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Increasing Private Cloud Host Virtualization with Servers and SSDs

Replacing HDDs with an Intel® SSD has reduced Intel IT's cloud host bill of materials cost by 4.7 percent.

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Executive Overview

Intel IT's enterprise private cloud has seen reduced total cost of ownership (TCO) annually and maintains a goal of absorbing private cloud growth while reducing absolute spending. To achieve this aggressive goal, continuous improvements in infrastructure efficiency and performance are required. In the second half of 2015, Intel IT evaluated two use cases with an Intel® Solid State Drive (Intel® SSD) to assess whether changes to our cloud hardware bill of materials were warranted to support the costs and efficiency goals.

Intel IT's prior-generation cloud host hardware bill of materials utilized a blade architecture, SAS disk controller, and dual mirrored hard disk drives (HDDs) to handle the host operating system and boot processes. In our periodic hardware plan of record review cycle, the economics of declining SSD prices provided the opportunity for elimination of HDDs in favor of a single Intel SSD.

In our study, we found private cloud hosts based on the Intel® Xeon® processor E5-2698 v3 utilizing an Intel SSD for host swap cache in a memory-constrained environment were the most efficient. The tests showed that a modest increase in server cost was offset by a rise in private cloud pool hosting and virtualization performance throughput. There was significant increase in performance when contrasted to relying on storage area network (SAN)-based storage for host swap cache. For our cloud hosts, using the SSD as the boot drive eliminated the SAS controller and mirrored drives from our cloud host bill of materials—reducing our compute hardware cost by 4.7 percent.

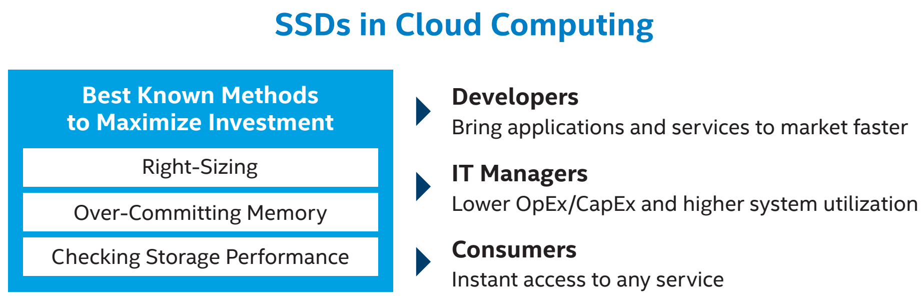

Figure 1. Maximizing our investment in SSDs in the private cloud host server environment can benefit developers, IT managers, and consumers.

Contents

Acronyms

BKM	best known method
HDD	hard disk drive
IOPS	input/output operations per second
NVMe	Non-Volatile Memory Express
PCIe	Peripheral Component Interconnect Express*
SAN	storage area network
SATA	serial AT attachment
SSD	solid-state drive
TCO	total cost of ownership
vCPU	virtual CPU
VM	virtual machine

Business Challenge

IT decision makers have to make tough choices to keep up with rapidly expanding storage requirements of the data center. The transition to the digital service economy is driving more applications to private, public, and hybrid cloud computing. This will help developers by enabling faster time to market, benefit IT by lowering operational and capital expenses and increasing system utilization, and enable the consumer to instantly access any service.

Solid-state drives (SSDs) are increasingly used in our high-performance computing environment for electronic design automation, delivering cost reductions and increased capacity. We use a single SSD, rather than dual mirrored hard disk drives (HDDs), in our virtualized servers for local storage. Because SSD technology improves both performance and total cost of ownership (TCO) in many applications, we are actively evaluating new opportunities to take advantage of SSDs in our highly diverse data center environment.

SSDs are most commonly used in the enterprise to accelerate existing applications for improved performance or server consolidation. They are also used to modernize the storage system by providing all-flash performance in place of traditional storage for improved agility and scalability. Typical applications that are best suited for SSD acceleration include virtualization, database, and big data analytics. Hyper-converged infrastructure is a common example of modernization.

Intel® SSDs have two interfaces, serial AT attachment (SATA) or Non-Volatile Memory Express (NVMe). NVMe SSDs are designed to deliver high bandwidth and low latency through the Peripheral Component Interconnect Express* (PCIe) interface with a new streamlined protocol and efficient performance, as well as industry-standard software, drivers, and memory management. Data centers will be able to deploy SSDs at scale with linear performance scaling and less CPU utilization for the same workloads, which lowers the storage footprint and increases input/output operations per second (IOPS) per unit of rack space.

