



# Oracle Database Performance: VMware Cloud on AWS i3 vs i3en

Performance Study - October 8, 2020



VMware, Inc. 3401 Hillview Avenue Palo Alto CA 94304 USA Tel 877-486-9273 Fax 650-427-5001 [www.vmware.com](http://www.vmware.com)

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## Executive Summary

This paper analyzes the increase in performance and capacity of the i3en instance type of VMware Cloud™ on AWS for Oracle® Database. The i3en instance type offers more compute cores, more memory, and other performance enhancements that allow it to host larger and more powerful VMs. Testing found that Oracle databases running on i3en compared to the i3 instance provided about 18 percent more throughput per core and about double the throughput for similar-sized SDDCs. With this higher performance capability, VMware Cloud on AWS with i3en instance types can run larger Oracle databases than in the past.

## Introduction

VMware Cloud on AWS is a jointly engineered service that brings VMware Cloud Foundation™ to Amazon Web Services™ (AWS). The service offers ultra-fast cloud migration powered by VMware HCX® and vMotion combined with consistent hybrid-cloud infrastructure and operations from AWS. Once applications are migrated, customers can run, manage, and modernize these applications with the VMware Tanzu portfolio as well as integrate native AWS services. More than 500 channel partners have achieved a VMware Cloud on AWS service competency, and there are more than 300 certified or validated technology solutions available to VMware Cloud on AWS customers.

VMware Cloud on AWS has historically run on i3 and r5 metal instances. In July of 2020, the new i3en instance based on 2nd generation Intel® Xeon® Scalable Processors became available. It's designed for storage-dense workloads with high-performance requirements and delivers superior economics at scale for datacenter migration and disaster recovery transformation projects. These new instances deliver 4x the raw storage capacity at roughly half the cost per gigabyte of storage per host of current offerings. In addition, it comes with low latency Non-Volatile Memory Express (NVMe™) SSD capacity for applications that require high random I/O access to large amounts of data such as relational databases.

The Oracle database management system has been a key component of many enterprises for decades with proven performance and scalability to act as the backbone database for some of the largest applications. The systems administrators that work with the Oracle database administrators to put together database solutions for their customers know that the performance is key. With both large and small deployments of Oracle, it is critical to be able to maintain the highest levels of performance with quick responses to queries of information from the database.

VMware vSphere has long been an excellent platform for Oracle databases in customer datacenters around the world. With the introduction of VMware Cloud on AWS several years ago, the VMware vSphere platform became available in the cloud to support Oracle instances as well. With the new i3en instance types announced recently, additional more powerful hardware is now available to support larger databases with higher performance requirements than that with the i3 instance types that were offered initially.

To measure these performance gains specifically with Oracle databases, a three-host software-defined data center (SDDC) was deployed on the VMware Cloud on AWS service using the new i3en instance type. A test environment was set up with Oracle database VMs, and many tests were run to measure and compare the performance gains found on the new i3en instance type. Results showed significant performance gains for single VM and multiple VM-based tests.

## Test Environment

For our tests, we deployed an SDDC using a three-host cluster from our VMware Cloud on AWS portal. The server instance type was i3en.metal, which was introduced as a new instance type for VMware Cloud on AWS in July of 2020, bringing new servers with more cores and more memory. We compared the results from this test with results using the same tests on an i3.metal three-host SDDC that were performed a few months earlier.

The servers of the SDDC used Intel Xeon Platinum 8259CL processors with 24 cores running at 2.5GHz with 789GB of RAM. (See **figure 1.**)

