VMware vSphere 8.0 Virtual Topology

Performance Study

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Table of Contents

Executive Summary 3

Introduction 3

- Configuring virtual topology 4
- Sockets and NUMA 6
- Checking sockets in the guest operating system 7

Overview of Workloads 8

Database Workloads 9

- Oracle in Linux 9
- SQL Server in Windows Server 2019 11

Virtual Desktop Infrastructure Workload 12

VMmark Benchmark 13

Storage Benchmark Tests 13

- Iometer tests in Windows 13
  - Experiment with thread affinity to fixed CPU cores 17
- Fio benchmark in Linux 19

Network Benchmark Tests 20

- Netperf tests in Windows 20
- Netperf tests in Linux 23

Conclusion 24

Appendix 24

References 25

Executive Summary

This paper describes the performance implications of using virtual topology—introduced in VMware vSphere® 8.0—in several workloads. Virtual topology simplifies a virtual machine's CPU assignments by exposing the appropriate topology at various levels. These topology levels include virtual sockets, virtual non-uniform memory access (vNUMA) nodes, and virtual last-level caches (LLC). Our testing shows that using virtual topology (also known as vTopology) for some typical applications run in a vSphere 8.0 VM will improve the application performance. In some cases, the application performance will remain unchanged.

Introduction

Emulating physical processor topology for virtual machines is critical for both execution and performance. ESXi provides options to create virtual CPUs, virtual sockets, virtual NUMA nodes, virtual LLC, and so on. Before vSphere 8.0, the default configuration of a VM was one core per socket. This configuration sometimes created inefficiencies and needed manual tweaks to get optimal performance. Now, ESXi automatically tunes the optimal cores per socket for the VM.

For example, figure 1 illustrates the high-level components of a two-socket system. Each socket connects to a local memory bank and thus creates a NUMA node. Each socket has four cores (each with L1 and L2 caches), and the cores share a common last-level cache (LLC). When a 4-vCPU VM is created, it will be configured with a single socket by default in vSphere 8.0 instead of four sockets, each containing a single vCPU.

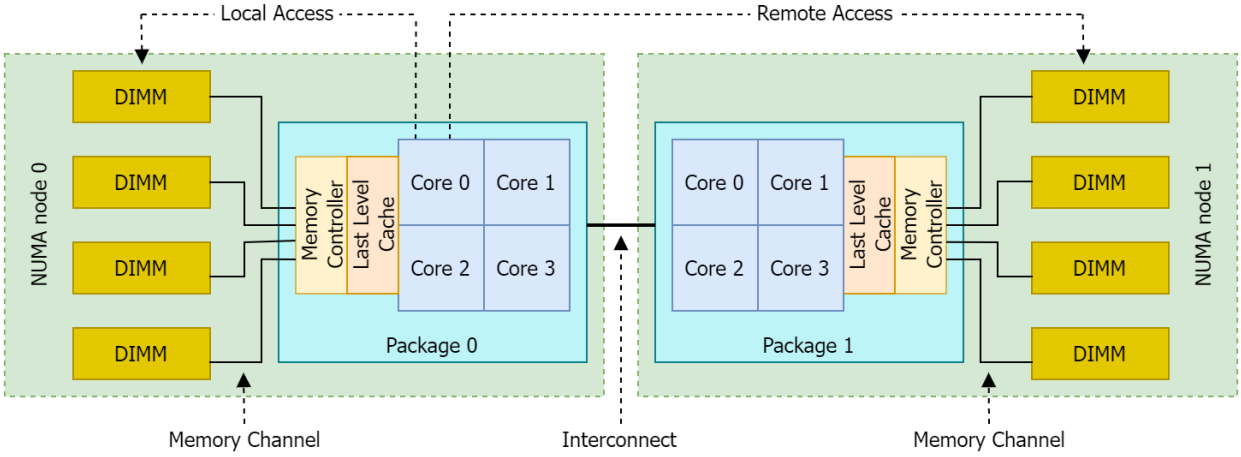


Figure 1. A two-socket system with two NUMA nodes

Configuring virtual topology

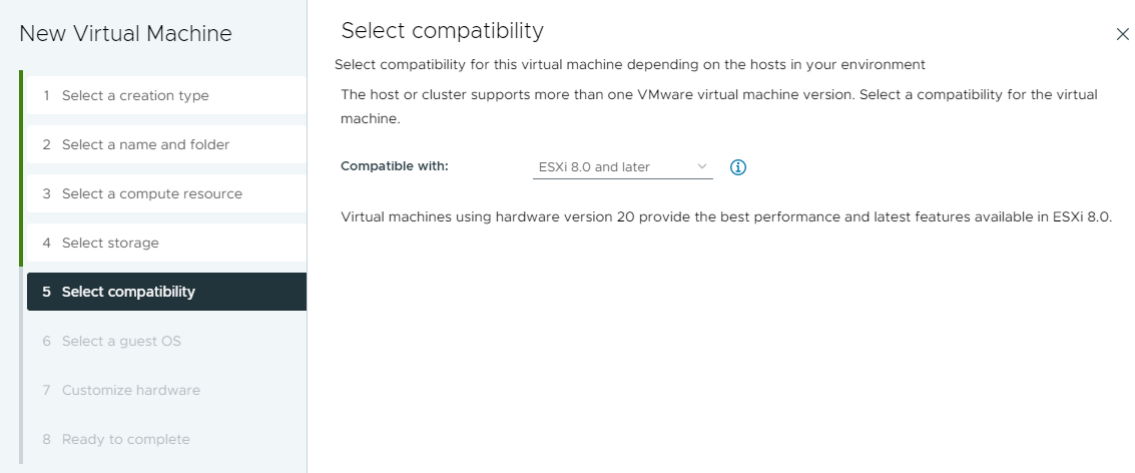
When configuring virtual CPUs within the vSphere Client, you can set the following:

- The total number of vCPUs for the virtual machine
- The number of cores per socket

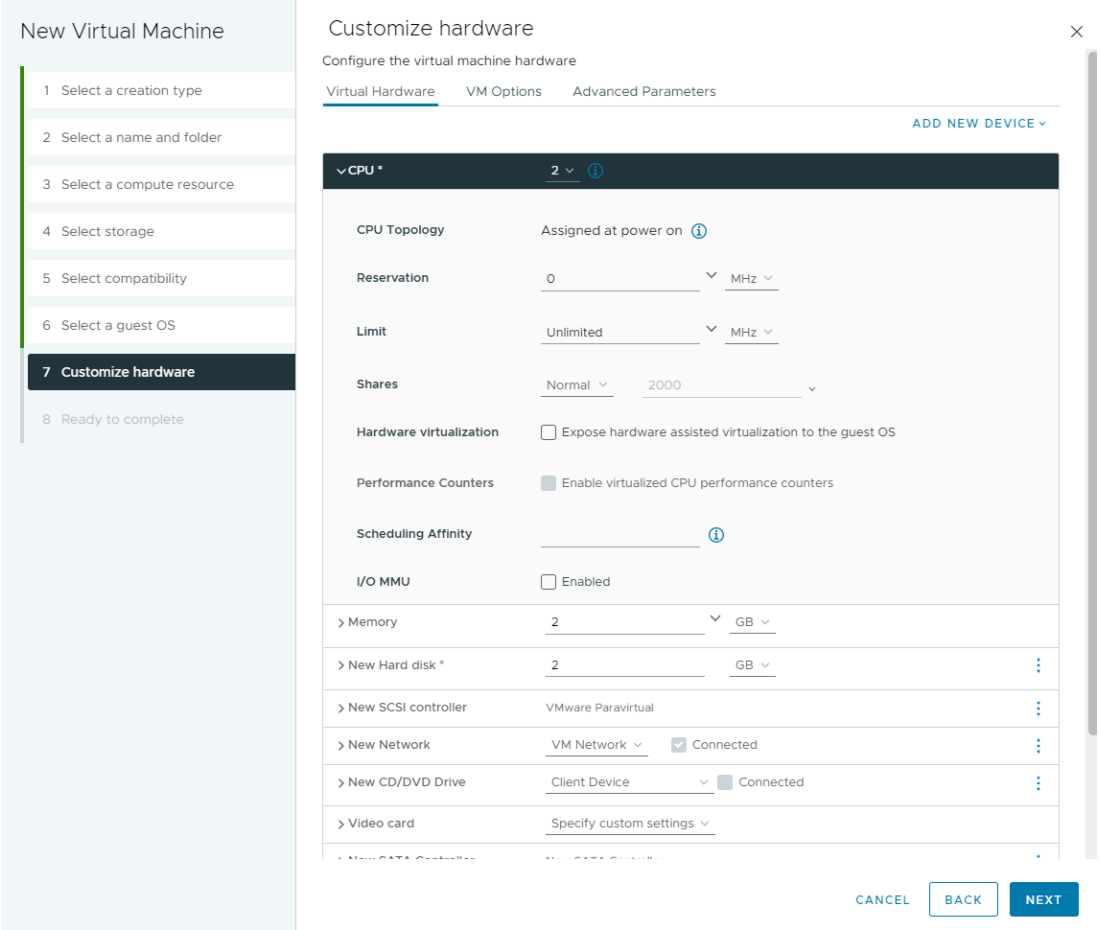
The following images show the user interface (UI) in the vSphere Client for creating a new virtual machine. When compatibility is ESXi 8.0 and later, the virtual topology feature is enabled by default and is shown as **Assigned at power on**. Virtual machines with previous hardware versions retain their existing behavior.

