB
c8m30	8	30GB	1000GB

	vCPU	Amazon Memory	Storage
c4.large	2	3.75	100GB
m3.large	2	7.5	100GB
c4.xlarge	4	7.5	500GB
m3.xlarge	4	15	500GB
c4.2xlarge	8	15	1000GB
m3.2xlarge	8	30	1000GB

	vCPU	Rackspace Memory	Storage
gen1-2	2	2	100GB
gen1-4	4	4	500GB
io1-15	4	15	500GB
gen1-8	8	8	1000GB
io1-30	8	30	1000GB

	vCPU	Softlayer Memory	Storage
2c4m	2	4	100GB
2c8m	2	8	100GB
4c8m	4	8	500GB
4c16m	4	16	500GB
8c16m	8	16	1000GB
8c32m	8	32	1000GB

Table A: The list of VM types and the amount of resources dedicated to each VM.

NXTGEN PERFORMANCE SUMMARY

Table 1 (*shown on the following page*) lists NxtGen's VM performance rankings as compared against the VMs on Amazon, Rackspace and SoftLayer from Table A (*above*). The 2vCPU rankings are out of 8 (1 – best performance, 8 – worst performance); the 4vCPU and

8vCPU rankings are out of 9 (1 – best performance, 9 – worst performance). VMs are ranked between VMs offering the same number of vCPUs.

TESTING RESULTS - PERFORMANCE RANKINGS											
	VM TYPE	vCPU		Memory	Sequential Read	Storage			Internal Network		
		Integer	Floating Point	Memory		Sequential Write	Random Read	Random Write	Iperf	Ping	
NxtGen	2vCPU	c2m2	5TH	6TH	2ND	3RD	2ND	2ND	1ST	4TH	3RD
		c2m4	6TH	5TH	1ST	1ST	1ST	1ST	2ND	3RD	4TH
		c2m8	7TH	7TH	3RD	2ND	3RD	3RD	3RD	2ND	2ND
	4vCPU	c4m4	8TH	9TH	5TH	3RD	3RD	3RD	3RD	3RD	5TH
		c4m8	9TH	8TH	7TH	2ND	2ND	2ND	2ND	2ND	3RD
		c4m15	7TH	7TH	4TH	1ST	1ST	1ST	1ST	4TH	4TH
	8vCPU	c8m8	9TH	9TH	6TH	3RD	3RD	3RD	3RD	6TH	4TH
		c8m15	8TH	8TH	5TH	1ST	2ND	1ST	1ST	4TH	3RD
		c8m30	7TH	7TH	4TH	2ND	1ST	2ND	2ND	5TH	6TH

Table 1: The ranking of NxtGen's performance scores compared to the other providers included in this study.

The results of the price-performance analysis yielded the following comparative rankings for the VMs on NxtGen compared to the VMs listed in Table A (*previous page*). Table 2 (*below*) shows NxtGen's VMs provide greater price-performance value than the other providers in the Storage tests across all VM sizes, while also providing greater value in the majority of Internal Network tests. The 2vCPU VMs in particular displayed the highest price-performance across all tests except for two.

VALUE ANALYSIS RESULTS – PRICE:PERFORMANCE PRICING										
	VM TYPE	vCPU		Memory	Sequential Read	Storage			Internal Network	
		Integer	Floating Point	Memory		Sequential Write	Random Read	Random Write	Iperf	Ping
NxtGen	2vCPU	c2m2	1ST	1ST	1ST	1ST	1ST	1ST	1ST	1ST
		c2m4	2ND	2ND	2ND	2ND	2ND	2ND	2ND	2ND
		c2m8	3RD	3RD	3RD	3RD	3RD	3RD	3RD	3RD
	4vCPU	c4m4	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND
		c4m8	4TH	4TH	2ND	1ST	2ND	1ST	2ND	3RD
		c4m15	6TH	6TH	3RD	3RD	3RD	3RD	3RD	4TH
	8vCPU	c8m8	3RD	3RD	1ST	1ST	1ST	1ST	2ND	2ND
		c8m15	5TH	5TH	2ND	2ND	2ND	2ND	3RD	3RD
		c8m30	6TH	6TH	3RD	3RD	3RD	3RD	5TH	4TH

Table 2: The ranking of NxtGen's price-performance value compared to the other providers included in this study.

vCPU PERFORMANCE SUMMARY

For this study, Cloud Spectator evaluated vCPU performance by benchmarking the VMs using Geekbench 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 period. Pricing was examined in conjunction with the performance tests.

vCPU Performance Key Findings:

- NxtGen's VMs exhibited the lowest vCPU performance in 4 out of 6 tests across all VM sizes; specifically the 4vCPU and 8vCPU VMs
- NxtGen's VMs offered the highest price-performance value for vCPU in 3 out of 6 tests across all VM sizes; specifically the 2vCPU VMs
- Of the three NxtGen VMs, the machines with the most allocated RAM performed highest on 4vCPU and 8vCPU processor tests

MEMORY PERFORMANCE SUMMARY

Memory was evaluated using the Geekbench 3 benchmark suite, which measures memory throughput using the STREAM benchmark. Memory throughput was measured over a 5-day testing period. Pricing was examined in conjunction with the performance tests.

Memory Performance Key Findings:

- NxtGen showed the highest memory performance for 2vCPU VMs
- NxtGen's VMs offered the highest price-performance value for memory in 6 out of 6 tests across all VM sizes
- Of the three NxtGen VMs, the machines with the most allocated RAM performed highest on 4vCPU and 8vCPU memory tests
- NxtGen and Softlayer's memory performance remains stagnant across all VM sizes, compared to Amazon and Rackspace which scale with size; possibly due dissimilar physical hosts allocated for different VM types on providers with tiered VM offerings

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 8kb were examined). Testing occurred over a 5-day 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:

- NxtGen's VMs exhibited the highest storage performance in 12 out of 12 storage tests across all VM sizes
- NxtGen's VMs exhibited the highest storage price-performance value in 12 out of 12 storage tests across all VM sizes
- Storage performance measured between 25-35k IOPS for sequential r/w and between 15-25k IOPS for random r/w operations

INTERNAL NETWORK PERFORMANCE SUMMARY

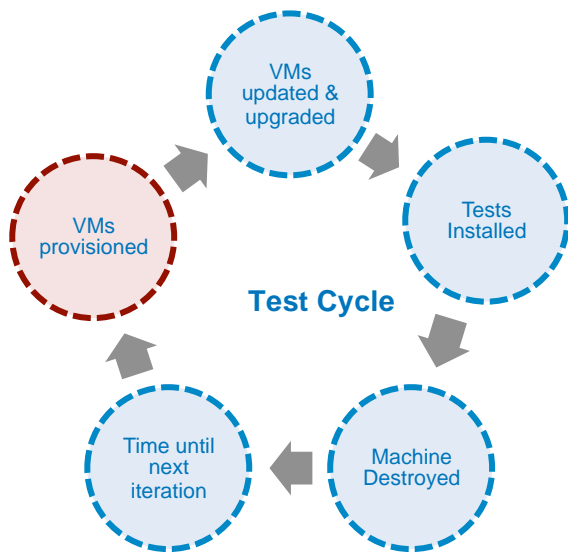
Internal network performance was measured as the throughput and latency between VMs within the local area network of the cloud provider's data center. Throughput and latency were measured using iperf and ping over the course of a 5-day test period. Pricing was examined in conjunction with the performance tests.

Internal Network Performance Key Findings:

- NxtGen exhibited the 2nd highest throughput for 2vCPU and 4vCPU VMs behind SoftLayer
- NxtGen exhibited the 2nd lowest latency for the majority of VMs behind Amazon
- NxtGen's throughput offered the highest price-performance value for 2vCPU and 4vCPU VMs; SoftLayer for the 8vCPU VMs, offering 14-50% higher price-performance value than NxtGen
- NxtGen's latency offered the highest price-performance value for the 2vCPU VMs

INTRODUCTION

Performance and pricing are both key considerations in the public cloud industry. The price wars between some of the largest providers, such as Amazon EC2, Microsoft Azure and Google Compute, have pressured the industry to increase innovation in order to stay competitive. Therefore, performance is quickly becoming an important focus as providers start introducing better performing offerings. This report specifically examines the performance and price-performance of Amazon EC2, NxtGen ECS, Rackspace Cloud Servers and SoftLayer Virtual Servers.



Cloud Spectator performed 5 iterations of vCPU, memory, storage and internal network tests on 2vCPU VMs, 4vCPU VMs and 8vCPU VMs (see the *Appendix for more detailed information*). Tests were conducted once per day for five consecutive days to capture variation in performance across different physical hosts.

Processor Performance Across the IaaS Industry

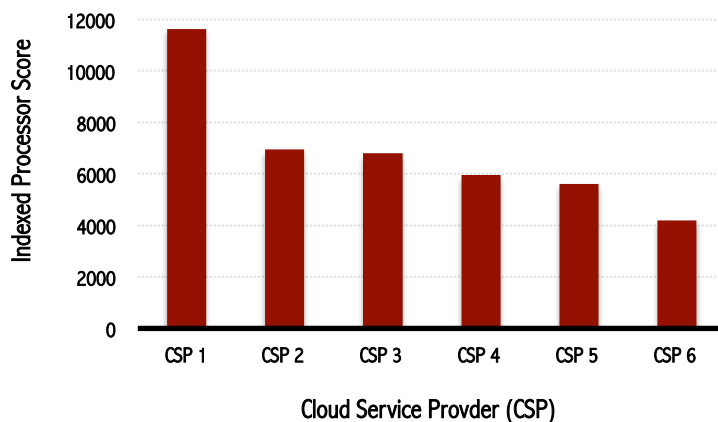


Figure 1: Variance in VM performance across the industry means that simply comparing features or pricing cannot make an apples-to-apples comparison.

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 to 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 or VM sizes 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. Table 3 below lists the four hardware components studied in this project, and each purpose as a function within the server.

CPU PERFORMANCE	MEMORY PERFORMANCE	STORAGE PERFORMANCE	INTERNAL 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 the best application performance in many cases.	In a cloud environment, internal network performance is critical. Distributed environments must maintain a strong network backbone for servers to communicate efficiently and synchronize data.

Table 3: 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 1 vCPU VM on Provider A can only be compared to a 1 vCPU 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 March 23, 2015. Pricing may change for the specified VMs after the release of this report.
- Testing was conducted on specific VM configurations for each provider. Different VM configurations may yield different comparative results between the providers.
- 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; 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, NxtGen, Rackspace and SoftLayer. The raw scores and rankings of the three different VM sizes examined across the four providers are shown below.

TESTING RESULTS - PERFORMANCE RANKINGS											
		VM TYPE	vCPU		Memory	Storage				Internal Network	
			Integer	Floating Point	Memory	Sequential Read	Sequential Write	Random Read	Random Write	Iperf	Ping
Amazon	2vCPU	c4.large	3RD	3RD	7TH	8TH	8TH	7TH	8TH	7TH	1ST
		m3.large	8TH	8TH	8TH	7TH	7TH	8TH	7TH	6TH	7TH
	4vCPU	c4.xlarge	4TH	4TH	2ND	8TH	6TH	8TH	6TH	8TH	1ST
		m3.xlarge	6TH	6TH	6TH	9TH	7TH	9TH	7TH	7TH	2ND
	8vCPU	c4.2xlarge	5TH	5TH	3RD	9TH	7TH	9TH	6TH	8TH	1ST
		m3.2xlarge	6TH	6TH	7TH	8TH	8TH	8TH	7TH	9TH	2ND
NxtGen	2vCPU	c2m2	5TH	6TH	2ND	3RD	2ND	2ND	1ST	4TH	3RD
		c2m4	6TH	5TH	1ST	1ST	1ST	1ST	2ND	3RD	4TH
	4vCPU	c2m8	7TH	7TH	3RD	2ND	3RD	3RD	3RD	2ND	2ND
		c4m4	8TH	9TH	5TH	3RD	3RD	3RD	3RD	3RD	5TH
		c4m8	9TH	8TH	7TH	2ND	2ND	2ND	2ND	2ND	3RD
	8vCPU	c4m15	7TH	7TH	4TH	1ST	1ST	1ST	1ST	4TH	4TH
		c8m8	9TH	9TH	6TH	3RD	3RD	3RD	3RD	6TH	4TH
		c8m15	8TH	8TH	5TH	1ST	2ND	1ST	1ST	4TH	3RD
Rackspace	2vCPU	gen1-2	2ND	2ND	4TH	4TH	4TH	4TH	4TH	8TH	8TH
		gen1-4	3RD	3RD	3RD	5TH	5TH	5TH	5TH	9TH	9TH
	4vCPU	io1-15	2ND	2ND	1ST	4TH	4TH	4TH	4TH	6TH	8TH
		gen1-8	4TH	4TH	1ST	4TH	5TH	4TH	4TH	7TH	9TH
		io1-30	3RD	3RD	2ND	5TH	4TH	5TH	5TH	3RD	8TH
SoftLayer	2vCPU	2c4m	4TH	4TH	5TH	6TH	6TH	6TH	6TH	1ST	5TH
		2c8m	1ST	1ST	6TH	5TH	5TH	5TH	5TH	5TH	6TH
	4vCPU	4c8m	5TH	5TH	9TH	6TH	9TH	7TH	9TH	5TH	7TH
		4c16m	1ST	1ST	8TH	7TH	8TH	6TH	8TH	1ST	6TH
	8vCPU	8c16m	1ST	2ND	9TH	6TH	9TH	6TH	8TH	2ND	7TH
		8c32m	2ND	1ST	8TH	7TH	6TH	7TH	9TH	1ST	5TH

vCPU PERFORMANCE TESTING RESULTS

vCPU – Integer Test

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 Geekbench¹, “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 four providers included in this study.

vCPU – Floating Point Test

Floating Point tasks is the other category of CPU operations that Geekbench tests in its benchmark. As stated by Geekbench¹, “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 four providers included in this study.