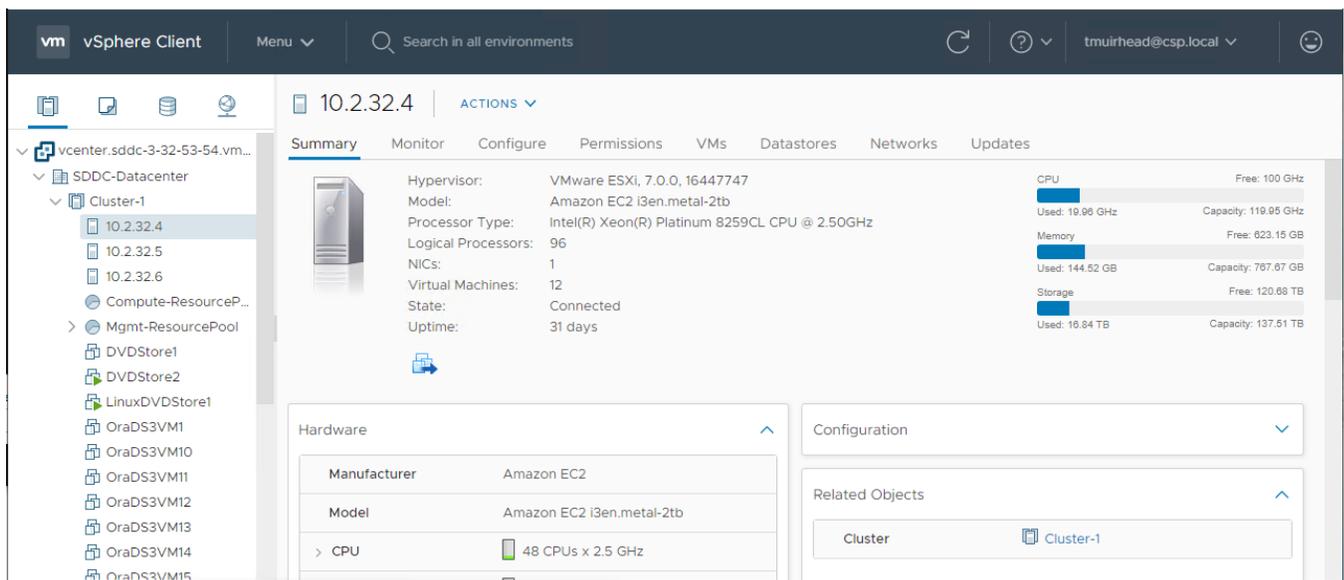


Figure 1. Screenshot of the test environment

Storage for the SDDC was provided by vSAN using the local NVMe devices in the hosts. vSAN is configured as part of the SDDC deployment and the storage is ready when you

log into vCenter for the first time. The amount of capacity available depends on the number of hosts in the SDDC. In our three-host SDDC environment used for testing, capacity was 137.5TB as shown in **figure 2**.