To create a new VM in vSphere 8.0 using the vSphere Client and configure it with the virtual topology feature:

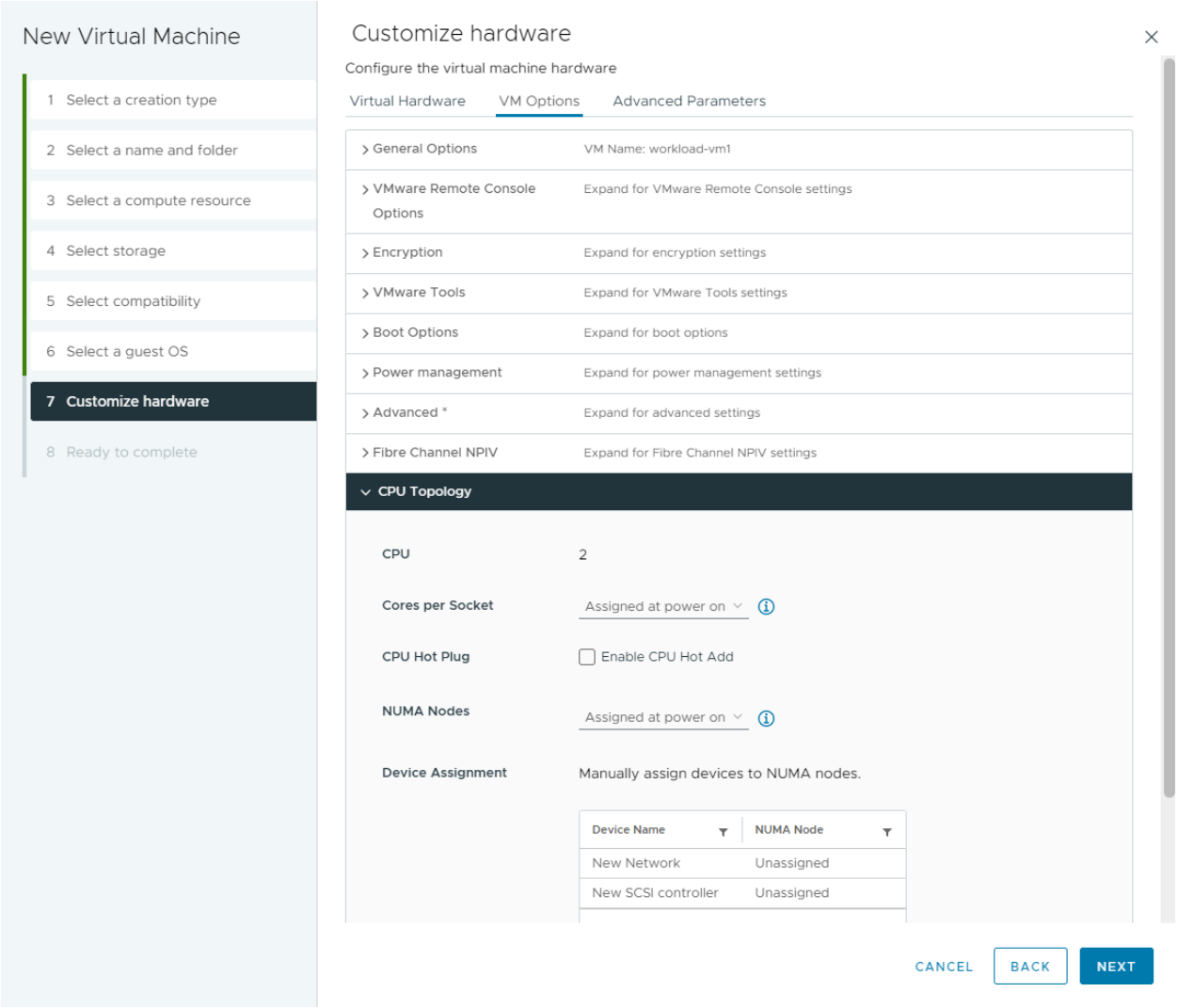
1. When you create a new VM, at **Select compatibility**, make sure **Compatible with** shows **ESXi 8.0 and later**.



2. In the **Customize hardware** section, select the number of virtual CPUs under the **Virtual Hardware** tab.



3. In the **VM Options** tab, there is a new **CPU Topology** section. Ensure the **Cores per Socket** setting shows **Assigned on power on** (the default).



Note: Equivalent options are also available in the virtual machine configuration (.vmx) file.

Sockets and NUMA

Since vSphere 6.5, changing the **Cores per Socket** value no longer influences vNUMA or the configuration of the vNUMA topology [1]. The configuration of **Cores per Socket** only affects the presentation of the virtual processors to the guest operating system. In the past, some software licensing schemes had limitations on socket counts, but not on core counts. For this reason, configuring the socket count to 1 resulted in better performance for some application workloads. Many of these licenses now use core count as the primary method for licensing and not socket count. Thus, providing virtual machines with topologies that are most optimal for the hardware where they're running eliminates the need for complicated tracking and provides more flexibility for running these VMs in data centers with diverse configurations.

Some operating systems (for example, Windows Server 2016 and Windows Server 2022) might not run on very large VMs ("monster VMs" with more than 64 sockets) when configured with the default settings from prior versions or might not run applications that rely on these operating systems (for example, SQL Server).

Some applications behave differently with cores per socket variations. For example, a single instance of SQL Server Standard edition [2] running on an 8-vCPU VM with 1 core per socket would be able to consume only 4 vCPUs. But if the same VM is configured with 1 socket (that is, 8 cores per socket), then all 8 vCPUs are leveraged. In the past, VMware provided guidance in appropriately choosing the CPU and cores per socket values. But, with the automatic **Cores per Socket** setting, you no longer need to set this manually. An optimal CPU topology is applied by default at the initial power-on of the VM; the configuration also persists when the VM is migrated with vMotion.

Checking sockets in the guest operating system

Let's look at a 4-vCPU VM. With 1 core per socket, the VM is presented to the guest operating system as a 4-socket system (each socket containing a CPU). With virtual topology, the VM is presented to the guest operating system as a 1-socket system (with that socket containing four CPUs). Table 1 shows a section of CoreInfo [3] in a VM running Windows Server 2022 on an Intel Xeon Gold 6148 Processor. In both cases, all the cores belong to a single NUMA node.