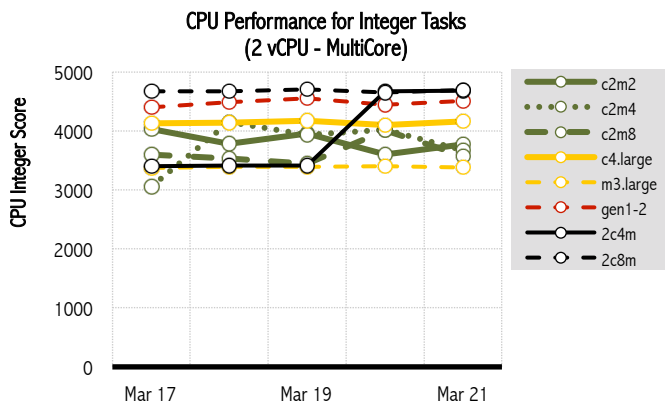
Observations:

- Rackspace and SoftLayer scale by approximately 2x when doubling vCPUs; NxtGen scales between 1.5-2x when doubling vCPUs
- SoftLayer's processor performance varies despite having the same amount of vCPUs. This is because SoftLayer provisioned the same VMs on two different physical processors during the course of the study:
 - Intel Xeon E5-2650 @ 2.00 GHz
 - Intel Xeon E5-2650 V2 @ 2.60 GHz
- Therefore, SoftLayer's CV of 18% is more aligned with the reality of their performance fluctuation (again, due to the variable processors).
- Performance between NxtGen servers of the same vCPU count was similar: 2vCPU and 4vCPU VMs scored within 10% of each other, 8vCPU VMs scored within 5%
- On the 4vCPU and 8vCPU tests, out of the three NxtGen VMs, the machines with the most RAM performed highest
- Variability of the 2vCPU VMs averaged 8%; 4vCPU VMs averaged 6%; 8vCPU VMs averaged 4%

See results on following page:

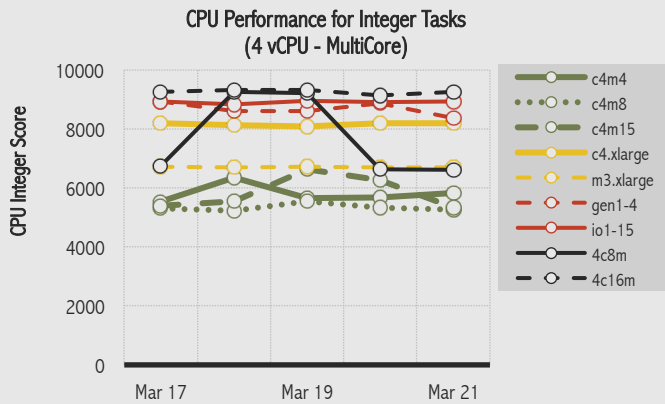
¹ <http://support.primatelabs.com/kb/geekbench/interpreting-geekbench-3-scores>

vCPU PERFORMANCE TESTING RESULTS: INTEGER TASKS



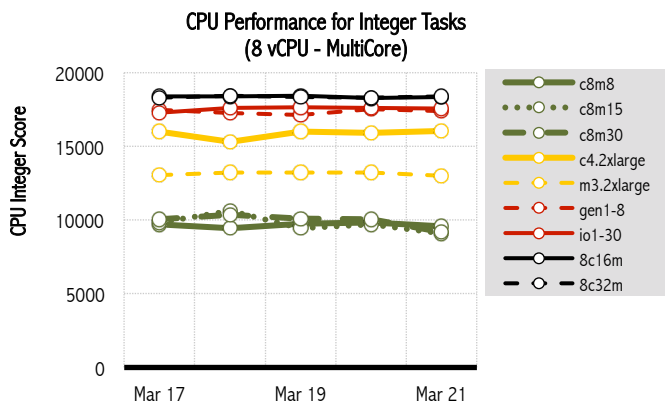
vCPU Performance – Integer Tasks (Multicore): 2vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	2c8m	4678	0%	4701	4650
Rackspace	gen1-2	4475	1%	4547	4394
Amazon	c4.large	4139	1%	4169	4098
SoftLayer	2c4m	3914	18%	4683	3398
NxtGen	c2m2	3825	4%	4028	3600
NxtGen	c2m4	3766	12%	4148	3058
NxtGen	c2m8	3630	6%	4003	3440
Amazon	m3.large	3384	0%	3396	3371



vCPU Performance – Integer Tasks (Multicore): 4vCPU

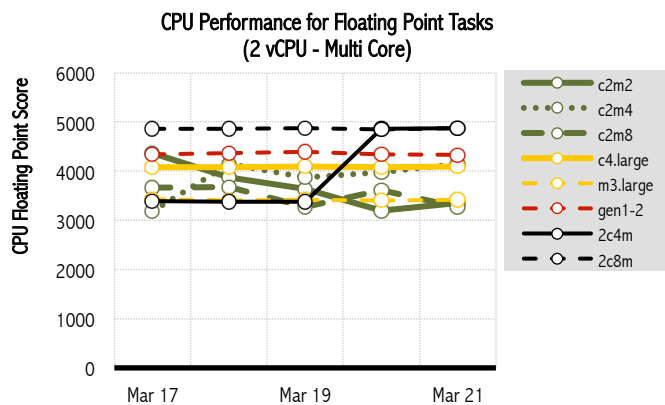
Provider	VM	Average	CV	Max	Min
SoftLayer	4c16m	9260	1%	9327	9133
Rackspace	io1-15	8908	1%	8955	8829
Rackspace	gen1-4	8671	3%	8938	8363
Amazon	c4.xlarge	8149	1%	8180	8073
SoftLayer	4c8m	7685	18%	9242	6611
Amazon	m3.xlarge	6698	0%	6710	6686
NxtGen	c4m15	5831	10%	6630	5334
NxtGen	c4m4	5806	5%	6339	5532
NxtGen	c4m8	5331	2%	5545	5223



vCPU Performance – Integer Tasks (Multicore): 8vCPU

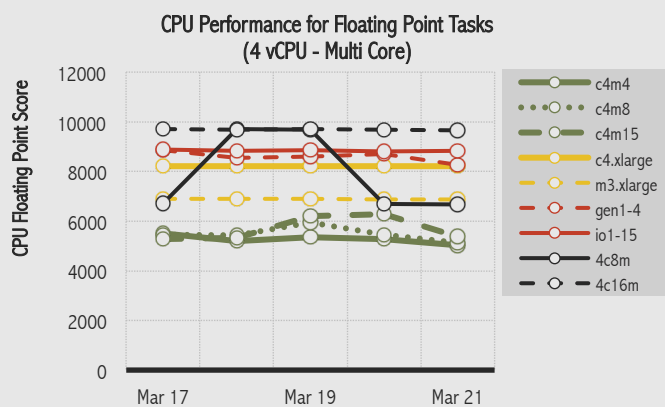
Provider	VM	Average	CV	Max	Min
SoftLayer	8c16m	18352	0%	18403	18265
SoftLayer	8c32m	18333	0%	18406	18270
Rackspace	io1-30	17530	1%	17631	17268
Rackspace	gen1-8	17338	1%	17509	17113
Amazon	c4.2xlarge	15832	2%	16018	15290
Amazon	m3.2xlarge	13138	1%	13224	12985
NxtGen	c8m30	9943	5%	10365	9170
NxtGen	c8m15	9725	6%	10611	9075
NxtGen	c8m8	9647	2%	9823	9417

vCPU PERFORMANCE TESTING RESULTS: FLOATING POINT TASKS



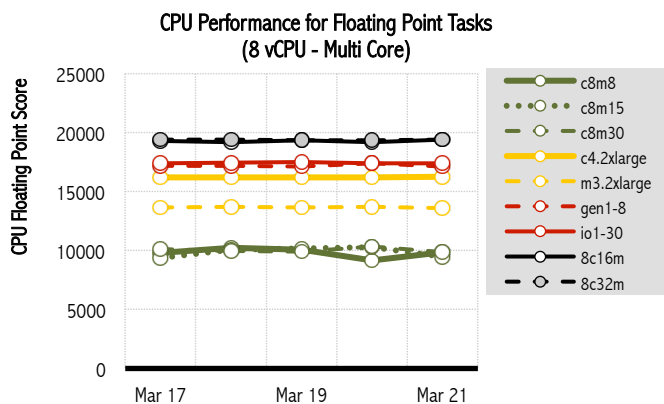
vCPU Performance – FP Tasks (Multicore): 2vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	2c8m	4863	0%	4869	4849
Rackspace	gen1-2	4355	1%	4390	4333
Amazon	c4.large	4085	0%	4096	4077
SoftLayer	2c4m	3975	21%	4872	3373
NxtGen	c2m4	3863	10%	4146	3182
NxtGen	c2m2	3684	12%	4364	3197
NxtGen	c2m8	3500	6%	3676	3271
Amazon	m3.large	3411	0%	3424	3399



vCPU Performance – FP Tasks (Multicore): 4vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	4c16m	9695	0%	9724	9657
Rackspace	io1-15	8847	0%	8880	8813
Rackspace	gen1-4	8595	3%	8861	8271
Amazon	c4.xlarge	8223	0%	8230	8205
SoftLayer	4c8m	7901	21%	9702	6676
Amazon	m3.xlarge	6894	0%	6909	6877
NxtGen	c4m15	5696	9%	6291	5281
NxtGen	c4m8	5486	5%	5960	5132
NxtGen	c4m4	5274	3%	5499	5031



vCPU Performance – FP Tasks (Multicore): 8vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	8c32m	19363	0%	19399	19321
SoftLayer	8c16m	19261	1%	19363	19146
Rackspace	io1-30	17418	0%	17490	17368
Rackspace	gen1-8	17189	1%	17387	17103
Amazon	c4.2xlarge	16199	0%	16229	16174
Amazon	m3.2xlarge	13647	0%	13688	13586
NxtGen	c8m30	10036	2%	10338	9861
NxtGen	c8m15	9872	4%	10290	9359
NxtGen	c8m8	9815	4%	10221	9157

MEMORY PERFORMANCE TESTING RESULTS

Memory Test

Memory performance was evaluated by running benchmark tests from the Geekbench 3 suite. The Geekbench 3 suite measures memory throughput using STREAM (*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 four providers included in this study.