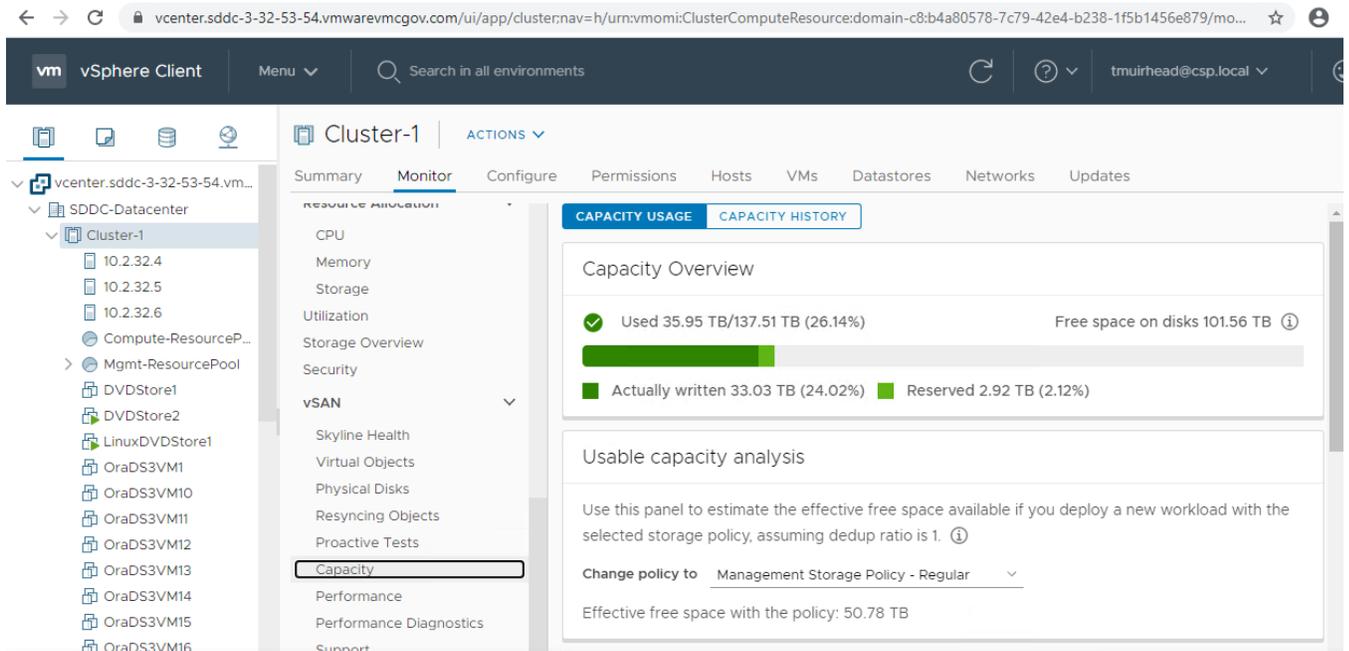


Figure 2. Screenshot of workload datastore configuration

**Figure 3** shows a three-node SDDC on AWS and its major components. We configured only the VMs that composed the Oracle database and load driver. The rest of the components and configuration were done automatically as part of the deployment from the VMware Cloud on AWS portal.

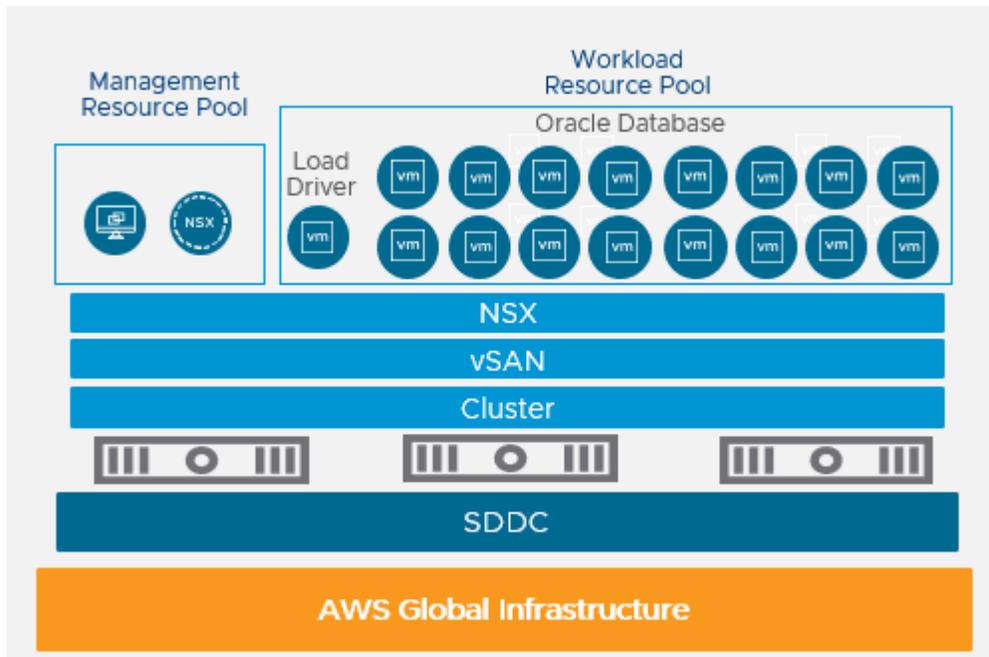


Figure 3. Cloud testbed configuration

## Test Workload

We used the workload from the open-source benchmark [DVD Store 3](#) [2]. DVD Store simulates an online store that allows customers to log on, search for DVDs, read reviews from other customers, rate the helpfulness of reviews, and purchase DVDs. DVD Store uses many common database features to support these operations, including tables, indexes, triggers, stored procedures, transactions, foreign keys, simple queries, and complex multi-join queries. The benchmark includes a client program that generates load against the database by simulating the actions of users on the site. Each simulated user thread does the full set of steps for a user from logon through purchase. The workload reports throughput in orders per minute (OPM).

For each test configuration, the number of user threads was increased with each iteration until the throughput reached its maximum level. We observed the maximum throughput corresponded to a host CPU utilization of between 90 and 99 percent.

DVD Store 3 allows for any size database to be created. For these tests, a database with approximately 240GB of on-disk size was used.

## Virtual Machine Configuration

We kept the configuration of the VMs constant except for the number of vCPUs, which we varied depending on the specific test. The VMs used the VMXNET3 virtual network adapter and paravirtual SCSI (PVSCSI) adapters. We assigned data and log virtual disks to separate PVSCSI adapters. We also configured the memory to be 128GB.