Without virtual topology	With virtual topology
Processor signature: 00050654 Logical to Physical Processor Map: *--- Physical Processor 0 -*-- Physical Processor 1 --*- Physical Processor 2 ---* Physical Processor 3 Logical Processor to Socket Map: *--- Socket 0 -*-- Socket 1 --*- Socket 2 ---* Socket 3 Logical Processor to NUMA Node Map: **** NUMA Node 0	Processor signature: 00050654 Logical to Physical Processor Map: *--- Physical Processor 0 -*-- Physical Processor 1 --*- Physical Processor 2 ---* Physical Processor 3 Logical Processor to Socket Map: **** Socket 0 Logical Processor to NUMA Node Map: **** NUMA Node 0

Table 1. CoreInfo output difference with virtual topology

In Linux and an 8-vCPU VM, we can use the `lscpu` or `numactl` command to see the CPU and socket settings. Table 2 shows the `lscpu` output differences inside a VM running Red Hat Enterprise Linux 8.1 on an AMD EPYC 7763 processor.

Without virtual topology		With virtual topology	
Architecture:	x86_64	Architecture:	x86_64
CPU op-mode(s):	32-bit, 64-bit	CPU op-mode(s):	32-bit, 64-bit
Byte Order:	Little Endian	Byte Order:	Little Endian
CPU(s):	8	CPU(s):	8
On-line CPU(s) list:	0-7	On-line CPU(s) list:	0-7
Thread(s) per core:	1	Thread(s) per core:	1
Core(s) per socket:	1	Core(s) per socket:	8
Socket(s):	8	Socket(s):	1
NUMA node(s):	1	NUMA node(s):	1
Vendor ID:	AuthenticAMD	Vendor ID:	AuthenticAMD
CPU family:	25	CPU family:	25
Model:	1	Model:	1
Model name:	AMD EPYC 7763 64-Core Processor	Model name:	AMD EPYC 7763 64-Core Processor
Stepping:	1	Stepping:	1
CPU MHz:	2445.405	CPU MHz:	2445.405
BogoMIPS:	4890.81	BogoMIPS:	4890.81
Hypervisor vendor:	VMware	Hypervisor vendor:	VMware
Virtualization type:	full	Virtualization type:	full
L1d cache:	32K	L1d cache:	32K
L1i cache:	32K	L1i cache:	32K
L2 cache:	512K	L2 cache:	512K
L3 cache:	262144K	L3 cache:	32768K
NUMA node0 CPU(s):	0-7	NUMA node0 CPU(s):	0-7

Table 2. Linux lscpu output difference with virtual topology

Overview of Workloads

Guest operating system schedulers and applications optimize workloads based on the available hardware topology. Some optimizations may place worker threads running within the same socket and may not migrate threads between sockets to avoid overhead from increased memory latencies. For a larger VM (for example, one with 32 vCPUs), the number of sockets with 1 core per socket by default may not be ideal and practical regarding available system implementations.

The latest processors provide various configurations with BIOS controls. Tuning an optimal setting of cores, sockets, and NUMA values for various workloads has become more complicated. Examples are sub-NUMA clustering (SNC) in Intel Xeon Scalable Processors and NUMA nodes per socket (NPS) in AMD EPYC processors. Virtual topology in vSphere 8.0 reduces this complexity while providing optimal performance for most customer workloads.

To analyze the performance impact of the new automatic cores per socket setting in vSphere 8.0, we looked at workloads varying from large-scale databases and applications to microbenchmarks. Each workload was run with the automatic cores per socket feature enabled and disabled.

- Database workloads: DVD Store 3.5
  - Oracle in Linux
  - SQL Server in Windows Server 2019
- Virtual desktop infrastructure (VDI) workload: Login VSI
- Web-scale multi-server virtualization platform benchmark: VMmark
- Storage benchmark tests:
  - Iometer tests in Windows
  - Fio benchmark in Linux
- Network benchmark tests:
  - Netperf tests in Windows
  - Netperf tests in Linux

We saw good performance in large database workloads (up to a 14% increase in Oracle and a 17% increase in Microsoft SQL server). Some workload performance (for example, the VMmark benchmark) remained unchanged. A few workloads (for example, the storage benchmarks) showed performance regression. We collected additional performance data to analyze and root cause the performance changes.

Database Workloads

Oracle in Linux

We used the open-source database benchmark application DVD Store 3.5 [4]. It simulates an online store with users logging on, searching for DVDs, reading and rating reviews, purchasing DVDs, and so on. The benchmark includes a client program that generates load against the database and reports throughput in orders per minute (OPM). We selected different numbers of threads in different virtual machine configurations.

We configured the virtual machines with different numbers of virtual CPUs (vCPUs) ranging from 8 to 51 and ran the benchmark application with and without virtual topology. The number of vCPUs used was based on the 24 cores per socket of the host and tested just above and below this number. We saw an average gain of 8.9% in orders per minute (OPM) across the workloads, with a maximum of up to 14%. The improvement correlates with an increase in CPU usage and I/O operations per second (IOPS).

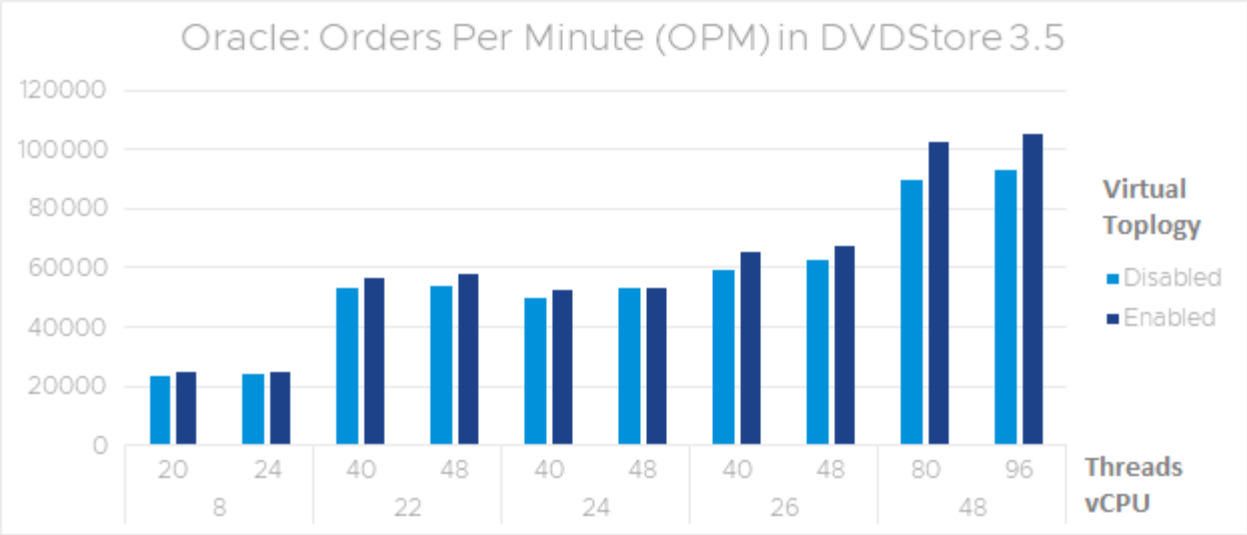


Figure 1. Orders Per Minute (OPM) in DVD Store 3.5 with and without virtual topology

We collected CPU interrupts, memory, and I/O operations using various Linux tools during the workload for a subset of the cases. We observed consistently higher CPU usage for the user mode and kernel mode components with virtual topology. Disk I/O throughput was also higher for both reads and writes.

We collected Linux guest performance data with various tools to analyze the root cause. Using the `mpstat` utility, we observed that the soft IRQ of the block devices was no longer distributed across all cores when virtual topology was enabled. This means that only a few CPUs (instead of all of them) were handling these soft IRQs.