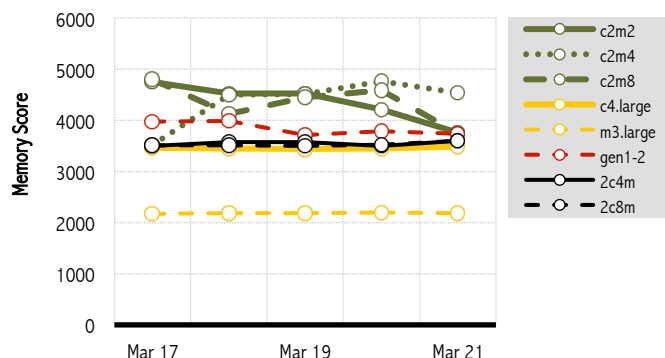
Observations:

- Amazon and Rackspace scale in memory bandwidth from 2vCPU to 4vCPU, and Rackspace continues scaling from 4vCPU to 8vCPU; NxtGen and SoftLayer memory bandwidth levels remain stagnant across all three VM sizes.
 - It should be noted that Amazon and Rackspace, which scales in memory bandwidth, offer packaged VMs, while SoftLayer and NxtGen, which do not scale, offer individually configurable VMs. AWS and possibly Rackspace place VMs on different physical hosts depending on the size of the VM. The motherboard and memory type may vary, which can have an effect on bandwidth availability of the memory.
- Performance between NxtGen servers was similar: VMs with 2vCPU and 8vCPU scored within 4% of each other, VMs with 4vCPU scored within 7%
- Similar to the vCPU tests, on the 4vCPU and 8vCPU memory tests, the machine with the most RAM performed the highest for each group

See results on following page:

MEMORY PERFORMANCE TESTING RESULTS

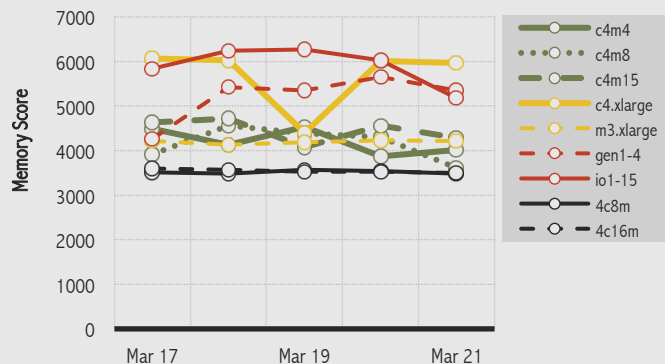
Memory Performance (2 vCPU - Multi Core)



Memory Performance (Multicore): 2vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c2m4	4369	11%	4768	3517
NxtGen	c2m2	4357	9%	4749	3761
NxtGen	c2m8	4343	10%	4801	3749
Rackspace	gen1-2	3842	3%	3995	3714
SoftLayer	2c4m	3551	1%	3597	3501
SoftLayer	2c8m	3531	1%	3598	3500
Amazon	c4.large	3458	1%	3489	3443
Amazon	m3.large	2185	0%	2193	2171

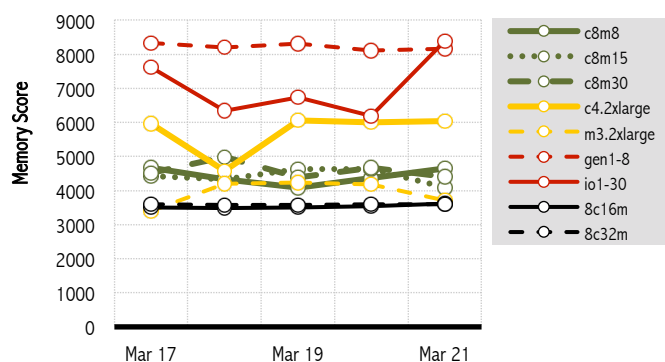
Memory Performance (4 vCPU - Multi Core)



Memory Performance (Multicore): 4vCPU

Provider	VM	Average	CV	Max	Min
Rackspace	io1-15	5909	8%	6275	5179
Amazon	c4.xlarge	5695	13%	6068	4400
Rackspace	gen1-4	5205	10%	5651	4260
NxtGen	c4m15	4456	6%	4717	4079
NxtGen	c4m4	4206	7%	4526	3866
Amazon	m3.xlarge	4194	1%	4227	4133
NxtGen	c4m8	4156	9%	4566	3610
SoftLayer	4c16m	3543	1%	3604	3491
SoftLayer	4c8m	3517	1%	3566	3481

Memory Performance (8 vCPU - Multi Core)



Memory Performance (Multicore): 8vCPU

Provider	VM	Average	CV	Max	Min
Rackspace	gen1-8	8224	1%	8330	8111
Rackspace	io1-30	7058	13%	8396	6185
Amazon	c4.2xlarge	5731	11%	6057	4579
NxtGen	c8m30	4593	5%	4983	4387
NxtGen	c8m15	4424	5%	4634	4096
NxtGen	c8m8	4419	5%	4661	4081
Amazon	m3.2xlarge	3949	9%	4233	3399
SoftLayer	8c32m	3591	0%	3603	3574
SoftLayer	8c16m	3533	1%	3617	3487

STORAGE PERFORMANCE TESTING RESULTS

Storage – FIO Test

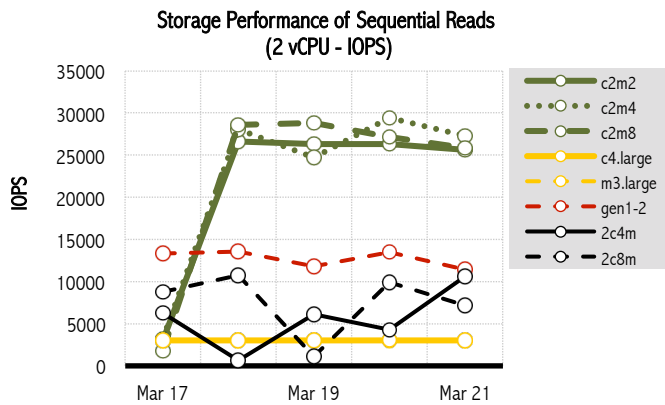
Storage performance was measured using the persistent network storage offerings from each provider. Storage performance was evaluated by running tests with the FIO disk benchmark (see *Methodology for details*). FIO was configured to test sequential read/write and random read/write operations across 8kb block sizes using a 2GB file. 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 100GB (2vCPU), 500GB (4vCPU) and 1000GB (8vCPU) storage volumes across the four providers included in this study.

Observations:

- NxtGen's 2vCPU and 4vCPU machines encountered significantly lower performance on the first iteration of testing; the 8vCPU machines remained stable throughout
- NxtGen's Sequential Read/Write operations score between 25-35,000 IOPS for the majority of data points measured across the three VM sizes (and associated storage volumes) ; the next highest performing provider, Rackspace, scored between 12-15,000 IOPS
- NxtGen's Random Read/Write operations score between 15-25,000 IOPS for the majority of data points measured across the three VM sizes (and associated storage volumes); the next highest performing provider, Rackspace, scored between 12-14,000 IOPS
- NxtGen's use of vSAN with hypervisor-convergence may be attributed to the high-performance on reads and writes AFTER the first test in a majority of scenarios—integrated caching with the vSAN can deliver optimized IO data paths.
- Performance between NxtGen servers was similar for the 8vCPU machines, scoring within 6% each
- NxtGen performance increased by varying levels as the vCPU and associated storage volume sizes increased; performance scaling varied on the other providers

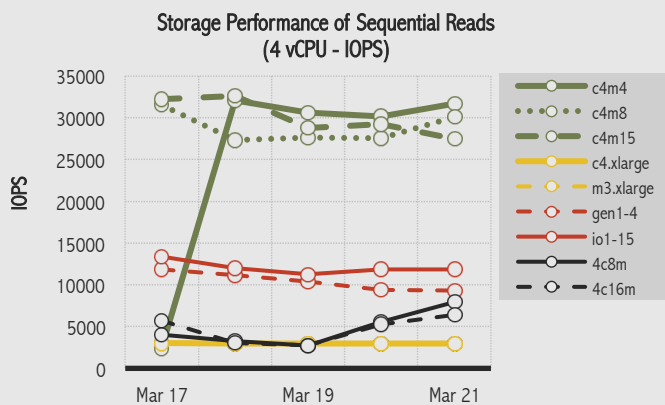
See results on following page:

STORAGE PERFORMANCE TESTING RESULTS: SEQUENTIAL READ



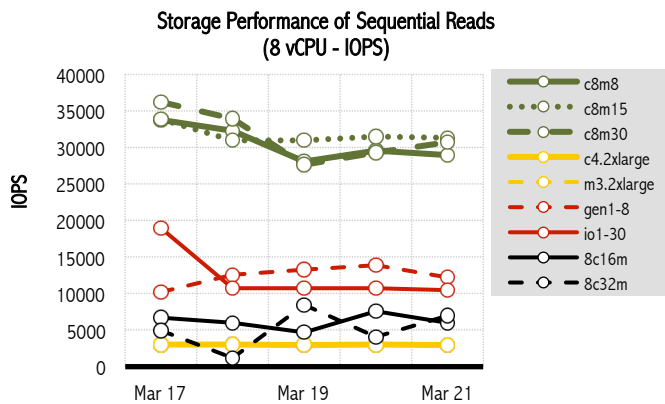
Storage Performance – Sequential Read: 2vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c2m4	22540	49%	29445	3217
NxtGen	c2m8	22433	52%	28834	1782
NxtGen	c2m2	21576	48%	26647	2981
Rackspace	gen1-2	12719	8%	13557	11395
SoftLayer	2c8m	7547	51%	10723	1114
SoftLayer	2c4m	5591	65%	10594	633
Amazon	m3.large	3035	0%	3046	3024
Amazon	c4.large	3034	0%	3042	3022



Storage Performance – Sequential Read: 4vCPU

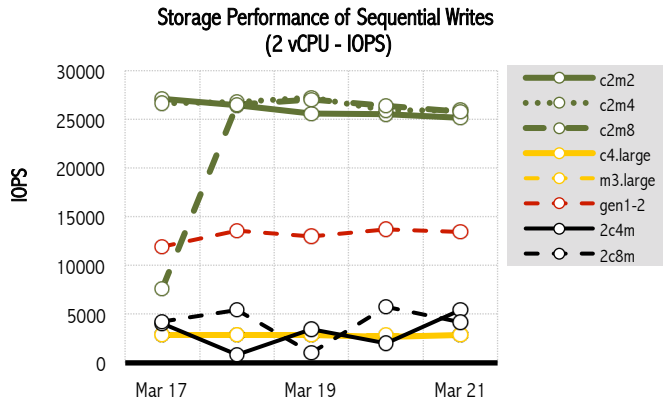
Provider	VM	Average	CV	Max	Min
NxtGen	c4m15	30040	8%	32575	27432
NxtGen	c4m8	28825	7%	31562	27293
NxtGen	c4m4	25367	51%	32096	2376
Rackspace	io1-15	12064	6%	13336	11261
Rackspace	gen1-4	10408	10%	11812	9287
SoftLayer	4c8m	4711	45%	7961	2718
SoftLayer	4c16m	4634	36%	6403	2763
Amazon	c4.xlarge	2986	0%	2995	2973
Amazon	m3.xlarge	2970	0%	2985	2955



Storage Performance – Sequential Read: 8vCPU

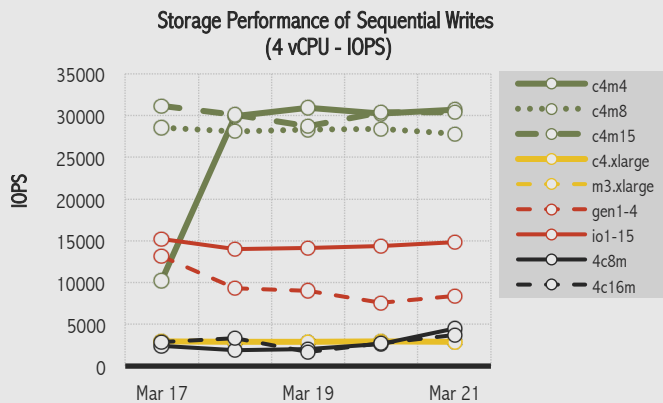
Provider	VM	Average	CV	Max	Min
NxtGen	c8m15	31719	4%	33883	30943
NxtGen	c8m30	31548	11%	36247	27601
NxtGen	c8m8	30525	8%	33800	28043
Rackspace	gen1-8	12429	11%	13870	10180
Rackspace	io1-30	12322	30%	18979	10452
SoftLayer	8c16m	6207	17%	7572	4684
SoftLayer	8c32m	5129	55%	8454	1165
Amazon	m3.2xlarge	2982	0%	2989	2968
Amazon	c4.2xlarge	2981	0%	2986	2965

STORAGE PERFORMANCE TESTING RESULTS: SEQUENTIAL WRITE



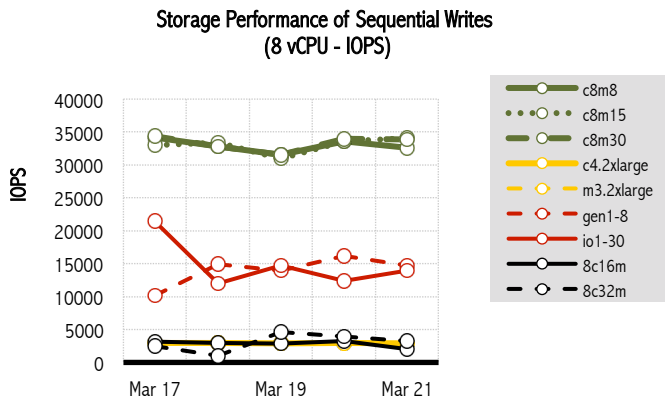
Storage Performance – Sequential Write: 2vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c2m4	26492	2%	27212	25884
NxtGen	c2m2	25939	3%	27086	25143
NxtGen	c2m8	22655	37%	27014	7617
Rackspace	gen1-2	13100	5%	13675	11923
SoftLayer	2c8m	4129	45%	5745	1028
SoftLayer	2c4m	3158	56%	5437	838
Amazon	m3.large	2854	0%	2864	2845
Amazon	c4.large	2812	3%	2860	2659