Benefits of Using SSDs in Intel® Silicon Design Workloads

Intel IT uses SSDs for silicon design workloads, which are increasing every year (see Figure 2). We found substituting lower cost SSDs for part of a server's physical memory resulted in a 1.63x performance normalized cost advantage. The SSDs are used as swap space for large silicon design workloads. In this usage model, the SSDs achieved up to 88 percent of the performance compared with running workloads entirely in more expensive DRAM. In addition, this Intel SSD-based solution required 60 percent less data center space and 79 percent less power and cooling per server.

Accelerating applications with SSDs alone is good, but using SSDs in data storage virtualization extends the benefits across a broader set of usages within a data center.

We needed to better understand several aspects of our private cloud hosting environment with SSDs before we could meet our goals of cost reduction and improved private cloud host utilization.

Compute and Storage for Silicon Design

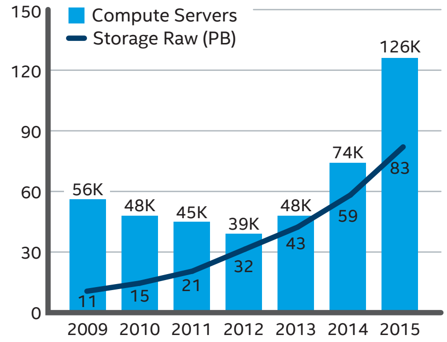

Figure 2. Despite continuing growth in compute and storage demand, our Design data centers are using Intel® technology to meet the demand without increasing data center floor space.

Choosing a Cloud Host Hardware Configuration for Cost Optimization

Before choosing a private cloud host server configuration, we needed to understand the performance characteristics of the virtual machines (VMs) in our environment. We did this by capturing the VM's total CPU MHz utilization, sensitivity to CPU Ready, cloud host core over-allocation, and the maximum amount of active memory used. Before we virtualized anything, we identified the performance characteristics of our workloads. Identifying these characteristics was an important first step.

We strive to follow three best known methods (BKMs) to maximize our investment in private cloud host server resources. These BKMs are right-sizing, over-committing memory, and checking storage performance.

1. **Right-sizing.** We allocate the exact amount of CPU and memory resources a VM needs to perform its function. We routinely review large VMs in our environment and reduce CPU and memory configurations where resources are not being consumed.
2. **Over-committing memory.** By utilizing memory optimization features on modern hypervisors such as memory sharing, compression, and ballooning, we over-commit as much memory as possible on our private cloud hosts. This approach helps us achieve an active memory utilization metric of 80 percent, which is an effective memory allocation of over 200 percent on some of our private cloud hosts.
3. **Checking storage performance.** We periodically review the storage performance of our private cloud. The latency endured by a storage frame can mask itself as CPU or memory contention, leading many capacity managers to believe an environment needs to add cloud hosts. Routinely reviewing storage metrics with storage administrators can pinpoint the issues before money is spent on capacity.

Benefits of Using SSDs instead of HDDs

- Higher IOPS
- Lower and consistent access times
- Higher reliability
- Lower power consumption
- Smaller data center footprint

2.3x
MORE TRANSACTIONS WITH SSDs

SSD Caching for Cloud Host Density Study

Intel IT is constantly looking for technologies and methods to increase the performance, efficiency, and density of our enterprise private cloud. As flash drive technology has matured and price/performance has become very attractive, we wanted to test SSD value with two use cases. Working closely with Intel's SSD product team, we sought to determine if basic SSD economics could be used to produce higher VM-to-physical cloud host densities. Testing in the lab was undertaken to validate a popular hypervisor's swap cache feature utilizing a single Intel® SSD DC S3710 Series.[1]

Test Methodology

Intel's private cloud workload profile is not predominately memory-intensive. Therefore, the testing was performed on hosts with reduced memory so that over-subscription would force swapping more quickly before other bottlenecks were reached.

We began testing in an Intel IT lab to validate the hypervisor swap cache feature utilizing a single DC S3710 Series. Utilizing an open source database benchmarking utility, HammerDB*, we executed a series of TPC-H*[2] workloads to trigger the condition where swapping occurs. VM density was then increased while executing a static TPC-H workload, where performance degradation of those TPC-H transactions was measured.

After lab tests were completed, we next tested the configurations in our pre-production enterprise private cloud environment. In addition to checking performance degradation, we were also concerned about testing performance within a live pre-production environment and how it would affect real customer data.