We installed the VM with Red Hat® Enterprise Linux® (RHEL) 7.2 as the operating system and Oracle Database 12.1.0.2 using the Oracle-provided installer RPM. We followed Oracle best practices documentation for this installation. We configured huge pages for RHEL and enabled them in Oracle, and we set the Oracle `sga_target` parameter to 100GB. This ensured that a large amount of the 240GB database would be available in the buffer cache, but not all, so that some disk accesses would occur during the tests.

## Scale-Up Performance

Scale-up performance testing entails testing to see how a single VM performs from small configurations up to larger and larger configurations. We performed scale-up tests with a VM configured with 8 vCPUs up to 32 vCPUs for the i3 instance and 8vCPUs up to 96 vCPUs for the i3en instance.

The DVD Store driver, which ran on a separate VM, generated the load. The load-driver VM and the Oracle database VM both ran in the VMware Cloud on AWS but were on different physical hosts in that cloud.

The results are shown in **figure 4**.

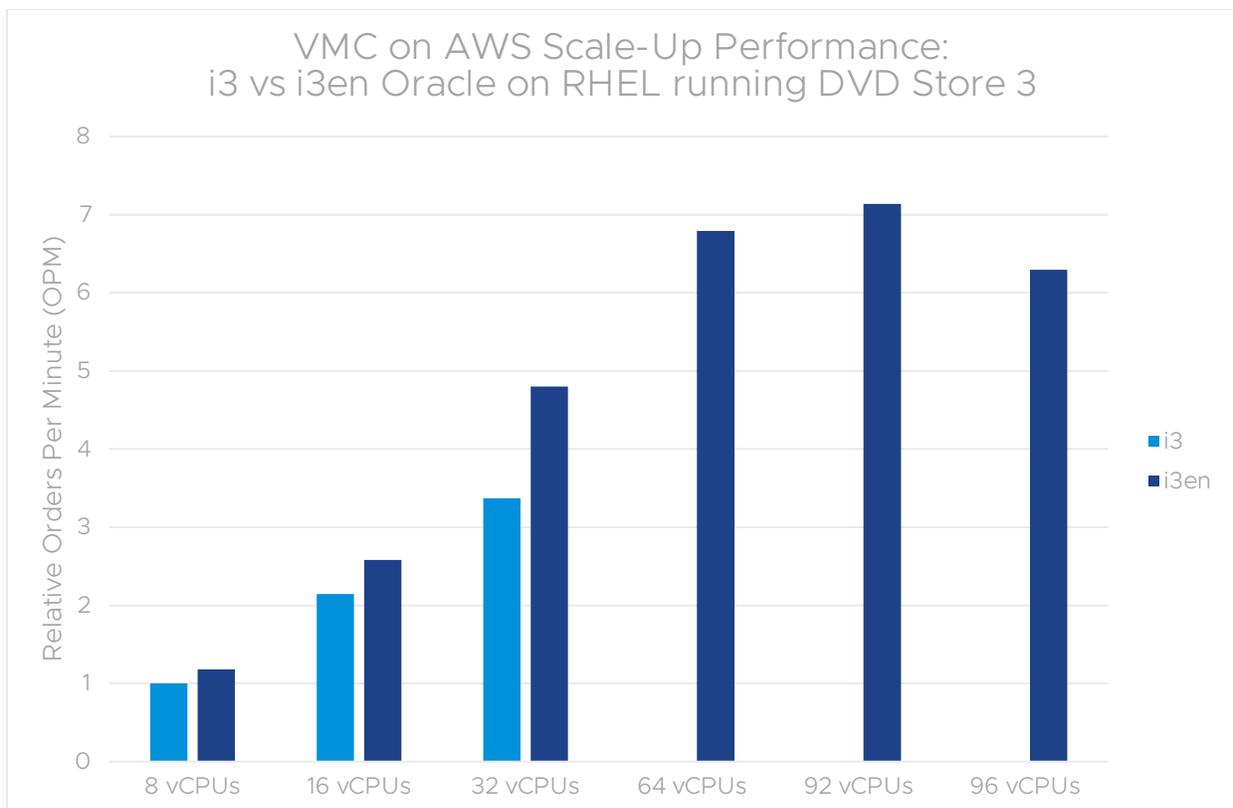


Figure 4. Oracle DB VM scale-up performance (adding processors)

The scale-up test results highlight the increased capability of the hosts used for the i3en instance type that result in better performance for Oracle database. In the case of comparing an 8-vCPU VM running on i3 vs an 8-vCPU VM on i3en, the performance advantage is 18 percent. This means that with the same number of vCPUs, the VM on i3en was able to outperform the i3 VM by a significant margin.