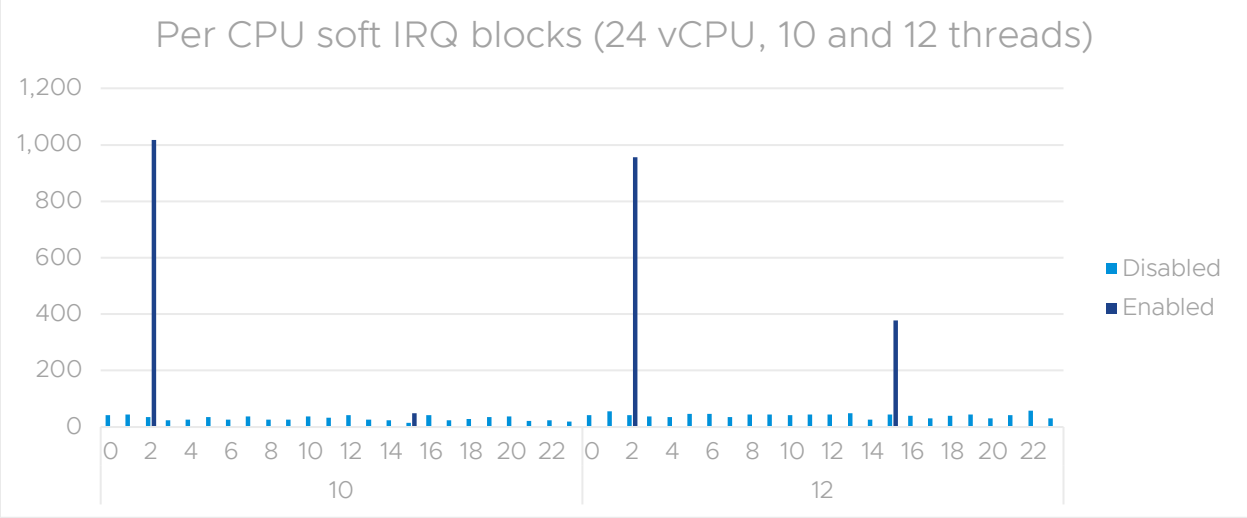


Figure 2. Per CPU soft IRQ blocks with and without virtual topology

From NUMA statistics collected in the Linux guest, we observed more NUMA hits and fewer NUMA misses when virtual topology was enabled. The following charts show the data from `numa_stats` normalized to orders per minute (OPM) values.

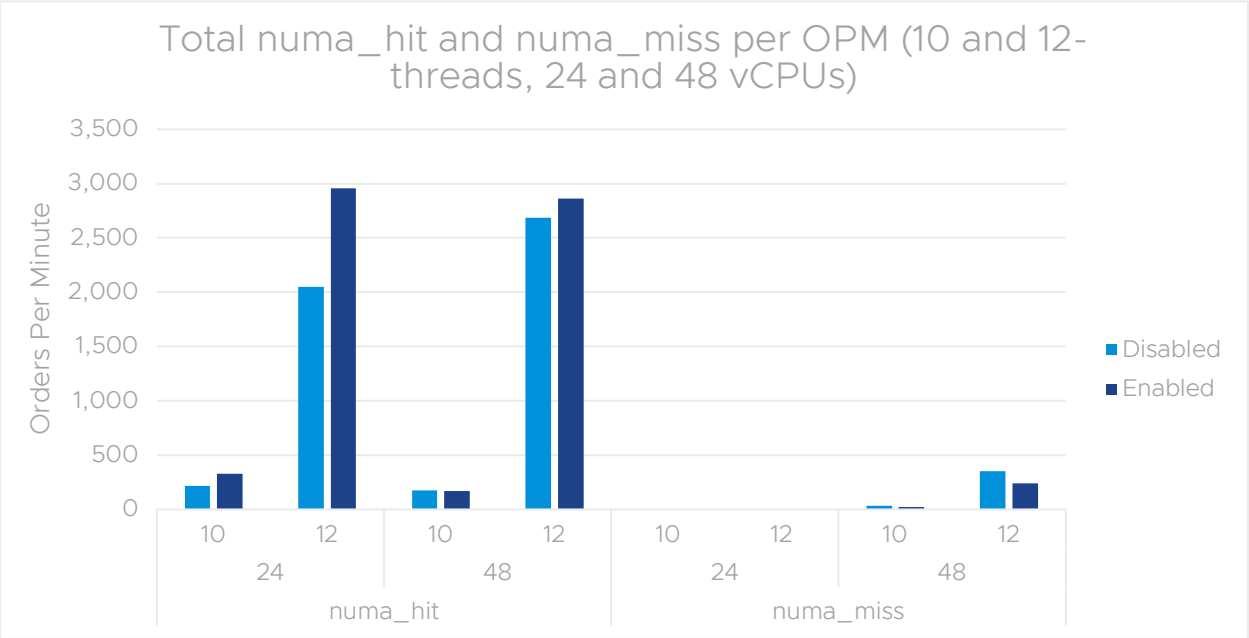


Figure 3. numa_hit and numa_miss per orders per minute (OPM) with and without virtual topology

When virtual topology is enabled, it helps Oracle to provide higher performance capabilities in Linux.

The testbed was made up of:

- A 4-socket Broadwell server with 24 cores per socket and 2TB of RAM
- Oracle 12c on CentOS 7 with 64GB of RAM and an SGA of 25GB
- DVD Store 3.5 with 5 stores of 3GB each; the workload ran 45GB of data and generated 17GB of logs

SQL Server in Windows Server 2019

We ran DVD Store 3.5 against a SQL Server VM and set a specific number of threads for each vCPU configuration. The average performance of the application remained unchanged with the feature across different configurations. We observed up to a 17% performance gain in the orders per minute (OPM) metric. In some cases, the performance was neutral, and in a few cases, we noticed a slight drop. Since the server has 24 cores per socket, the settings with 24 vCPUs match the physical configuration. Virtual topology provides good improvements in this test case.

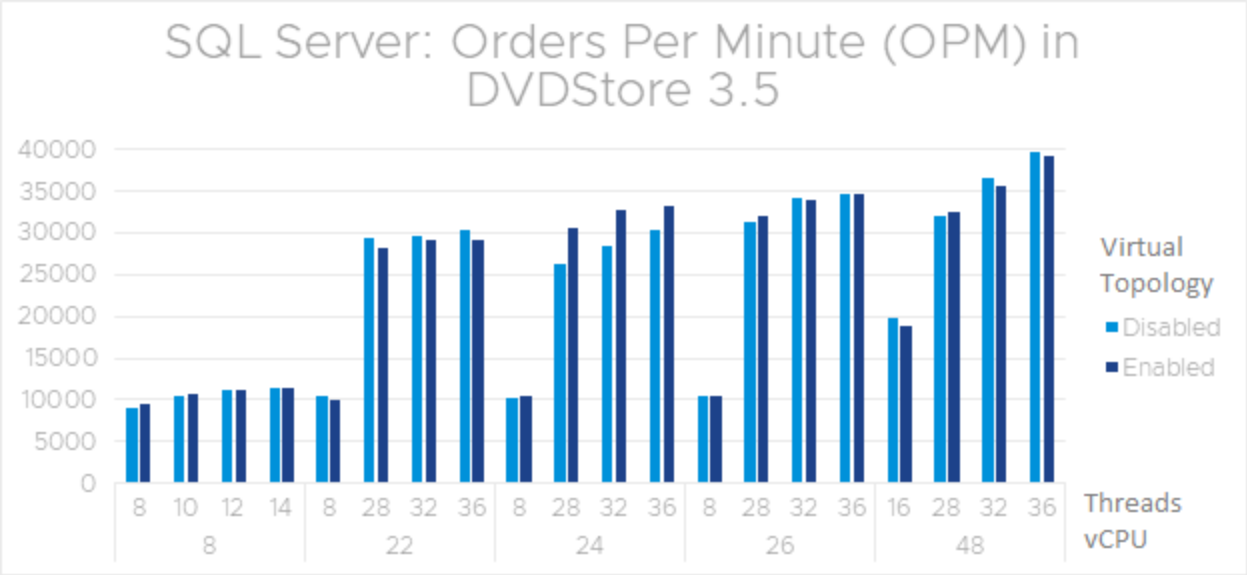


Figure 4. Orders Per Minute (OPM) in DVD Store 3.5 on SQL Server with and without virtual topology

We did not manually configure soft NUMA [5] instead, we left the SQL Server database engine to detect the CPU cores and create soft NUMA nodes automatically. Virtual topology still helps with a significant performance improvement in several configurations.