Storage Performance – Sequential Write: 4vCPU

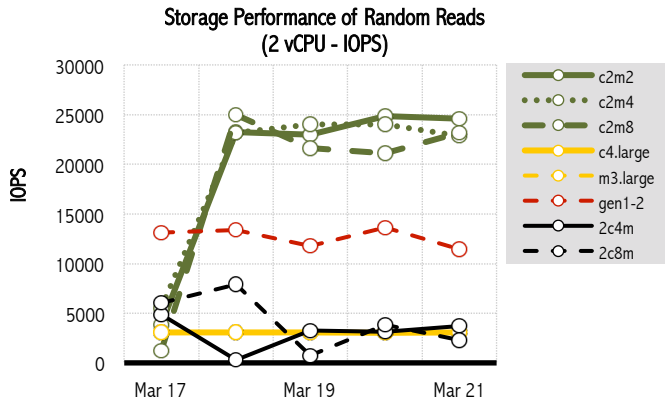
Provider	VM	Average	CV	Max	Min
NxtGen	c4m15	30146	3%	31161	28712
NxtGen	c4m8	28227	1%	28541	27814
NxtGen	c4m4	26389	34%	30952	10196
Rackspace	io1-15	14504	3%	15182	14004
Rackspace	gen1-4	9497	23%	13166	7581
Amazon	c4.xlarge	2914	0%	2922	2905
Amazon	m3.xlarge	2900	0%	2914	2886
SoftLayer	4c16m	2895	27%	3745	1684
SoftLayer	4c8m	2681	39%	4462	1902



Storage Performance – Sequential Write: 8vCPU

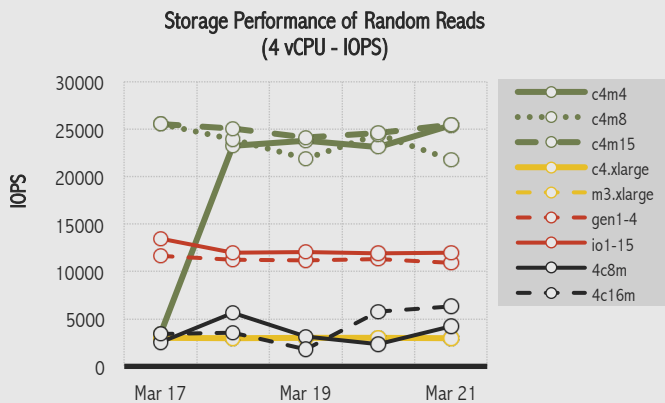
Provider	VM	Average	CV	Max	Min
NxtGen	c8m30	33298	4%	34316	31494
NxtGen	c8m15	32981	4%	34039	30927
NxtGen	c8m8	32905	3%	34120	31511
Rackspace	io1-30	14905	26%	21437	11996
Rackspace	gen1-8	13988	16%	16216	10137
SoftLayer	8c32m	3055	46%	4600	1003
Amazon	c4.2xlarge	2913	0%	2923	2898
Amazon	m3.2xlarge	2912	0%	2922	2894
SoftLayer	8c16m	2842	17%	3240	2023

STORAGE PERFORMANCE TESTING RESULTS: RANDOM READ



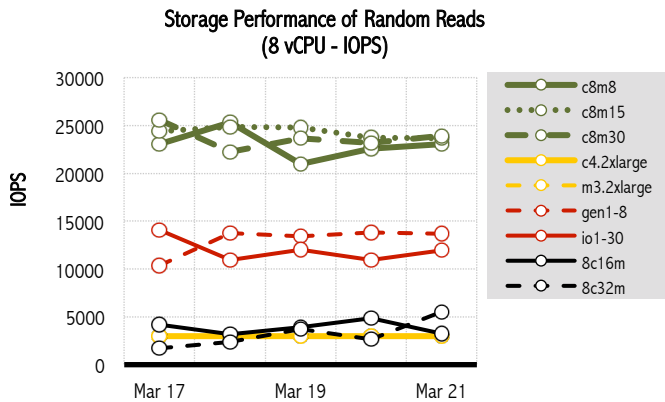
Storage Performance – Random Read: 2vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c2m4	19942	41%	24043	5519
NxtGen	c2m2	19908	45%	24878	3852
NxtGen	c2m8	18430	53%	24987	1188
Rackspace	gen1-2	12681	8%	13646	11428
SoftLayer	2c8m	4146	69%	7875	715
SoftLayer	2c4m	3053	55%	4883	287
Amazon	c4.large	3047	0%	3063	3028
Amazon	m3.large	3043	0%	3064	3028



Storage Performance – Random Read: 4vCPU

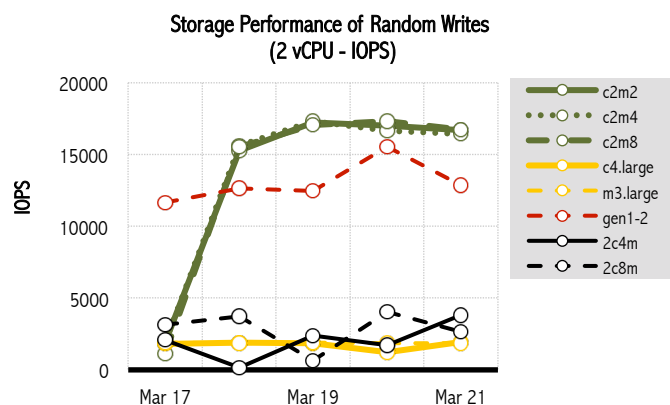
Provider	VM	Average	CV	Max	Min
NxtGen	c4m15	24992	2%	25589	24144
NxtGen	c4m8	23529	7%	25538	21810
NxtGen	c4m4	19810	46%	25391	3443
Rackspace	io1-15	12285	5%	13490	11894
Rackspace	gen1-4	11274	2%	11645	10919
SoftLayer	4c16m	4156	45%	6306	1782
SoftLayer	4c8m	3583	38%	5634	2340
Amazon	c4.xlarge	2980	0%	2989	2968
Amazon	m3.xlarge	2968	0%	2980	2952



Storage Performance – Random Read: 8vCPU

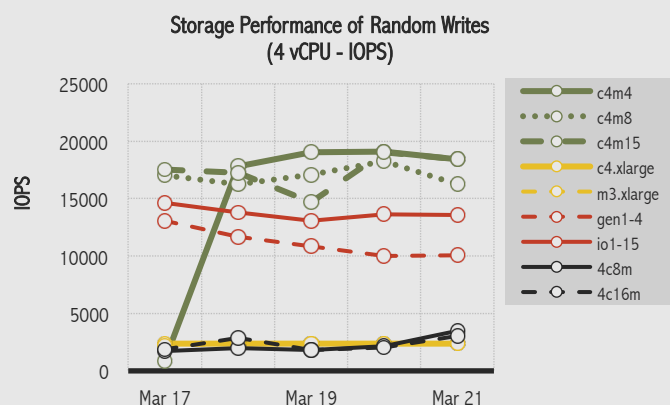
Provider	VM	Average	CV	Max	Min
NxtGen	c8m15	24295	2%	24880	23665
NxtGen	c8m30	23707	5%	25604	22214
NxtGen	c8m8	22999	7%	25336	20947
Rackspace	gen1-8	12999	11%	13809	10349
Rackspace	io1-30	11993	11%	14108	10929
SoftLayer	8c16m	3884	18%	4850	3179
SoftLayer	8c32m	3184	47%	5503	1707
Amazon	c4.2xlarge	2978	0%	2986	2960
Amazon	m3.2xlarge	2978	0%	2984	2965

STORAGE PERFORMANCE TESTING RESULTS: RANDOM WRITE



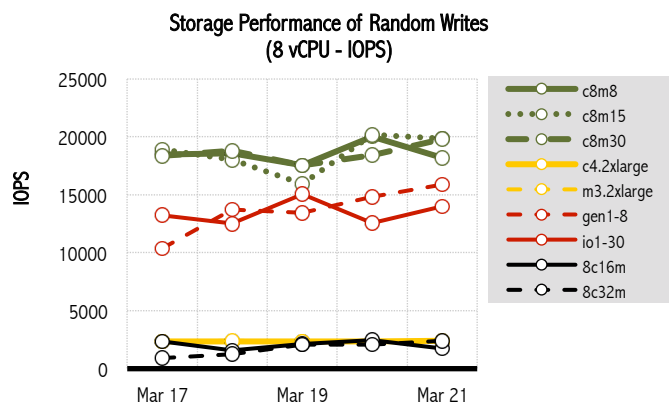
Storage Performance – Random Write: 2vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c2m2	13620	48%	17227	1918
NxtGen	c2m4	13608	48%	17332	1944
NxtGen	c2m8	13566	51%	17338	1155
Rackspace	gen1-2	13033	11%	15539	11644
SoftLayer	2c8m	2843	47%	4052	639
SoftLayer	2c4m	2022	65%	3800	150
Amazon	m3.large	1876	1%	1903	1858
Amazon	c4.large	1750	17%	1928	1222



Storage Performance – Random Write: 4vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c4m15	17385	10%	19023	14665
NxtGen	c4m8	16979	5%	18282	16226
NxtGen	c4m4	15054	53%	19114	858
Rackspace	io1-15	13744	4%	14648	13076
Rackspace	gen1-4	11143	11%	13068	10001
Amazon	c4.xlarge	2366	1%	2387	2346
Amazon	m3.xlarge	2347	4%	2398	2180
SoftLayer	4c16m	2339	25%	3061	1809
SoftLayer	4c8m	2234	32%	3505	1725



Storage Performance – Random Write: 8vCPU

Provider	VM	Average	CV	Max	Min
NxtGen	c8m15	18606	9%	20213	15942
NxtGen	c8m30	18591	4%	19803	17544
NxtGen	c8m8	18580	5%	20041	17552
Rackspace	gen1-8	13648	15%	15883	10381
Rackspace	io1-30	13473	8%	15044	12531
Amazon	c4.2xlarge	2371	1%	2422	2339
Amazon	m3.2xlarge	2352	1%	2392	2328
SoftLayer	8c16m	2056	19%	2466	1570
SoftLayer	8c32m	1739	36%	2398	898

INTERNAL NETWORK PERFORMANCE TESTING RESULTS: THROUGHPUT

Internal Network – Iperf Test

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. Internal 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.

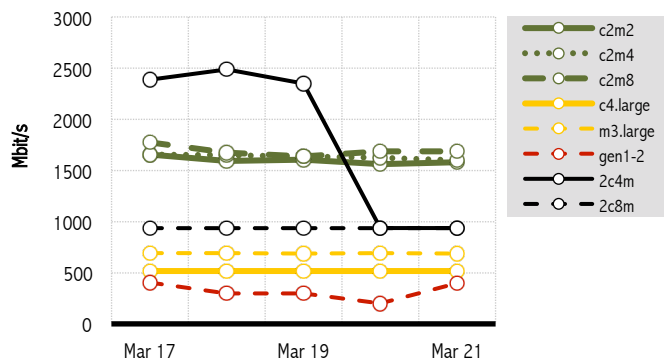
Observations:

- All NxtGen VMs achieve the same, steady level of throughput, while Amazon, Rackspace, and SoftLayer VMs scale with size
- For reasons unknown, SoftLayer's network throughput varies between 1GB/sec and 2.5-3GB/sec. Possibilities include the differences in physical hosts.