A single VM on i3en (92 vCPUs) was able to achieve double the throughput of what a single VM on i3 (32 vCPUs) was able to achieve. There are two main factors that contribute to the big performance difference seen in this comparison. The i3en instance has more cores per socket than the i3. The i3 instance does not have hyperthreading enabled due to the L1TF vulnerability that existed in the older Intel processors, but it does not exist in the newer Intel processors used in the i3en instance type. In addition to more cores and hyperthreading, the i3en instance type also has vSAN configured without compression or deduplication and has better and faster NICs. Future versions of i3en instances will have compression and/or deduplication enabled which will increase storage capacity while potentially decreasing performance.

An interesting final point on these results is that the best performing VM is not created at the absolute max size possible of 96 vCPUs, but instead was 92 vCPUs. This is often seen when running a VM that has all the CPU resources assigned to it, which in this case is 96 vCPUs, and that VM is run at very high utilization levels of over 95 percent. With this

configuration and such a high utilization level, the system does not have resources to handle the hypervisor and virtual networking without taking cycles from the cores that the VM is using to perform its tasks. In this way the VM and the system compete for resources, and the overall performance of the application suffers. By leaving a couple of threads per socket unassigned, the hypervisor and network functions have some resources to use without having to interrupt the VM; this results in better overall performance. For this reason, we recommend you size the VMs to be slightly smaller than the system to optimize performance.

These scale-up tests with a single VM show that the i3en instance type provides the capability to host much larger Oracle database VMs with more performance than was possible with the i3 instance type.

## Scale-Out Performance

Another way to measure performance is with multiple VMs running at the same time, which is known as scale-out performance. The setup is the same as the previous single VM scale-up tests, but the workload driver system now spreads the worker threads across a number of target VMs simultaneously. The database VMs are spread out across the cluster as well, based on the best load balancing as determined by VMware vSphere® Distributed Resource Scheduling™ (DRS). The total number of OPMs achieved across all the Oracle Database VMs is then reported for each set of VMs.

### Two VMs per Host Processor

We performed the first set of scale-out tests with 8-vCPU VMs for i3 and 12 vCPUs for i3en. In each case this was sizing the VMs such that two would fit in each host processor. For example, the i3en hosts have 24 cores per socket, which means that two 12 vCPU VMs would fit in each socket without over-provisioning. We increased the number of VMs up to 2 VMs per socket per host, which, in this case, was 12.

The results are shown in **figure 5**.