The testbed configuration included:

- A 4-socket Broadwell server with 24 cores per socket and 2TB of RAM
- DVD Store 3.5 with 2 SQL instances, each with 5 stores of 3GB each and SQL memory set to 50GB
- SQL Server 2019 on Windows Server 2019 with 512GB - used existing VM
- SQL Server 2019 Developer edition

Virtual Desktop Infrastructure Workload

For a virtual desktop infrastructure (VDI) workload, we used Virtual Session Indexer (Login VSI) [6].

Login VSI is an industry-standard benchmarking tool for measuring the performance and scalability of centralized desktop environments. Login VSI gradually increases the number of simulated users until the CPU and other resources (memory, disk, and so on) are saturated. When the system is saturated, the response times of the applications increase significantly. The latency indicates that the system is almost overloaded. After the test is performed, the response times can be analyzed to calculate the maximum active sessions per desktop capacity. This metric is called VSImax.

The simulated desktop workload is scripted in a 70-minute loop when a simulated Login VSI user is logged on and performs generic office “knowledge” worker activities (examples, Microsoft Office, Internet Explorer, and Adobe Reader). We loaded the system under test with the number of VMs to achieve VSImax.

We ran the workload with virtual topology enabled and disabled. We did not observe any significant changes in latency and throughput or CPU utilization for this workload. The VMs created by Login VSI are small, and their performance seems to be neutral to virtual topology features.

The testbed used here included:

- Dual socket, 40 cores, Intel Xeon Platinum 8380 Processor @ 2.30GHz
- Memory: 1TB
- VM: 2 vCPU, 2GB memory with knowledge worker profile
- Guest: Windows 10 Enterprise version 21H2
- Baseline: 1 core per socket
- Virtual topology: 2 cores per socket

VMmark Benchmark

VMmark 3 [7] is a free tool used to measure the performance and scalability of virtualization platforms. We used the tool with various configurations to measure the performance of the virtual topology feature. We ran the maximum number of tiles, and we did not see any performance change with the workload.

The testbed included:

- Dell PowerEdge R640
- 2 Xeon Platinum 8260C servers @ 2.40GHz
- 768GB RAM
- 2 Intel X710 10Gb NICs
- QLE2692 HBA
- Dell EMC XtremIO X2 Storage Array with a Violin V6000 flash memory array

Storage Benchmark Tests

Iometer tests in Windows

Iometer [8] is an I/O subsystem measurement and characterization tool for single and clustered systems. The tool consists of two executables: Iometer and Dynamo.

Iometer creates a worker thread for each disk and assigns it to a processor. It does not explicitly provide any CPU affinity setting for the threads. The worker thread waits for I/O completions before issuing the next I/O. The workload is not compute-intensive. When a thread has a specific affinity to a CPU core, the operating system scheduler will re-use the same core (unless it's unavailable due to a higher priority thread running there).

We looked at the storage drivers for the VMware paravirtual SCSI (PVSCSI) controller and the non-volatile memory express (NVMe) controller, workloads varying from 4, 64, and 256KB, and a combination of read and write operations with sequential and random I/O patterns. The following results are shown for four tests:

1. 4096_100_0: 4K, 100% read, all sequential
2. 4096_100_100: 4K, 100% read, all random
3. 65536_0_0: 64K, 100% write, all sequential
4. 262144_70_100: 256K, 70% read, and 30% write, 100% random

We measured performance using CPU cycles per I/O (CPIO). This metric is influenced by both I/O throughput and CPU usage. CPU cycles were calculated with an internal tool that relies on a CPU performance counter (CPU_CLK_UNHALTED). Throughput, measured in I/O per seconds (IOPS), increased up to 2.27% with virtual topology. We also saw an increase in CPU usage in the CPIO metric (up to 21%). This is illustrated in figures 5 and 6.