See results on following page:

INTERNAL NETWORK PERFORMANCE TESTING RESULTS: THROUGHPUT

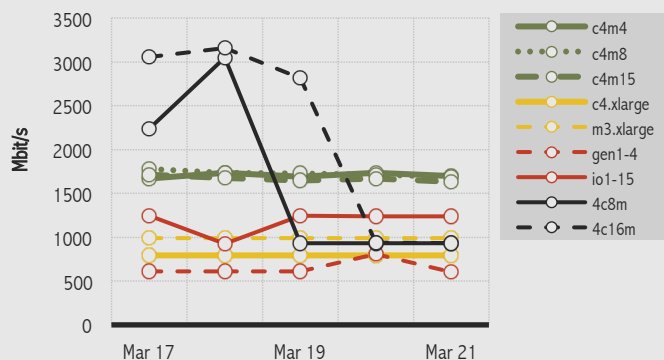
Network Throughput Performance (2 vCPU)



Internal Network Performance – Throughput: 2vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	2c4m	1822	44%	2492	938
NxtGen	c2m8	1691	3%	1773	1639
NxtGen	c2m4	1634	1%	1658	1600
NxtGen	c2m2	1600	2%	1654	1563
SoftLayer	2c8m	937	0%	938	936
Amazon	m3.large	690	0%	692	688
Amazon	c4.large	516	0%	516	516
Rackspace	gen1-2	320	26%	402	201

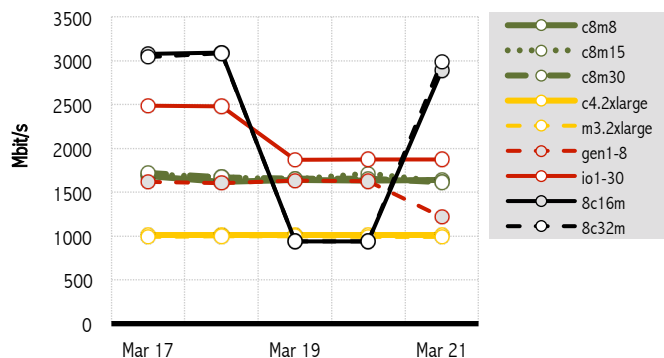
Network Throughput Performance (4 vCPU)



Internal Network Performance – Throughput: 4vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	4c16m	2180	52%	3161	934
NxtGen	c4m8	1728	2%	1779	1690
NxtGen	c4m4	1706	2%	1734	1671
NxtGen	c4m15	1667	2%	1711	1634
SoftLayer	4c8m	1618	60%	3048	932
Rackspace	io1-15	1179	12%	1244	926
Amazon	m3.xlarge	989	0%	991	988
Amazon	c4.xlarge	791	0%	791	791
Rackspace	gen1-4	647	14%	805	603

Network Throughput Performance (8 vCPU)



Internal Network Performance – Throughput: 8vCPU

Provider	VM	Average	CV	Max	Min
SoftLayer	8c32m	2199	52%	3084	939
SoftLayer	8c16m	2189	52%	3094	939
Rackspace	io1-30	2117	16%	2488	1871
NxtGen	c8m15	1672	2%	1712	1622
NxtGen	c8m30	1662	2%	1719	1615
NxtGen	c8m8	1642	1%	1681	1617
Rackspace	gen1-8	1540	12%	1635	1215
Amazon	c4.2xlarge	1010	0%	1011	1010
Amazon	m3.2xlarge	994	0%	997	990

INTERNAL NETWORK PERFORMANCE TESTING RESULTS: LATENCY

Internal Network – Ping Test

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 the physical host a VM may be provisioned on. Low network latency is crucial to cluster environments that demand high performance, such as distributed file systems (e.g., Hadoop).

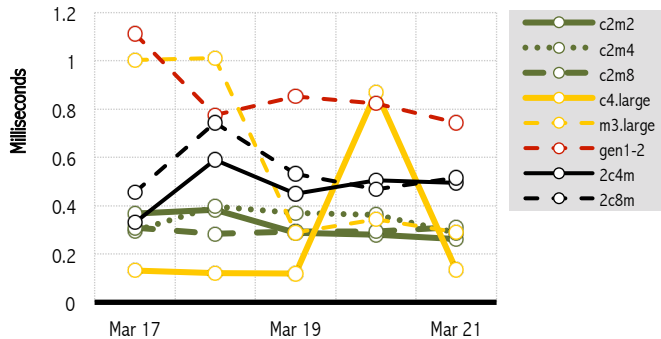
Observations:

- NxtGen's internal network latency is relatively the same across all three VM sizes; displaying values slightly above Amazon
- Performance stability varies between VMs, however given the small scale of the measurements, the variance is negligible

See results on following page:

INTERNAL NETWORK PERFORMANCE TESTING RESULTS: LATENCY

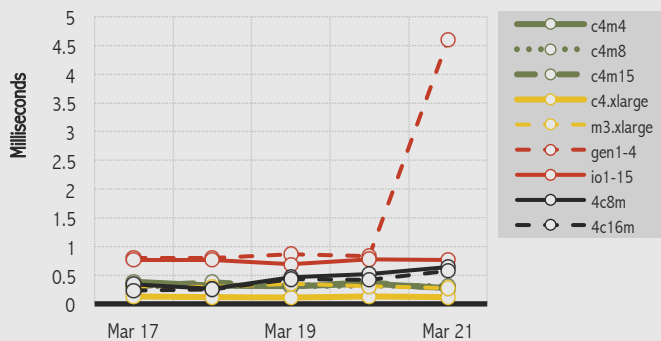
Network Latency Performance (2 vCPU) *Lower is Better*



Internal Network Performance – Latency: 2vCPU

Provider	VM	Average	CV	Max	Min
Amazon	c4.large	0.3	121%	0.9	0.1
NxtGen	c2m8	0.3	4%	0.3	0.3
NxtGen	c2m2	0.3	17%	0.4	0.3
NxtGen	c2m4	0.3	14%	0.4	0.3
SoftLayer	2c4m	0.5	20%	0.6	0.3
SoftLayer	2c8m	0.5	22%	0.7	0.5
Amazon	m3.large	0.6	65%	1.0	0.3
Rackspace	gen1-2	0.9	17%	1.1	0.7

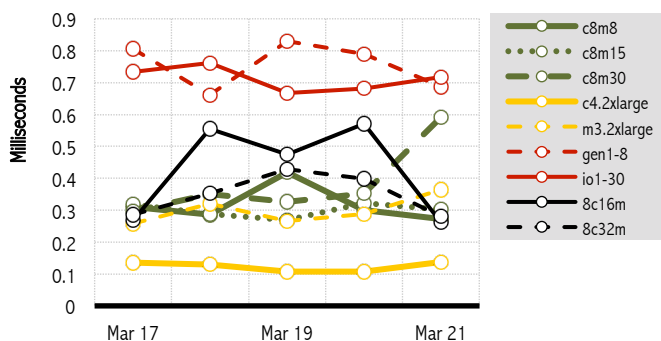
Network Latency Performance (4 vCPU) *Lower is Better*



Internal Network Performance – Latency: 4vCPU

Provider	VM	Average	CV	Max	Min
Amazon	c4.xlarge	0.1	8%	0.1	0.1
Amazon	m3.xlarge	0.3	10%	0.4	0.3
NxtGen	c4m8	0.3	3%	0.3	0.3
NxtGen	c4m15	0.3	15%	0.4	0.3
NxtGen	c4m4	0.3	13%	0.4	0.3
SoftLayer	4c16m	0.4	37%	0.6	0.2
SoftLayer	4c8m	0.4	34%	0.6	0.3
Rackspace	io1-15	0.8	5%	0.8	0.7
Rackspace	gen1-4	1.6	107%	4.6	0.8

Network Latency Performance (8 vCPU) *Lower is Better*



Internal Network Performance – Latency: 8vCPU

Provider	VM	Average	CV	Max	Min
Amazon	c4.2xlarge	0.1	12%	0.1	0.1
Amazon	m3.2xlarge	0.3	15%	0.4	0.3
NxtGen	c8m15	0.3	7%	0.3	0.3
NxtGen	c8m8	0.3	18%	0.4	0.3
SoftLayer	8c32m	0.3	19%	0.4	0.3
NxtGen	c8m30	0.4	31%	0.6	0.3
SoftLayer	8c16m	0.4	36%	0.6	0.3
Rackspace	io1-30	0.7	5%	0.8	0.7
Rackspace	gen1-8	0.8	10%	0.8	0.7

PRICE-PERFORMANCE 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*).

VALUE ANALYSIS RESULTS – PRICE:PERFORMANCE PRICING										
	VM TYPE	vCPU		Memory	Storage				Internal Network	
		Integer	Floating Point	Memory	Sequential Read	Sequential Write	Random Read	Random Write	Iperf	Ping
Amazon	2vCPU	c4.large	5TH	5TH	5TH	7TH	7TH	5TH	7TH	4TH
		m3.large	8TH	8TH	8TH	8TH	8TH	8TH	6TH	6TH
	4vCPU	c4.xlarge	5TH	5TH	4TH	8TH	7TH	8TH	7TH	1ST
		m3.xlarge	8TH	8TH	7TH	9TH	9TH	9TH	6TH	6TH
	8vCPU	c4.2xlarge	4TH	4TH	4TH	8TH	8TH	8TH	7TH	1ST
		m3.2xlarge	8TH	8TH	8TH	9TH	9TH	9TH	8TH	7TH
NxtGen	2vCPU	c2m2	1ST	1ST	1ST	1ST	1ST	1ST	1ST	1ST
		c2m4	2ND	2ND	2ND	2ND	2ND	2ND	2ND	2ND
		c2m8	3RD	3RD	3RD	3RD	3RD	3RD	3RD	3RD
	4vCPU	c4m4	1ST	2ND	1ST	2ND	1ST	2ND	1ST	2ND
		c4m8	4TH	4TH	2ND	1ST	2ND	1ST	2ND	3RD
		c4m15	6TH	6TH	3RD	3RD	3RD	3RD	3RD	4TH
	8vCPU	c8m8	3RD	3RD	1ST	1ST	1ST	1ST	2ND	2ND
		c8m15	5TH	5TH	2ND	2ND	2ND	2ND	3RD	3RD
Rackspace	2vCPU	gen1-2	4TH	4TH	4TH	4TH	4TH	4TH	8TH	8TH
		gen1-4	7TH	7TH	6TH	4TH	4TH	4TH	8TH	9TH
	4vCPU	io1-15	9TH	9TH	9TH	7TH	5TH	6TH	5TH	9TH
		gen1-8	7TH	7TH	5TH	5TH	4TH	4TH	4TH	6TH
		io1-30	9TH	9TH	9TH	7TH	5TH	6TH	5TH	9TH
Softlayer	2vCPU	2c4m	6TH	6TH	6TH	6TH	5TH	7TH	6TH	4TH
		2c8m	7TH	7TH	7TH	5TH	6TH	6TH	5TH	7TH
	4vCPU	4c8m	2ND	1ST	5TH	5TH	6TH	5TH	6TH	5TH
		4c16m	3RD	3RD	8TH	6TH	8TH	7TH	8TH	4TH
	8vCPU	8c16m	1ST	1ST	6TH	4TH	6TH	5TH	6TH	1ST
		8c32m	2ND	2ND	7TH	6TH	7TH	7TH	8TH	4TH

Provider Performance Analysis: Provider Pricing

Below are the prices per tested virtual machine across all providers and all virtual machine sizes. Storage prices are broken out from the virtual machine price as persistent storage was tested for every machine size.

2vCPU VMs								
NXTGEN			AMAZON*		RACKSPACE*	SOFTLAYER		
	c2m2	c2m4	c2m8	c4.large	m3.large	gen1-2	2c4m	2c8m
VM Price	\$43.75	\$54.05	\$74.63	\$110.96	\$143.08	\$65.70	\$120.40	\$163.60
Storage Price	\$ 14.48	\$14.48	\$14.48	\$14.48	\$12.00	\$12.00	\$54.97	\$10.29
Total	\$58.23	\$68.53	\$89.11	\$122.96	\$155.08	\$120.67	\$130.69	\$173.89

		4vCPU VMs								
		NXTGEN			AMAZON*		RACKSPACE*		SOFTLAYER	
		c4m4	c4m8	c4m15	c4.xlarge	m3.xlarge	gen1-4	io1-15	4c8m	4c16m
		VM Price	\$84.29	\$104.87	\$146.05	\$221.92	\$286.16	\$131.40	\$492.75	\$193.60
Storage Price	\$72.38	\$72.38	\$72.38	\$60.00	\$60.00	\$274.85	\$274.85	\$28.57	\$28.57	
Total	\$156.67	\$177.25	\$218.43	\$281.92	\$346.16	\$406.25	\$767.60	\$222.17	\$294.17	

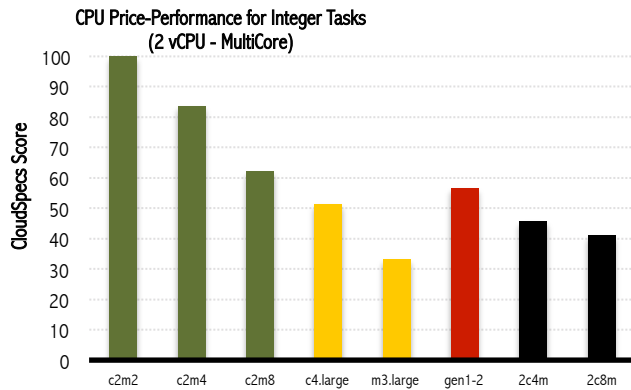
		8vCPU VMs								
		NXTGEN			AMAZON*		RACKSPACE*		SOFTLAYER	
		c8m8	c8m15	c8m30	c4.2xlarge	m3.2xlarge	gen1-8	io1-30	8c16m	8c32m
VM Price	\$165.35	\$206.53	\$268.30	\$443.84	\$572.32	\$262.80	\$985.50	\$325.60	\$440.80	
Storage Price	\$144.77	\$144.77	\$144.77	\$120.00	\$120.00	\$549.69	\$549.69	\$57.14	\$57.14	
Total	\$310.12	\$351.30	\$413.07	\$563.84	\$692.32	\$812.49	\$1,535.19	\$382.74	\$497.94	

* Monthly prices are based on 730 hours per month.