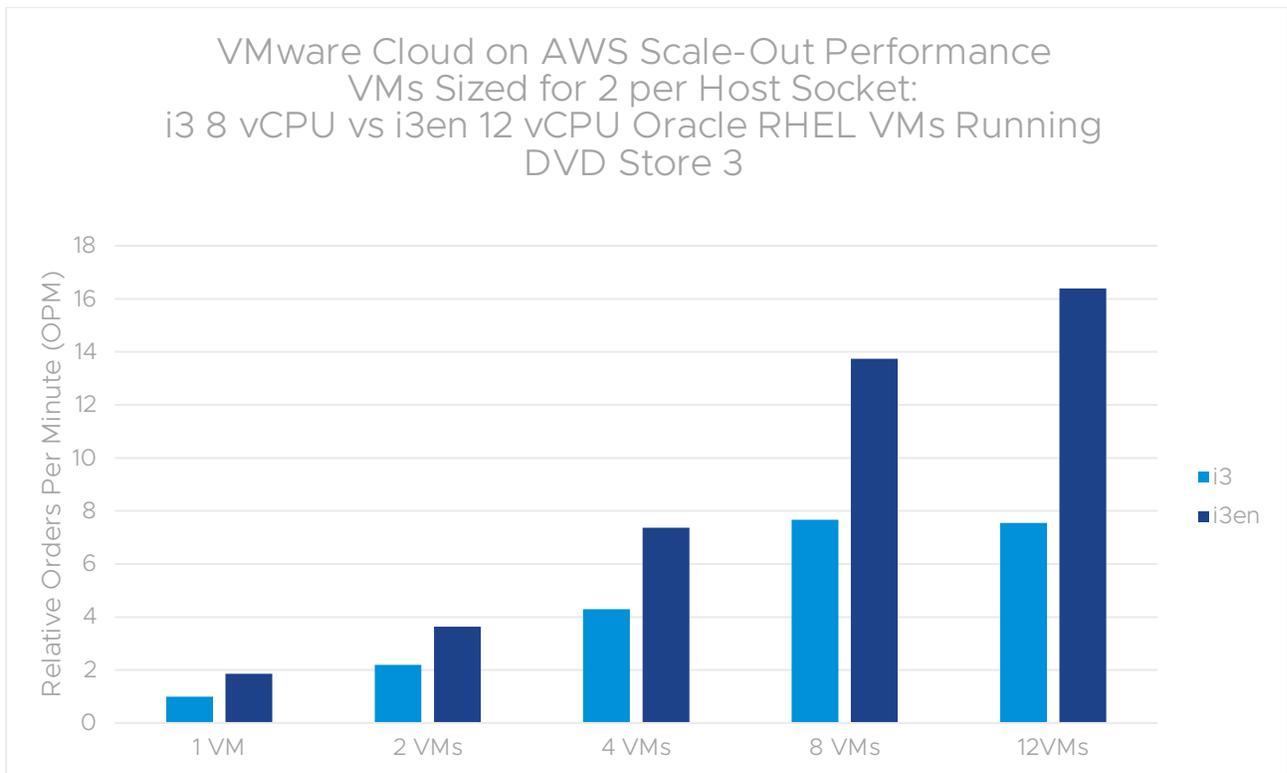


Figure 5. Scale-out performance with 8 vCPU VMs

By scaling the VM to take advantage of the additional cores in the i3en instance type, we can compare the total system performance as the number of VMs are scaled out. In the final case with four Oracle database VMs per host, the total throughput of the i3en SDDC is about double that of the i3 SDDC. This is for the same reasons that a single i3en outperformed a single i3 VM: mainly more cores, better cores, and hyperthreading.

### One VM Per Host Processor

The next test case used 16-vCPU VMs for i3 and 24-vCPU VMs for i3en in a scale-out test scenario. This is a scale-out test with one VM per socket, which gives us a look at scaling out with larger Oracle Database VMs on the same i3 and i3en SDDCs.

Results are shown in **figure 6**.

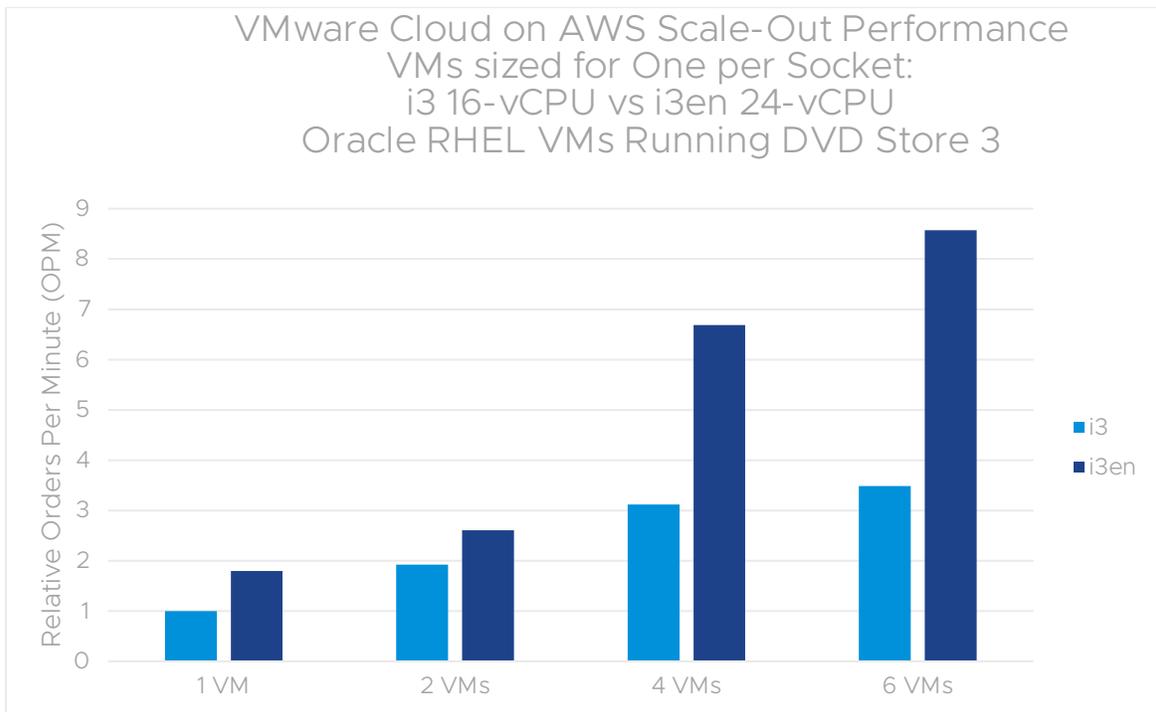


Figure 6. Scale-out performance with 16 vCPU on i3 and 24 vCPU on i3en Oracle/RHEL VMs running DVD Store 3