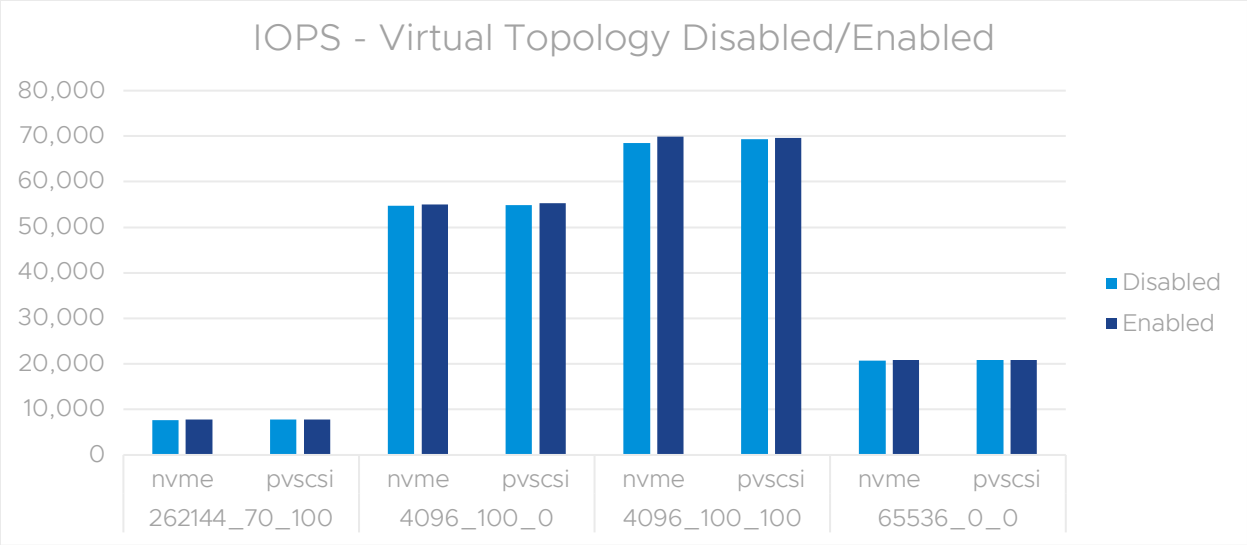


Figure 5. IOPS in Iometer test with and without virtual topology

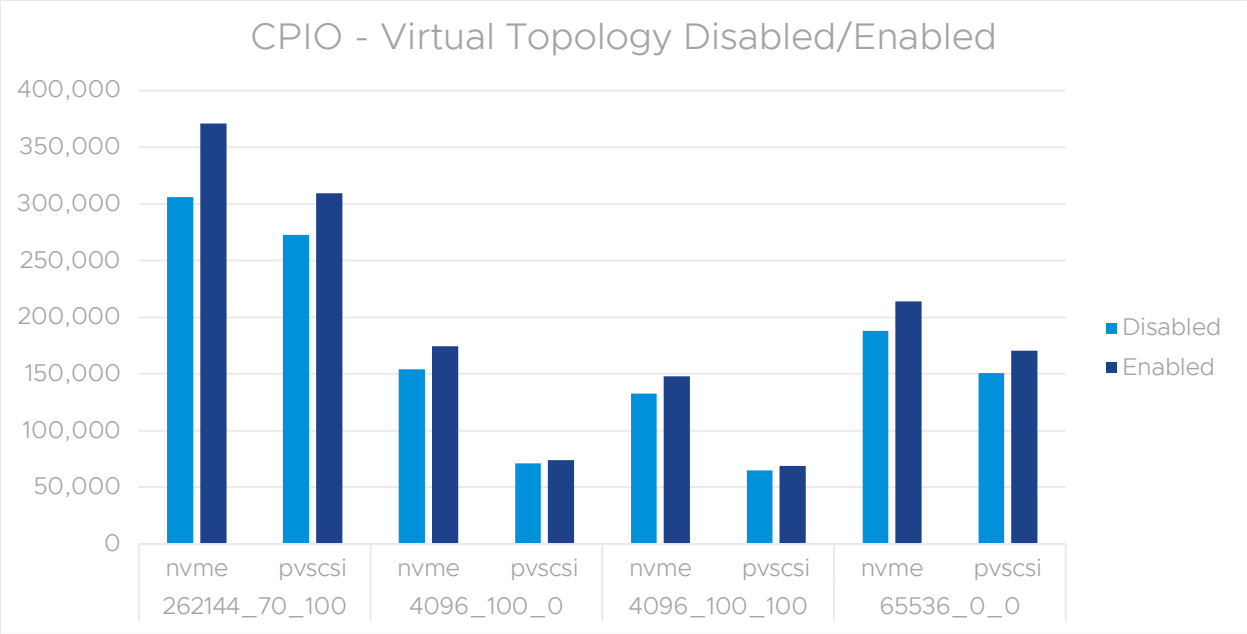


Figure 6. CPIO in Iometer test with and without virtual topology

To find the cause of this CPU utilization, we profiled the application and looked at the scheduling behavior. Overall, CPU utilization depends on the number of IOPS, which is higher when the request size is small (that is, 4K bytes). We collected event tracing for Windows (ETW) in the guest and analyzed the traces using media experience analyzer (MXA).

Figure 7 shows scheduling patterns of the NVMe controller with 2 disks in a VM and 14 CPUs when virtual topology is disabled (for example, 1 core per socket). Here, the x-axis shows the timeline in seconds. The y-axis shows per-core thread scheduling of the worker threads in Dynamo.exe at the top, and interrupt service routines (ISR) and deferred procedure calls (DPC) filtered for the storage controller at the bottom. The two worker threads are mostly scheduled in the same CPU cores: core-10 for the blue-colored thread and core-11 or core-12 for the yellow-colored thread. ISR/DPC from the NVMe storage controller are scheduled in the corresponding CPU cores. The CPU caches benefit the thread execution because it stays in the same CPU.

Figure 7. CPU scheduler and ISRs and DPCs view in Media eXperience Analyzer without virtual topology

When virtual topology is enabled, all 14 cores belong to the same socket. As figure 8 shows, the threads are being scheduled in all cores in a round-robin fashion. The NVMe controller interrupts, and DPCs follow the same cores. As a thread moves to a new CPU within a short interval, it generates a lot of L1 and L2 cache misses and takes more CPU cycles to complete the execution.

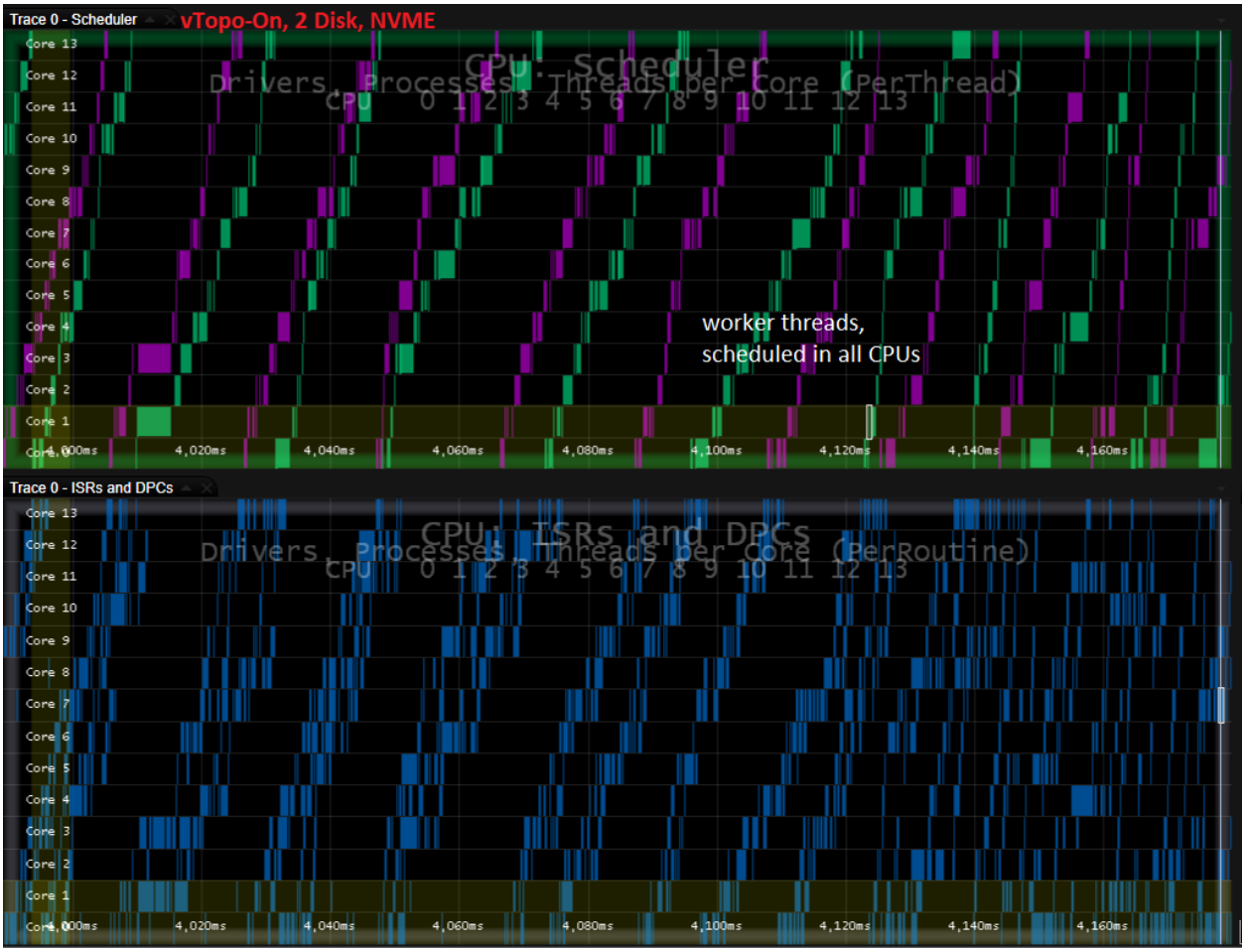


Figure 8. CPU scheduler and ISRs and DPCs view in Media eXperience Analyzer with virtual topology

When we launched the application with a specific CPU affinity (for example, `start /affinity 0x4 Iometer.exe` ...) we observed a performance improvement over the non-affinity case. However, this configuration set the process having affinity to the set of processors that were passed in the parameter, and the threads from the process were still free to migrate within the allowed CPU cores. To make an apples-to-apples comparison, we needed to have thread affinity, which required changing the application code.

Experiment with thread affinity to fixed CPU cores

We modified the Iometer tool so that it created worker threads to have affinity to specific CPU cores. We named this Iometer2. We collected data with virtual topology enabled and disabled. With Iometer2, we got a new baseline. We no longer observed consistent differences in the throughput (IOPS) and CPU usage (CPIO) metrics. Figures 9 and 10 show the data for the NVMe controller.