Pricing Considerations:

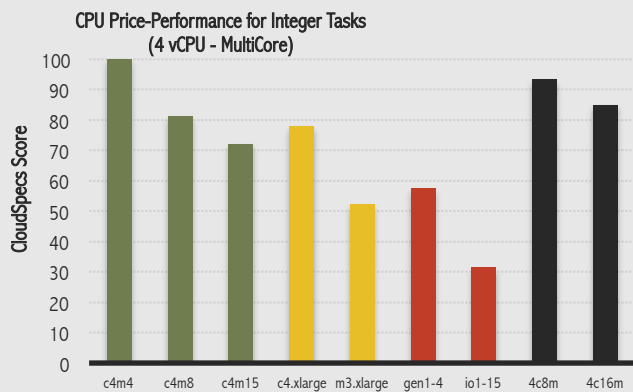
- NxtGen's VM price incorporates a \$3.20 per month shared 5Mbps Redundant Internet Bandwidth fee
- Rackspace VM price incorporates the Managed Infrastructure service charge
- SoftLayer's VM price incorporates a \$20 per month 1Gbps Port Speed fee

vCPU VALUE ANALYSIS RESULTS: INTEGER



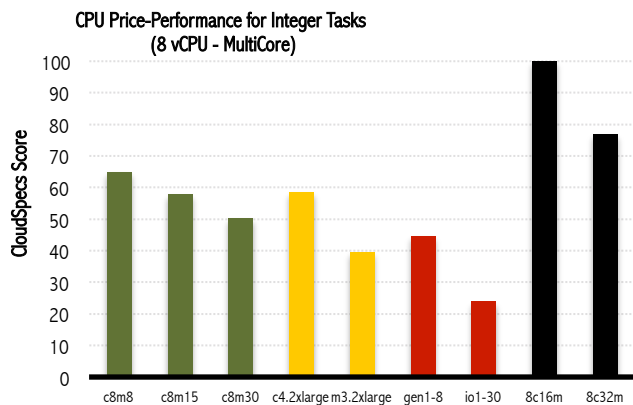
vCPU Value – Integer Tasks (Multicore): 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	84
NxtGen	c2m8	62
Rackspace	gen1-2	56
Amazon	c4.large	51
SoftLayer	2c4m	46
SoftLayer	2c8m	41
Amazon	m3.large	33



vCPU Value – Integer Tasks (Multicore): 4vCPU

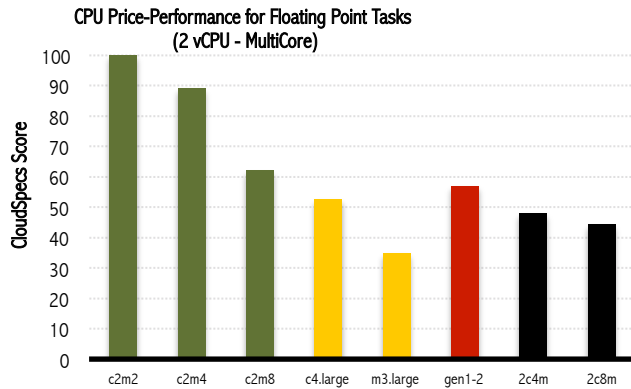
Provider	VM	CloudSpecs Score
NxtGen	c4m4	100
SoftLayer	4c8m	93
SoftLayer	4c16m	85
NxtGen	c4m8	81
Amazon	c4.xlarge	78
NxtGen	c4m15	72
Rackspace	gen1-4	58
Amazon	m3.xlarge	52
Rackspace	io1-15	31



vCPU Value – Integer Tasks (Multicore): 8vCPU

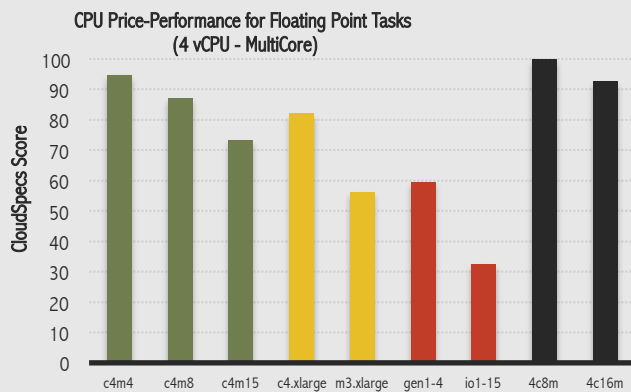
Provider	VM	CloudSpecs Score
SoftLayer	8c16m	100
SoftLayer	8c32m	77
NxtGen	c8m8	65
Amazon	c4.2xlarge	59
NxtGen	c8m15	58
NxtGen	c8m30	50
Rackspace	gen1-8	45
Amazon	m3.2xlarge	40
Rackspace	io1-30	24

vCPU VALUE ANALYSIS RESULTS: FLOATING POINT



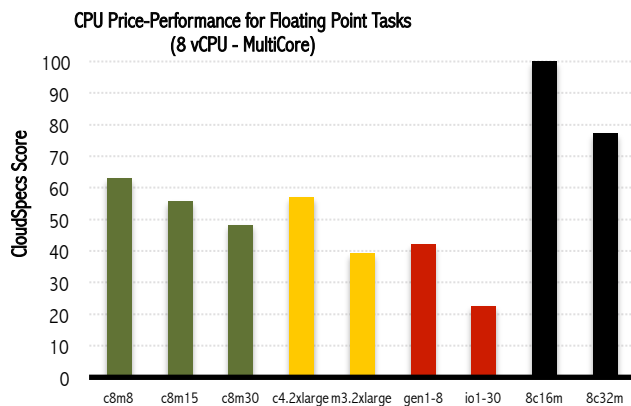
vCPU Value – Floating Point Tasks (Multicore): 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	89
NxtGen	c2m8	62
Rackspace	gen1-2	57
Amazon	c4.large	53
SoftLayer	2c4m	48
SoftLayer	2c8m	44
Amazon	m3.large	35



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

Provider	VM	CloudSpecs Score
SoftLayer	4c8m	100
NxtGen	c4m4	95
SoftLayer	4c16m	93
NxtGen	c4m8	87
Amazon	c4.xlarge	82
NxtGen	c4m15	73
Rackspace	gen1-4	59
Amazon	m3.xlarge	56
Rackspace	io1-15	32

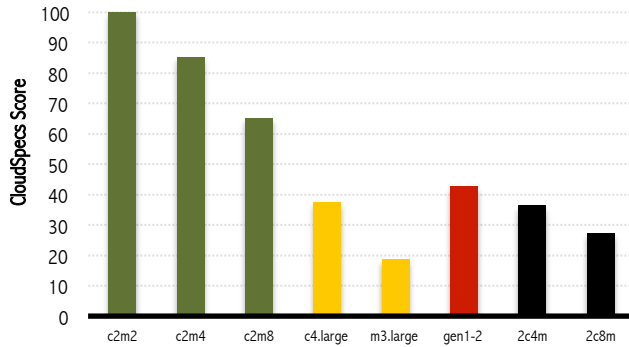


vCPU Value – Floating Point Tasks (Multicore): 8vCPU

Provider	VM	CloudSpecs Score
SoftLayer	8c16m	100
SoftLayer	8c32m	77
NxtGen	c8m8	63
Amazon	c4.2xlarge	57
NxtGen	c8m15	56
NxtGen	c8m30	48
Rackspace	gen1-8	42
Amazon	m3.2xlarge	39
Rackspace	io1-30	23

MEMORY VALUE ANALYSIS RESULTS

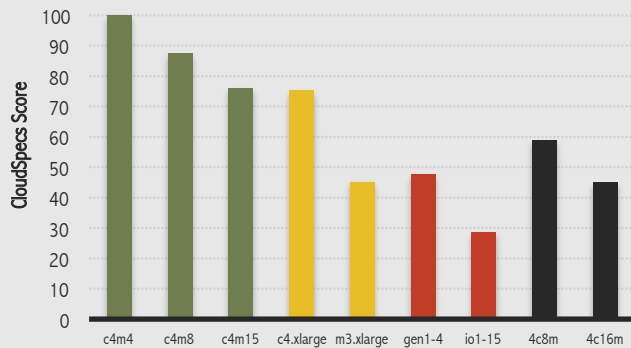
Memory Price-Performance (2 vCPU - MultiCore)



Memory Value (Multicore): 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	85
NxtGen	c2m8	65
Rackspace	gen1-2	43
Amazon	c4.large	38
SoftLayer	2c4m	36
SoftLayer	2c8m	27
Amazon	m3.large	19

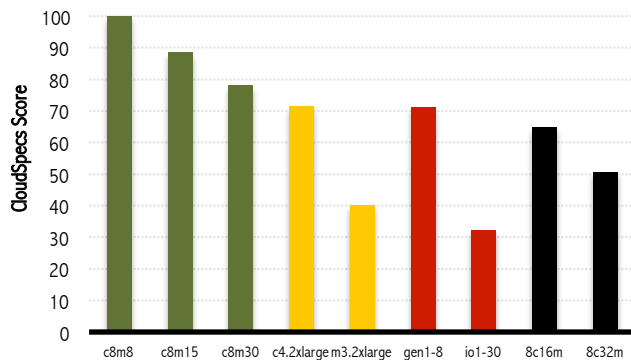
Memory Price-Performance (4 vCPU - MultiCore)



Memory Value (Multicore): 4vCPU

Provider	VM	CloudSpecs Score
NxtGen	c4m4	100
NxtGen	c4m8	87
NxtGen	c4m15	76
Amazon	c4.xlarge	75
Amazon	m3.xlarge	45
Rackspace	gen1-4	48
Rackspace	io1-15	29
SoftLayer	4c8m	59
SoftLayer	4c16m	45

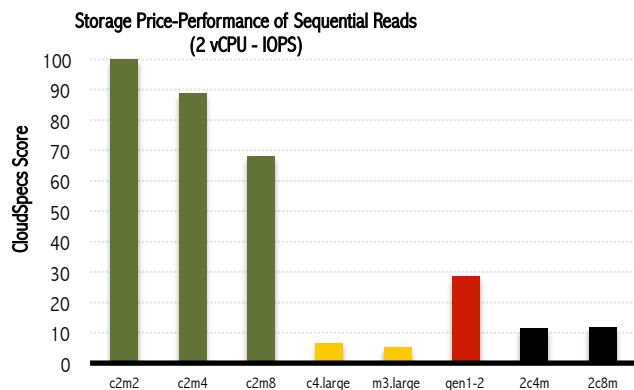
Memory Price-Performance (8 vCPU - MultiCore)



Memory Value (Multicore): 8vCPU

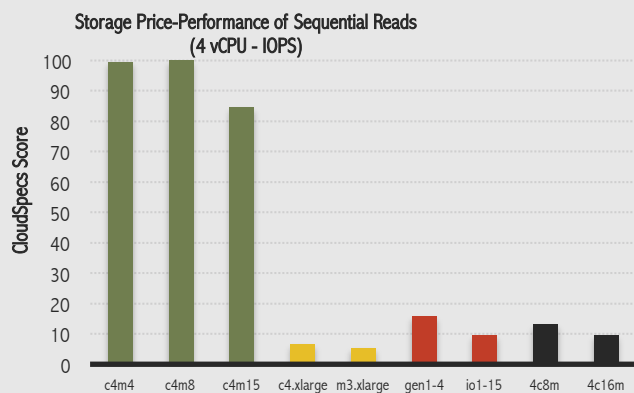
Provider	VM	CloudSpecs Score
NxtGen	c8m8	100
NxtGen	c8m15	88
NxtGen	c8m30	78
Amazon	c4.2xlarge	71
Rackspace	gen1-8	71
SoftLayer	8c16m	65
SoftLayer	8c32m	51
Amazon	m3.2xlarge	40
Rackspace	io1-30	32

STORAGE VALUE ANALYSIS RESULTS: SEQUENTIAL READS



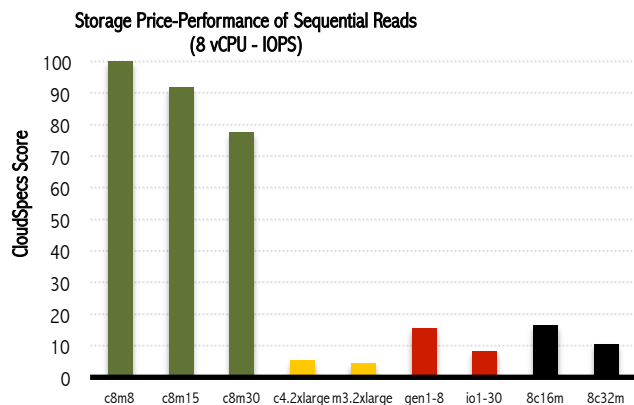
Storage Value – Sequential Read: 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	89
NxtGen	c2m8	68
Rackspace	gen1-2	28
SoftLayer	2c4m	12
SoftLayer	2c8m	12
Amazon	c4.large	7
Amazon	m3.large	5