The results are very similar to the previous scale-out test with half-socket-sized VMs. Throughput performance is more than double with the i3en SDDC when we have six of the larger 24-vCPU VMs running vs six of the 16-vCPU VMs on i3.

## Combined Results

**Figure 8** is a combination of the results presented in the previous sections to allow for easy side-by-side comparison. The combination graph shows some interesting comparisons. The baseline here is the performance of an 8-vCPU VM running on i3. The i3 scale-out maximum is almost 8x as much throughput, which is just slightly higher than a single VM scale-up maximum throughput for i3en. Finally, the scale-out performance of i3en with both 12 and 24 vCPU VMs are similar with the overall efficiency being a bit better with the larger 24 vCPU VMs.

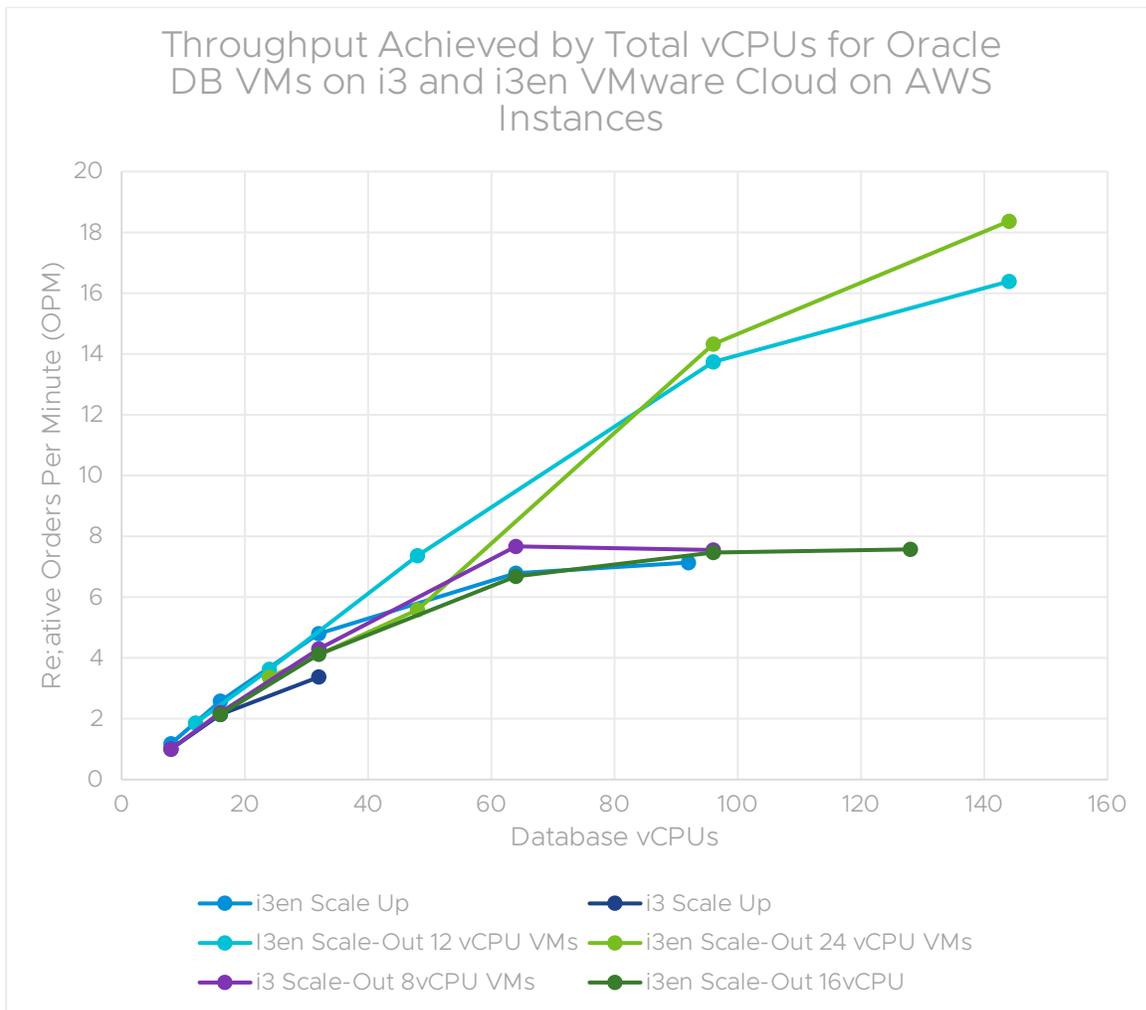


Figure 7. VMware Cloud on AWS scale-up and scale-out performance relative combination plotted graph

## Analysis

i3en instances provide significant performance and capacity advantages over i3 instances and are well designed to serve Oracle database workloads. The VMware-published [Oracle Databases on VMware Best Practices Guide](#) [3] is the best source for complete details on best practices.

## Distributed Resource Scheduling

DRS is a feature of vSphere that decides where to place VMs upon power-on and when to move running VMs. This is the VM load balancing feature that is used to make sure that VMs are placed so that performance is optimal across a vSphere cluster. When using VMware Cloud on AWS, this feature is turned on and configured as part of the service. VMs are placed and moved around the cloud automatically.

Initial placement of the VMs was fairly easy for DRS in the test cases where there were enough resources—this was all of the test cases with 8 VMs or less. In cases where there were more, DRS would sometimes decide to move VMs around after load was applied to the VMs; this meaning that, in some of the tests with more than 8 VMs, multiple vMotion migrations occurred during the first test run with that number of VMs. This sometimes caused the initial set of tests to have lower than expected throughput in the form of low OPMs. Once the vMotion migrations completed, throughput increased back to expected levels.

## VM Sizing

It is important to size the VM with the amount of virtual CPUs and memory that are needed for that workload. Creating VMs that are larger than they need to be can result in wasted resources and lower overall performance across all VMs. The scale-out results show that the performance scales well with VMs that are right-sized based on a CPU core count that leads to efficient utilization.