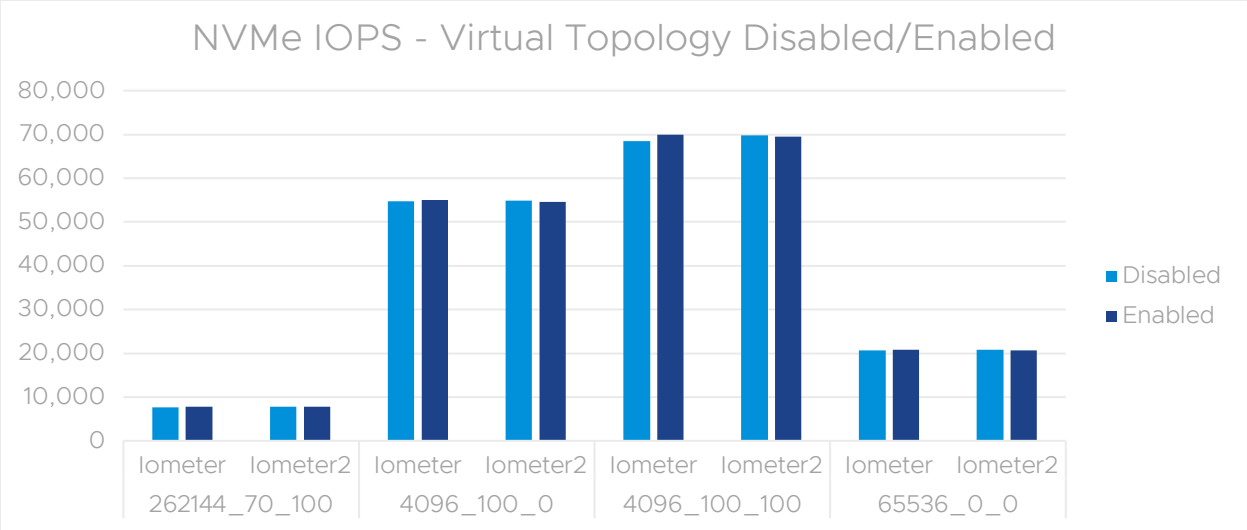


Figure 9. IOPS in Iometer2 (with thread-affinity) test with and without virtual topology

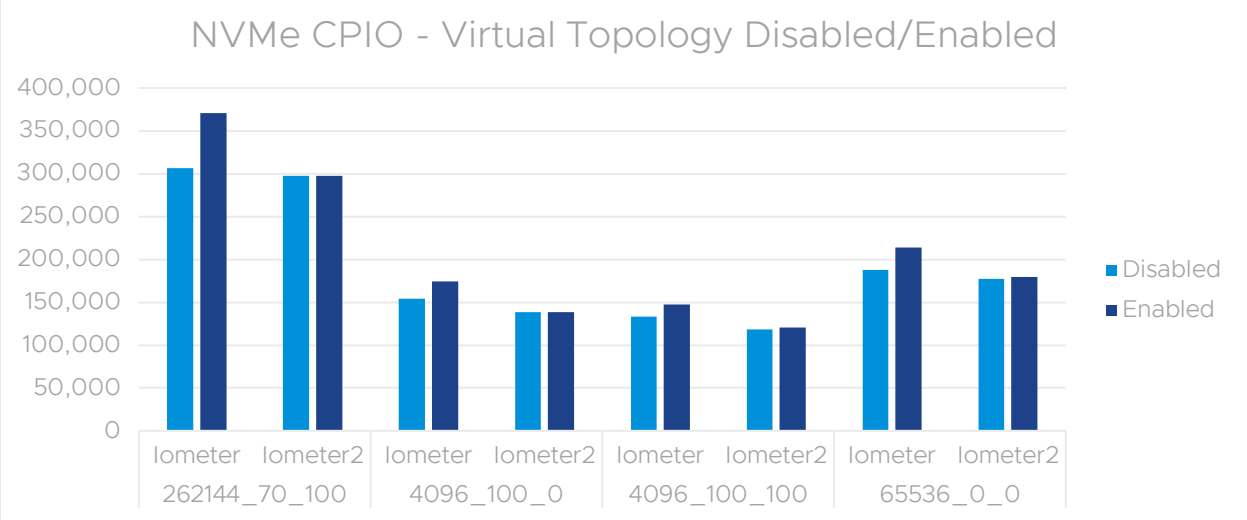


Figure 10. CPIO in Iometer2 (with thread-affinity) test with and without virtual topology

We concluded that virtual topology is not the root cause behind the regression in the tests. The guest scheduler contributed to the additional CPU cost, and the appropriate application changes mitigated this cost. This benchmark, however, does not reflect a real-life workload, so the regression due to the application's nature is not concerning.

The testbed was made up of the following:

- Server: Dell PowerEdge R930
- CPU: 4 Intel Xeon Processors E7-8880 v4 @2.2GHz with 22 physical cores
- Hyper-Threading (HT): Yes
- Memory: 1024GB
- Physical Disks: 3 non-RAID SSDs
- Guest Operating System: Windows Server 2022

Fio benchmark in Linux

Flexible IO Tester (Fio) [9] is a benchmarking and workload simulation tool for Linux/Unix. It's highly tunable and widely used for storage performance benchmarking. We used the tool with various configurations to simulate different workloads. For example, the following command was used for a sequential write test of a 64K block size on 8 virtual disks with a 10-minute duration.

```
fio -name=fio-test -ioengine=libaio -iodepth=4 -rw=write -bs=65536 -thread -direct=1
-numjobs=8 -group_reporting=1 -time_based -runtime=600
-filename=/dev/sdb:/dev/sdc:/dev/sdd:/dev/sde:/dev/sdf:/dev/sdg:/dev/sdh:/dev/sdi
-significant_figures=10
```

While I/O throughput remains the same, we see a 5.86% increase in CPU utilization.

Metric	Virtual Topology		%Diff
	Disabled	*Enabled*	
IOPS	12530	12553	0.18
CPIO	151278	160143	5.86

Table 3. IOPS and CPIO with and without virtual topology

We collected traces in the host using `esxtop` and Linux guest statistics using `vmstats`, `pidstat`, `mpstat`, and so on to understand the changes. Esxtop showed higher CPU and memory usage of the VM when virtual topology was enabled.

In the `numastat` output, we observed that the VM was allocating more memory (that is, higher `numa_hit`) on node-0. Vmstat also showed a higher memory cache usage. This should have had a positive impact. However, we saw higher context switches and more activity between vCPUs. In `/proc/interrupts`, we saw a much higher rate of rescheduling interrupts, which indicated that the driver was trying to distribute the load among the processors. In the `mpstat` output, we saw the BLOCK interrupt (soft IRQ of block devices) was scheduled evenly among the CPUs when virtual topology was disabled. But when virtual topology was enabled, all the soft IRQ of block devices were sent to one CPU, and this eventually resulted in a higher rescheduling of interrupts. This guest behavior resulted in higher CPU utilization with virtual topology turned on.

The testbed for these tests included the following:

- Server: Dell PowerEdge R740xd
- CPU: Intel Xeon Gold 5120 Processor @ 2.20GHz, 2 sockets, 28 cores total
- Memory: 128GB
- VM configuration: CentOS 7, 4 vCPUs, 4GB memory

Network Benchmark Tests

Netperf tests in Windows

Netperf [10] is a benchmarking tool that can be used to measure the performance of many different types of networking. It can be used for TCP and UPD packets.

Netperf TCP_RR (request-response) tests report round-trip latency and throughput between two systems. We used the following command line that uses small packets without any delay.

```
Netperf -l 60 -H DestinationIP -p port -t TCP_RR -v 2 -- -s 8K -S 8K -r 1,1 -m 1 -b 4
-D
```

With virtual topology, we saw the networking throughput degrade and latency increase, which brings it more in line with a multi-core, bare-metal performance of a similar configuration.

Setting	RoundTrip Latency usec/Transfer	Transfer Rate per Second
4 vCPU VM (1 core per socket)	122.32	40926.38
4 vCPU VM (4 cores per socket)	147	34115.58
Bare metal (4-CPU), HT off	144.63	34571.06

Table 4. Roundtrip latency and transfer rate of Netperf tests in Windows

With a setting of 1 core per socket, the worker thread and networking driver (`ndis.sys`) run in the same core (that is, core-2 in figure 11). When virtual topology is enabled, the worker thread mostly runs in three cores (cores 0, 1, 2) and skips the core where the networking driver's interrupt/DPCs are scheduled (core-3 in figure 12).