To minimize risk, we took a standard configuration control host (server with dual-socket Intel® Xeon® processors E5-2698 v3 and 256 GB of memory) running the TPC-H workload and added VMs incrementally. The hypervisor environment was monitored for performance degradation and configured to isolate performance bottlenecks to the VM executing the TPC-H synthetic load in case of failure. The test was then repeated, substituting another host with one DC S3710 Series and host swap cache feature enabled. Performance degradation of the synthetic TPC-H workload (query completion time) was measured.

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[1] The Intel® SSD DC S3710 Series is part of Intel® Solid State Drive Data Center Family for SATA. For more information, visit intel.com/content/www/us/en/solid-state-drives/solid-state-drives-dc-s3710-series.html.

[2] TPC-H stands for transaction processing performance council ad-hoc, decision support benchmark. More information can be found at tpc.org/tpch

Test Configurations

Depending on the test, we configured the server so that the workloads were loaded entirely in memory and used an HDD or one DC S3710 Series as a swap drive. Specifications for the server and SSD are shown in Tables 1 and 2.

Results

Minimal Performance Degradation in Heavy Database Queries with an Intel® SSD

The testing validated that with memory-intensive workloads, utilization of SSD flash-based swap cache allowed synthetic database query performance to degrade at a much slower pace over the control host. As VMs were added to the host running the TPC-H workload, we observed a consistent slow pace for query performance degradation.

The practical result of this testing concludes that the SSD-equipped server can tolerate higher degrees of oversubscription, because when VM workloads are forced to swap, they benefit from the higher performance of the SSD flash swap cache. In practical terms, this increased workload oversubscription tolerance leads to greater VM-to-cloud host densities.

The results show that for equivalent levels of performance degradation of the synthetic workload, increased oversubscription of host memory of 150 percent was achieved on the cluster. This measurement was taken when the host swap cache was enabled on only one host.

Figure 3 shows the cloud host testing results with and without the SSD. The Y-axis represents the length of time for the query sets to complete. The X-axis shows the different tests with varying configurations. Once memory was oversubscribed at a level of 125 percent and greater, we saw a significant difference in performance between the SSD-enabled swap cache versus utilizing a storage area network (SAN)-based swap.

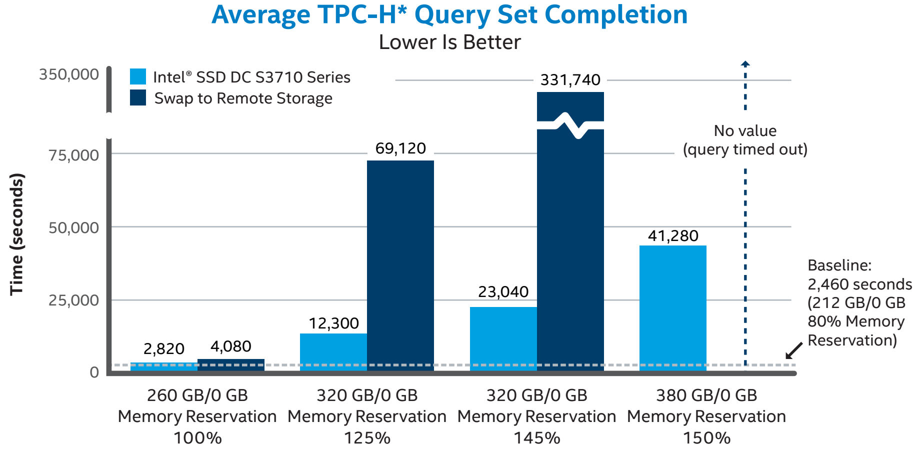

Figure 3. Test results of average TPC-H* query set completion times.

Table 1. Test Swap Drives Configurations

	Intel® SSD DC S3710 Series	SAS Hard Disk Drive
Capacity	400 GB	900 GB
Component Specification	25nm NAND	10,000 RPM
Read Bandwidth	500 MB/s	No data
Write Bandwidth	460 MB/s	No data
Read Latency	50 µs	2.9 ms (average)
Random 4-KB Reads	75,000 IOPS	No data
Random 4-KB Writes	36,000 IOPS	No data
Interface	SATA 6 Gb/s NCQ	SAS 6 Gb/s
Mean Time Between Failures	2,000,000 hours	1,600,000 hours