Storage Value – Sequential Read: 4vCPU

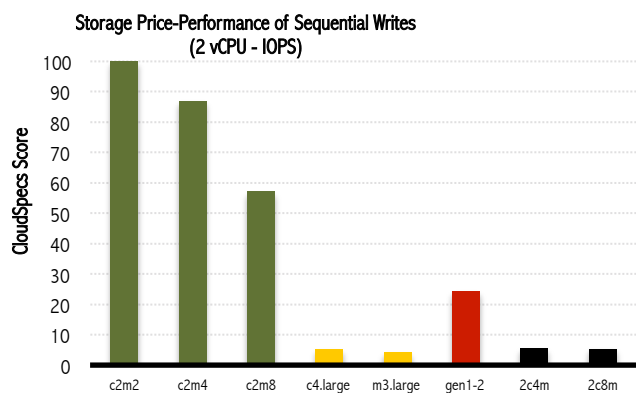
Provider	VM	CloudSpecs Score
NxtGen	c4m4	100
NxtGen	c4m8	100
NxtGen	c4m15	85
Rackspace	gen1-4	16
SoftLayer	4c8m	13
Rackspace	io1-15	10
SoftLayer	4c16m	10
Amazon	c4.xlarge	7
Amazon	m3.xlarge	5



Storage Value – Sequential Read: 8vCPU

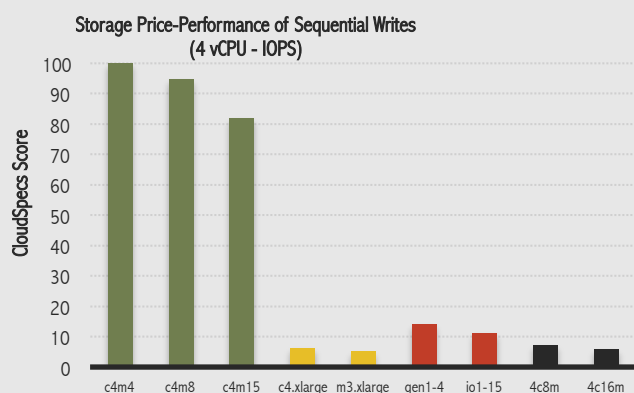
Provider	VM	CloudSpecs Score
NxtGen	c8m8	100
NxtGen	c8m15	92
NxtGen	c8m30	78
Rackspace	gen1-8	16
SoftLayer	8c16m	16
SoftLayer	8c32m	10
Rackspace	io1-30	8
Amazon	c4.2xlarge	5
Amazon	m3.2xlarge	4

STORAGE VALUE ANALYSIS RESULTS: SEQUENTIAL WRITES



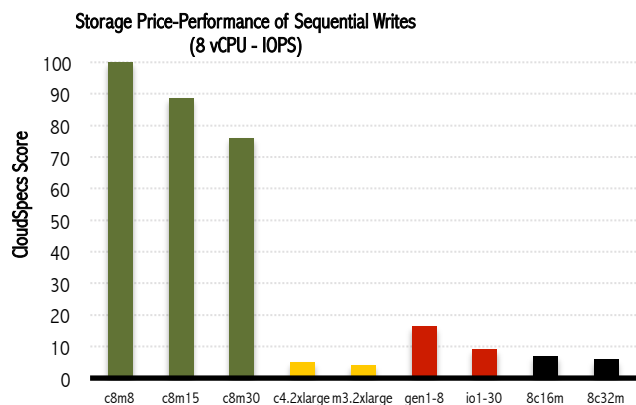
Storage Value – Sequential Write: 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	87
NxtGen	c2m8	57
Rackspace	gen1-2	24
Amazon	c4.large	5
SoftLayer	2c4m	5
SoftLayer	2c8m	5
Amazon	m3.large	4



Storage Value – Sequential Write: 4vCPU

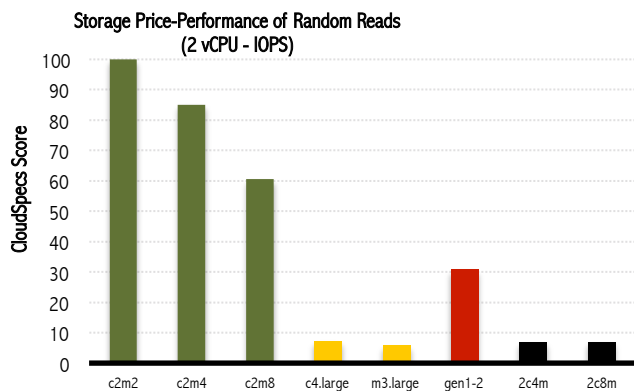
Provider	VM	CloudSpecs Score
NxtGen	c4m4	100
NxtGen	c4m8	95
NxtGen	c4m15	82
Rackspace	gen1-4	14
Rackspace	io1-15	11
SoftLayer	4c8m	7
Amazon	c4.xlarge	6
SoftLayer	4c16m	6
Amazon	m3.xlarge	5



Storage Value – Sequential Write: 8vCPU

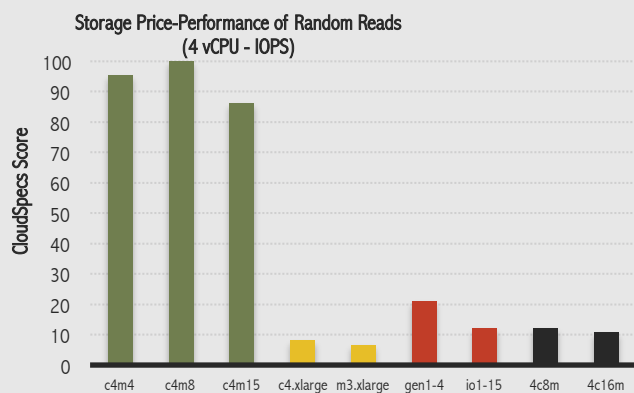
Provider	VM	CloudSpecs Score
NxtGen	c8m8	100
NxtGen	c8m15	88
NxtGen	c8m30	76
Rackspace	gen1-8	16
Rackspace	io1-30	9
SoftLayer	8c16m	7
SoftLayer	8c32m	6
Amazon	c4.2xlarge	5
Amazon	m3.2xlarge	4

STORAGE VALUE ANALYSIS RESULTS: RANDOM READS



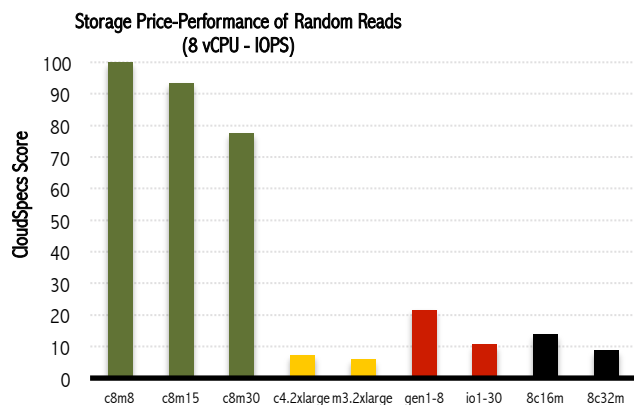
Storage Value – Random Read: 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	85
NxtGen	c2m8	60
Rackspace	gen1-2	31
Amazon	c4.large	7
SoftLayer	2c4m	7
SoftLayer	2c8m	7
Amazon	m3.large	6



Storage Value – Random Read: 4vCPU

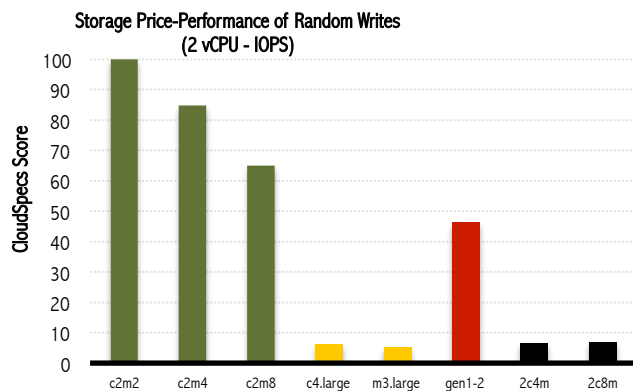
Provider	VM	CloudSpecs Score
NxtGen	c4m8	100
NxtGen	c4m4	95
NxtGen	c4m15	86
Rackspace	gen1-4	21
Rackspace	io1-15	12
SoftLayer	4c8m	12
SoftLayer	4c16m	11
Amazon	c4.xlarge	8
Amazon	m3.xlarge	6



Storage Value – Random Read: 8vCPU

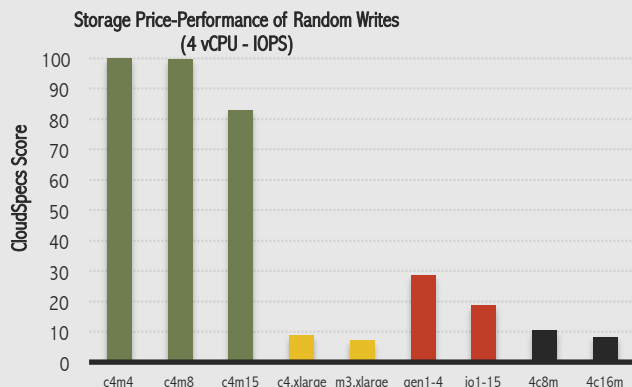
Provider	VM	CloudSpecs Score
NxtGen	c8m8	100
NxtGen	c8m15	93
NxtGen	c8m30	77
Rackspace	gen1-8	22
SoftLayer	8c16m	14
Rackspace	io1-30	11
SoftLayer	8c32m	9
Amazon	c4.2xlarge	7
Amazon	m3.2xlarge	6

STORAGE VALUE ANALYSIS RESULTS: RANDOM WRITES



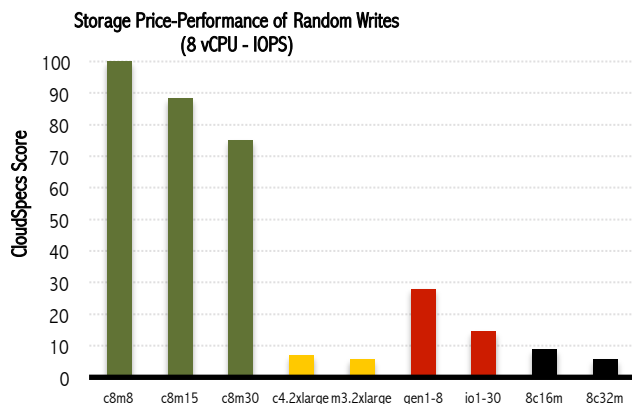
Storage Value – Random Write: 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	85
NxtGen	c2m8	65
Rackspace	gen1-2	46
SoftLayer	2c4m	7
SoftLayer	2c8m	7
Amazon	c4.large	6
Amazon	m3.large	5



Storage Value – Random Write: 4vCPU

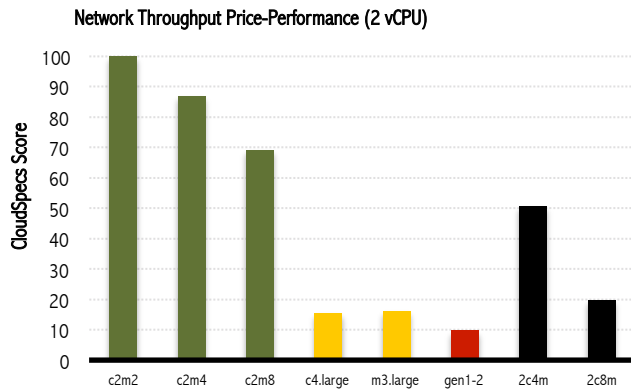
Provider	VM	CloudSpecs Score
NxtGen	c4m4	100
NxtGen	c4m8	100
NxtGen	c4m15	83
Rackspace	gen1-4	29
Rackspace	io1-15	19
SoftLayer	4c8m	10
Amazon	c4.xlarge	9
SoftLayer	4c16m	8
Amazon	m3.xlarge	7