## Performance

The performance scalability that we observed in these tests on the VMware Cloud on AWS environment were very similar to what is seen with Oracle database test workloads running on VMware vSphere onsite. Because the software stack is essentially the same and the key difference is the location and deployment methodology, this was expected. High-performance Oracle databases run successfully with good performance on VMware Cloud on AWS.

## Comparing i3 vs i3en Instances

In some ways, the comparison of i3 vs i3en is a bit of apples vs oranges due to some of the underlying configuration differences. For example, hyperthreading is disabled on i3 due to the L1TF vulnerability, but it is enabled on i3en because L1TF is not an issue on that generation of CPU. Another example is that vSAN on i3 has compression and deduplication enabled, but on i3en they are both disabled. These settings are locked down and cannot be changed by users. Further, VMware Cloud on AWS is a service that is sold only with these two different options. Because of this, we compared the instances against each other so that customers can understand the performance advantage offered by i3en.

## Conclusion

The ability to quickly get a complete VMware vSphere environment up and running on AWS cloud infrastructure is a powerful solution. A best-practices-based setup with compute, storage, and network resources can be quickly ready to run Oracle databases with high performance requirements. For larger database deployments with higher performance requirements, the i3en instance type provides some clear advantages over the i3 instance type due to its higher number of cores, additional RAM, and better overall performance.

## References

- [1] VMware, Inc. (2018) VMware Cloud on AWS Resources.  
<https://cloud.vmware.com/vmc-aws/resources>
- [2] Todd Muirhead. (2017, December) DVD Store version 3.  
<http://www.github.com/dvdstore/ds3>
- [3] VMware, Inc. (2016, May) Oracle Databases on VMware Best Practices.  
<https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/solutions/vmware-oracle-databases-on-vmware-best-practices-guide.pdf>

**Disclaimer:** Results do not represent the performance of Oracle software, neither are they meant to measure Oracle performance nor compare the performance of Oracle to another DBMS. We simply use Oracle on VMware Cloud on AWS to observe and optimize the performance of virtual machines in this environment.

## Author Info

**Todd Muirhead** is a performance engineer at VMware and has worked with many different databases, servers, and storage systems to develop best practices and performance guides. He is also the co-creator and maintainer of the DVD Store open source benchmark.