Table 2. Cloud Host Test System Specifications

Component	Specification
Hypervisor Host Configuration	2x Intel® Xeon® processors E5-2698 v3 with 256 GB (16x16 GB) DDR3-1600
TPC-H* Server Configuration	12 virtual CPUs with 256 GB (16x16 GB) DDR3-1600
TPC-H Work Load Profile	100-GB database with 6 concurrent virtual users
Hosted Enterprise Server Load Profile	• Puppet* • McAfee • Endpoint device manager • OS defrag • Simulated memory leak (PowerShell*) • General file operations (copy/read/delete)
Data Collectors/ Monitors	• HammerDB* (TPC-H) • Application monitor (OS) • Hybrid cloud manager (hypervisor)

Cloud Host Configurations: CPU MHz Utilization and VM Density

For both private cloud hosts and VMs, we strive to achieve as close to an average of 80 percent of the CPU utilization as possible. In many instances, CPU utilization can run at 100 percent for long periods of time without affecting a VM's service level agreement. The guiding metric for understanding if this level of CPU utilization is possible is the CPU Ready percentage.

We also consider the number of cores that the physical CPUs have when measuring CPU Ready, as well as the average and maximum amount of virtual CPUs (vCPUs) that are assigned to the VMs. When a VM has more vCPUs assigned to it than what is available on a single socket in the private cloud host, the VM has to schedule processes and use memory in another socket. This can increase the CPU Ready percentage for those VMs. If the majority of the environment is comprised of VMs that require eight or more vCPUs, we have found that it is advantageous to pair private cloud hosts with high-core-count CPUs so VMs can run within a single socket. High-core-count CPUs are also beneficial in environments with smaller CPU configurations because they give VMs more opportunities to schedule with physical CPU cores without increasing the CPU Ready percentage.

In our experience, it is critical to right-size VMs with the proper amount of vCPUs to maximize the performance of an individual VM and reduce the performance impact to other VMs and the private cloud host. Over-allocating vCPUs when they are not needed reduces performance and can lead to wasting money on purchasing additional private cloud hosts that are not necessary.

Increased Densities of Compute, VM, and Storage Lower TCO

TCO was not measured in this study; however, we did create a very dense and more efficient private cloud footprint which intuitively should lead to a lower TCO. The increased VM and compute densities combined with the smaller form factor of Intel SSDs reduce data center footprints versus JBOD systems or SAN storage. This smaller data center footprint can reduce TCO in areas of data center power, cooling, storage, and network connectivity costs. Additionally, increased VM density per cloud host can reduce costs related to the license and maintenance costs of software such as OS, applications, middleware, security products, backup and restore, and manageability (monitoring, alerting, compliance, patching, and provisioning).

The TCO provided by a solution depends on the costs of maintenance and repair. Higher failure rates mean higher costs. The Intel SSD failure rate data is derived from over four million SSDs, with failure rates running at less than 0.2 percent per year, well below HDDs. Intel's industry-leading field reliability means lower costs and better TCO.[3]

[3] Source: Ian Paul, PC World, "Three-year, 27,000 drive study reveals the most reliable hard drive makers," January 21, 2014.

Conclusion

Our study showed that private cloud hosts based on the Intel Xeon processor E5-2698 v3 utilizing an Intel SSD for host swap cache in a memory-constrained environment were the most efficient. Also, servers with high-core-count processors were well-suited for VM density and had the lowest four-year cost per VM. In addition, we expect this configuration to help control operational and software licensing costs with greater virtualization density, requiring fewer servers and less data center space and power.

Intel IT's standard cloud host bill of materials consists of a blade-based server, configured with a dual-socket Intel Xeon processor E5-2698 v3 with 256 GB of memory, and a single DC S3710 Series. Intel's cloud workload profile is not predominately memory-intensive; therefore, the testing was performed on hosts with reduced memory so that oversubscription would force swapping more quickly before other bottlenecks were reached.

This hardware configuration provides the following benefits:

- Substantial increase in private cloud pool hosting and virtualization performance throughput for a modest increase in server cost
- Significant increase in performance when contrasted to relying on SAN-based storage for host swap cache

Ultimately, we chose not to use flash SSD-based host swap cache since our private cloud is not memory-bound, but rather processor-bound. Our study has helped provide Intel IT with a method to deal with memory-constrained hosts where replacement or physical memory augmentation is not practical or economically feasible. We will continue to evaluate this capability for deployment or alignment into other use cases within our enterprise environment.

Our results suggest that other technical applications with intensive memory demand, such as simulation and verification applications in the auto, aeronautical, oil and gas, and life sciences industries, could see similar improvements, depending on workload characteristics.

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