Storage Value – Random Write: 8vCPU

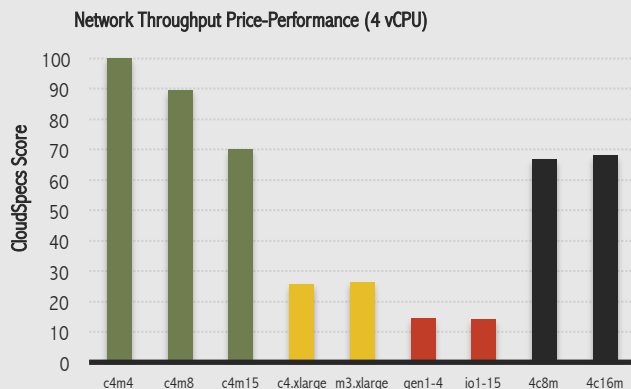
Provider	VM	CloudSpecs Score
NxtGen	c8m8	100
NxtGen	c8m15	88
NxtGen	c8m30	75
Rackspace	gen1-8	28
Rackspace	io1-30	15
SoftLayer	8c16m	9
Amazon	c4.2xlarge	7
Amazon	m3.2xlarge	6
SoftLayer	8c32m	6

INTERNAL NETWORK VALUE ANALYSIS RESULTS: THROUGHPUT



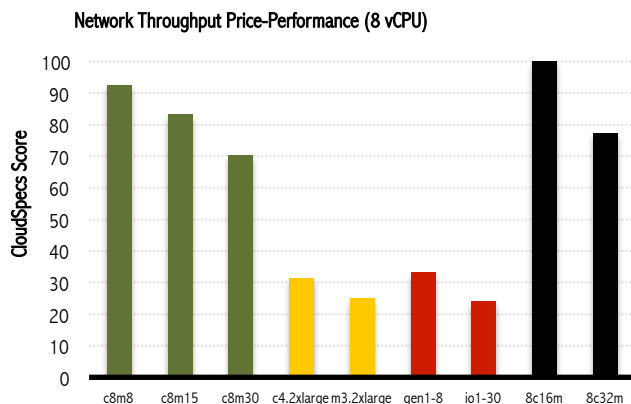
Internal Network Value – Throughput: 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	87
NxtGen	c2m8	69
SoftLayer	2c4m	51
SoftLayer	2c8m	20
Amazon	m3.large	16
Amazon	c4.large	15
Rackspace	gen1-2	10



Internal Network Value – Throughput: 4vCPU

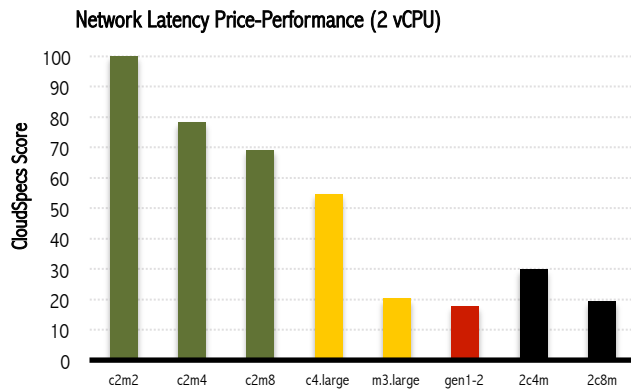
Provider	VM	CloudSpecs Score
NxtGen	c4m4	100
NxtGen	c4m8	90
NxtGen	c4m15	70
SoftLayer	4c16m	68
SoftLayer	4c8m	67
Amazon	c4.xlarge	26
Amazon	m3.xlarge	26
Rackspace	gen1-4	15
Rackspace	io1-15	14



Internal Network Value – Throughput: 8vCPU

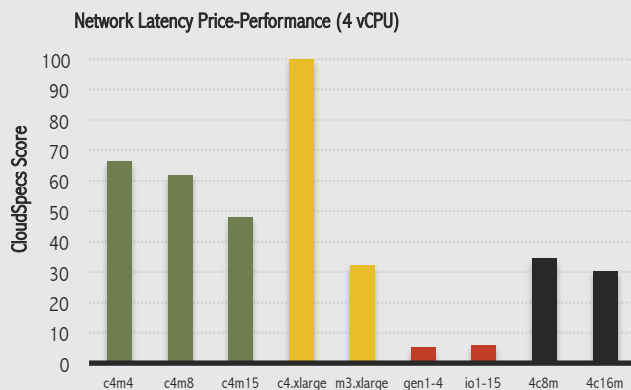
Provider	VM	CloudSpecs Score
SoftLayer	8c16m	100
NxtGen	c8m8	93
NxtGen	c8m15	83
SoftLayer	8c32m	77
NxtGen	c8m30	70
Rackspace	gen1-8	33
Amazon	c4.2xlarge	31
Amazon	m3.2xlarge	25
Rackspace	io1-30	24

INTERNAL NETWORK VALUE ANALYSIS RESULTS: LATENCY



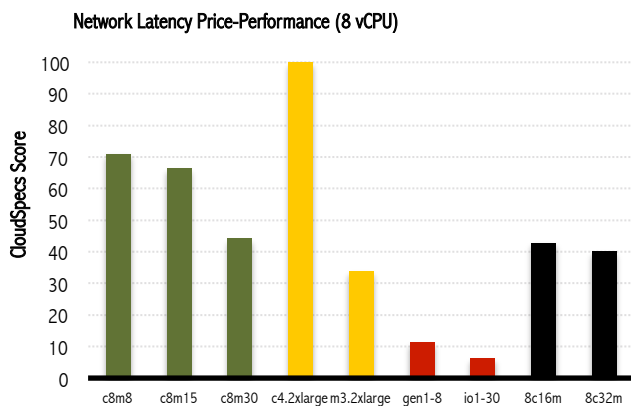
Internal Network Value – Latency: 2vCPU

Provider	VM	CloudSpecs Score
NxtGen	c2m2	100
NxtGen	c2m4	78
NxtGen	c2m8	69
Amazon	c4.large	54
SoftLayer	2c4m	30
Amazon	m3.large	20
SoftLayer	2c8m	19
Rackspace	gen1-2	18



Internal Network Value – Latency: 4vCPU

Provider	VM	CloudSpecs Score
Amazon	c4.xlarge	100
NxtGen	c4m4	66
NxtGen	c4m8	62
NxtGen	c4m15	48
SoftLayer	4c8m	34
Amazon	m3.xlarge	32
SoftLayer	4c16m	30
Rackspace	io1-15	6
Rackspace	gen1-4	5



Internal Network Value – Latency: 8vCPU

Provider	VM	CloudSpecs Score
Amazon	c4.2xlarge	100
NxtGen	c8m8	71
NxtGen	c8m15	66
NxtGen	c8m30	44
SoftLayer	8c16m	43
SoftLayer	8c32m	40
Amazon	m3.2xlarge	34
Rackspace	gen1-8	11
Rackspace	io1-30	6

CONCLUSION

The purpose of this study was to examine the differences in performance and price-performance value of the cloud infrastructure offerings across various cloud IaaS providers. The price-performance of the servers were examined to understand the value each service offers, 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.

In certain areas, NxtGen offered relatively higher performance, such as in the memory tests and particularly the storage tests. vCPU performance was at the bottom half of the camp when comparing against the other providers included in the study. Internal network throughput performed at the same level across all the VM sizes, indicating possible throttling of the network. It is also possible the performance examined is the maximum throughput of the platform, which would be expected to display greater variability dependent on time-of-day and network loads based on user traffic. The consistent throughput is an advantage for the smaller VM sizes compared to the other providers, which offer lower throughput with smaller VM sizes; however at the 8vCPU level, multiple providers begin outperforming NxtGen. SoftLayer exhibited strong performance in vCPU and internal network throughput tests. Price-performance value varied greatly between the different resources and VM sizes, but NxtGen offered strong price-performance value overall.

The study showed that NxtGen's ECS offers a niche performance advantage and moderate price-performance advantage over existing cloud vendors. Network throughput and storage IOPS are high for small VMs and for large VMs. While initially this may be a unique value proposition for consumers utilizing smaller sized VMs, resources may become constrained as the product matures. Many existing providers will throttle performance of smaller VMs to prevent performance degradation of the larger VMs, which are expected to offer higher performance overall. The strong performance of NxtGen's base storage offering highlights the vendor's potential value in use cases where the storage performance is the bottleneck of an application. NxtGen's competitive storage performance, in conjunction with overall high price-performance value, combines to offer a uniquely focused cloud solution with high potential for data heavy workloads. Cloud infrastructure is far from a mature industry, which leads to varying strengths across providers, making the vendor selection process critical for a successful cloud strategy.

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.

After the testing was conducted for this study, SoftLayer unveiled a new Block Storage offering. The new storage type is comparable to the persistent storage from Amazon EBS and Rackspace Cloud Block Storage and should be considered in future testing.

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.

For more information about Cloud Spectator or questions about the report methodology, reach us at [contact \[at\] cloud spectator \[dot\] com](mailto:contact@cloudspectator.com)

TESTING SETUP

Cloud Spectator identified and provisioned equivalent sized VMs across each provider. The locations of the VMs were all in the Asia Pacific region. The chosen benchmarking software was then installed on each VM and run once per day for a period of five 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"> Subtests include: Integer Math, Floating Point Math
Geekbench 3	Memory	Four separate memory tests that are all aggregated into a final score. <ul style="list-style-type: none"> Subtests include: Add, Copy, Triad, Scale
FIO	Disk	Combination of Sequential Read, Sequential Write, Random Read and Random Write operations <ul style="list-style-type: none"> An 8kb block size was used
Iperf	Network	Transfers data bi-directionally between 2 nodes within 60 seconds, measured in megabits per second.
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 by vCPU allocations. All VMs ran Linux 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

	NxtGen	NxtGen	NxtGen	Amazon	Amazon	Rackspace	SoftLayer	SoftLayer
OFFERING NAME	c2m2	c2m4	c2m8	c4.large	m3.large	gen1-2	2c4m	2c8m
vCPUs	2	2	2	2	2	2	2	2
MEMORY IN GB	2	4	8	3.5	7.5	2	4	8
BLOCK STORAGE	100GB	100GB	100GB	100GB	100GB	100GB	100GB	100GB
VM PRICE (\$/Month)	\$43.75	\$54.05	\$74.63	\$110.96	\$143.08	\$65.70	\$120.40	\$163.60
STORAGE (\$/Month)	\$14.48	\$14.48	\$14.48	\$12.00	\$12.00	\$54.97	\$10.29	\$10.29
DATA CENTER	Bangalore	Bangalore	Bangalore	Singapore	Singapore	Hong Kong	Singapore	Singapore

4 vCPU

	NxtGen	NxtGen	NxtGen	Amazon	Amazon	Rackspace	Rackspace	SoftLayer	SoftLayer
OFFERING NAME	c4m4	c4m8	c4m15	c4.xlarge	m3.xlarge	gen1-4	io1-15	4c8m	4c16m
vCPUs	4	4	4	4	4	4	4	4	4
MEMORY IN GB	4	8	15	7.5	15	4	15	8	16
BLOCK STORAGE	500GB	500GB	500GB	500GB	500GB	500GB	500GB	500GB	500GB
VM PRICE (\$/Month)	\$84.29	\$104.87	\$146.05	\$221.92	\$286.16	\$131.40	\$492.75	\$193.60	\$265.60
STORAGE (\$/Month)	\$72.38	\$72.38	\$72.38	\$60.00	\$60.00	\$274.85	\$274.85	\$28.57	\$28.57
DATA CENTER	Bangalore	Bangalore	Bangalore	Singapore	Singapore	Hong Kong	Hong Kong	Singapore	Singapore

8 vCPU

	NxtGen	NxtGen	NxtGen	Amazon	Amazon	Rackspace	Rackspace	SoftLayer	SoftLayer
OFFERING NAME	c8m8	c8m15	c8m30	c4.2xlarge	m3.2xlarge	gen1-8	io1-30	8c16m	8c32m
vCPUs	8	8	8	8	8	8	8	8	8
MEMORY IN GB	8	15	30	15	30	8	30	16	32
BLOCK STORAGE	1000GB	1000GB	1000GB	1000GB	1000GB	1000GB	1000GB	1000GB	1000GB
VM PRICE (\$/Month)	\$165.35	\$206.53	\$268.30	\$443.84	\$572.32	\$262.80	\$985.50	\$325.60	\$440.80
STORAGE (\$/Month)	\$144.77	\$144.77	\$144.77	\$120.00	\$120.00	\$549.69	\$549.69	\$57.14	\$57.14
DATA CENTER	Bangalore	Bangalore	Bangalore	Singapore	Singapore	Hong Kong	Hong Kong	Singapore	Singapore

TESTING NOTES

- Testing was conducted for a period of 5 days.
 - The testing spanned from 3/17/15 to 3/21/15.
 - Tests were conducted once 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 a General Purpose EBS SSD.
 - The storage volume of Rackspace was a Cloud Block Storage SSD.
 - The storage volume of NxtGen was a SSD Storage volume.
 - The storage volume of SoftLayer was a SAN volume.