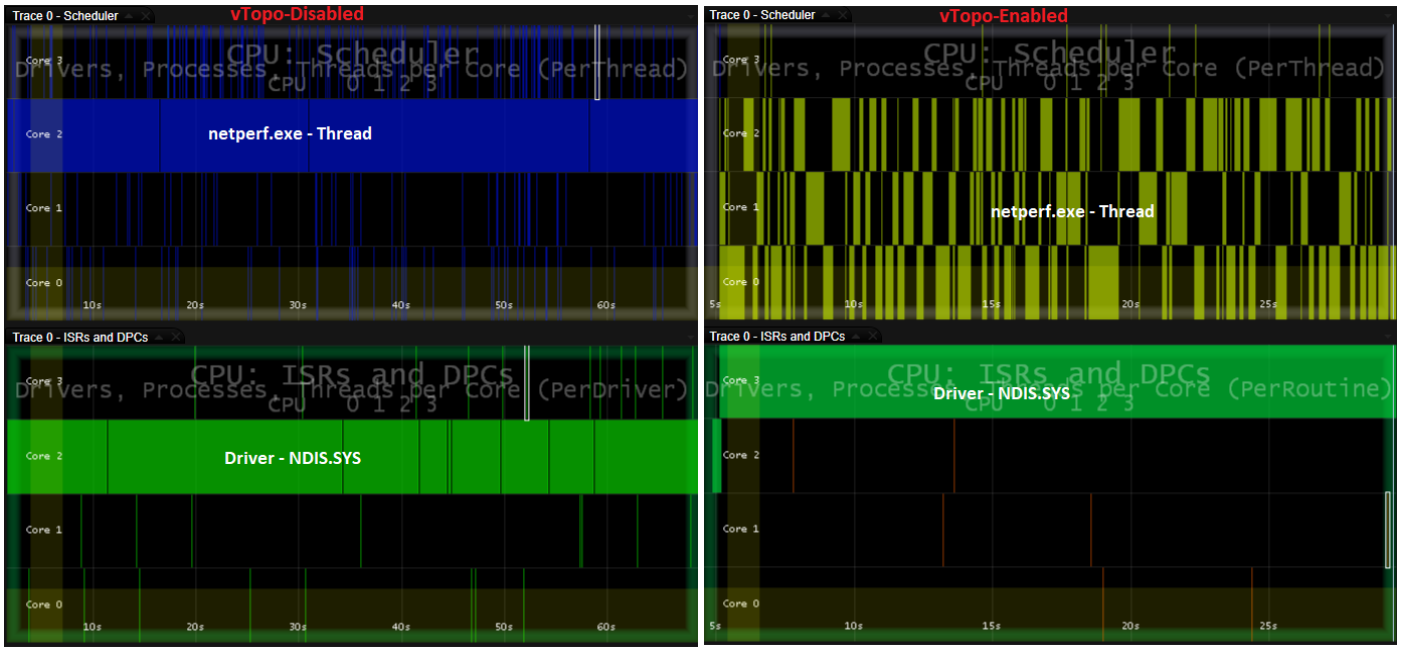


Figure 11. (left) CPU scheduler and ISRs and DPCs view in Media eXperience Analyzer without virtual topology during Netperf test. Figure 12. (right) CPU scheduler and ISRs and DPCs view in Media eXperience Analyzer with virtual topology

The scheduling pattern and driver behavior with virtual topology on is simililar to a bare-metal system running Windows Server 2022, as shown in Figure 13. The number of CPUs are constrained to 4 (as a boot parameter) and Hyper-Threading is turned off in the BIOS. We see that the network driver's interrupt and DPC routines are scheduled in one core (core-1). The worker thread of the application is mostly scheduled in another core (core-2) with occasional migration to other cores.

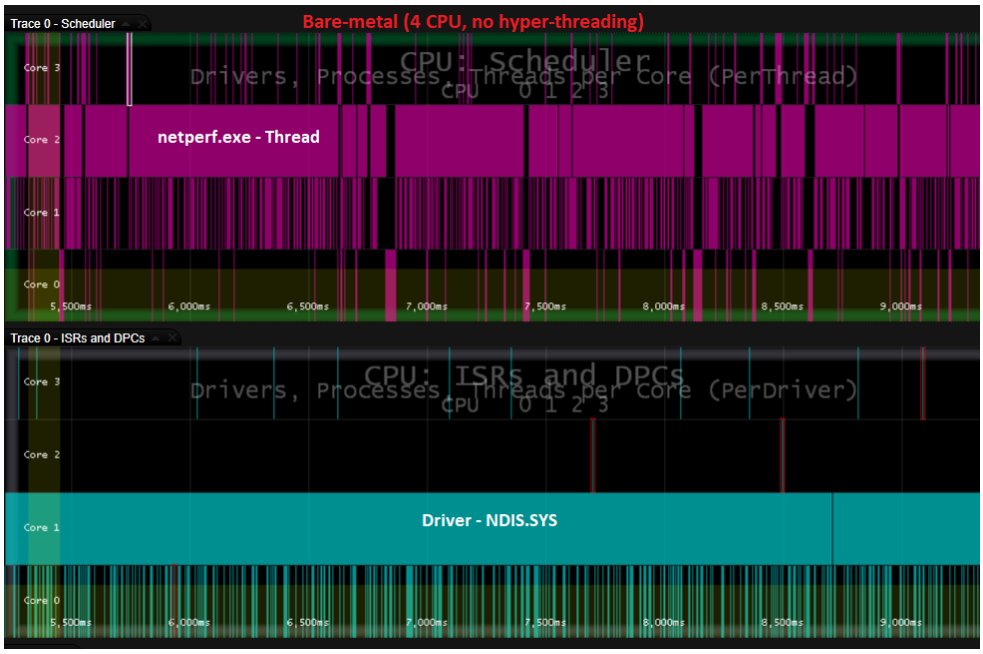


Figure 13. CPU scheduler and ISRs and DPCs view in Media eXperience Analyzer during Netperf test in Windows running on a bare-metal host

Netperf.exe has a single worker thread for processing the network traffic. When the VM has 1 core per socket, the Windows scheduler keeps the thread within the same socket, and we do not see thread migrations between cores. Execution of the thread benefits from the code locality and instruction cache of the processor. Moreover, the network driver's interrupt and DPC routines are scheduled within the same socket (that is, in the same core). The data packets also get the data caching advantages when they are copied from the driver to the process memory. Therefore, a VM with 1 core per socket provides lower latency and less CPU utilization than running on a bare-metal (4-CPU) or on a VM with 4 cores per socket setting. We recommend continuing to use the same setting via manual configuration to keep optimal performance under this benchmark condition.

The testbed included:

- Server: Dell PowerEdge R930
- CPU: 4 Intel Xeon Processors E7-8880 v4 @2.2GHz with 22 cores
- Hyper-Threading (HT): Yes
- Memory: 1024GB
- Disks: 3 SSD non-RAID physical disks
- Operating System: Windows Server 2022

Netperf tests in Linux

Among different tests using Netperf, we analyzed one that sends UDP traffic from a bare-metal client to a Linux VM. The send and receive socket buffer size was 256K in both client (which ran the netperf binary) and server (which ran the netserver binary). 256 bytes of the buffer were passed in during send/receive calls.

```
netperf -l 60 -H DestinationIP -p port -t UDP_STREAM -- -s 256K -S 256K -m 256 -M 256
-n 1
```

We saw a decrease in throughput as received messages per second dropped about 26% (table 5).

Metric	Virtual Topology		%Diff
	Disabled	*Enabled*	
Recv Msg per Second	352,777.5	259,852.25	26.34

Table 5. Comparison of virtual topology disabled and enabled using Netperf

We collected stats in the Linux VM which had 16 vCPUs. `vmstat` showed a slightly higher interrupt rate when virtual topology was enabled. `pidstat` showed that both user-level and kernel-level CPU utilization was higher. We did not see a major difference in the number of rescheduling interrupts, but the distribution of those was not the same. With virtual topology disabled, we saw an even distribution among all the cores. But when virtual topology was enabled, only a subset of all the cores was active with the rescheduling interrupts. The CPU utilization of the cores followed similar patterns. This scheduling difference in the guest operating system contributed to the regression of the scenario.

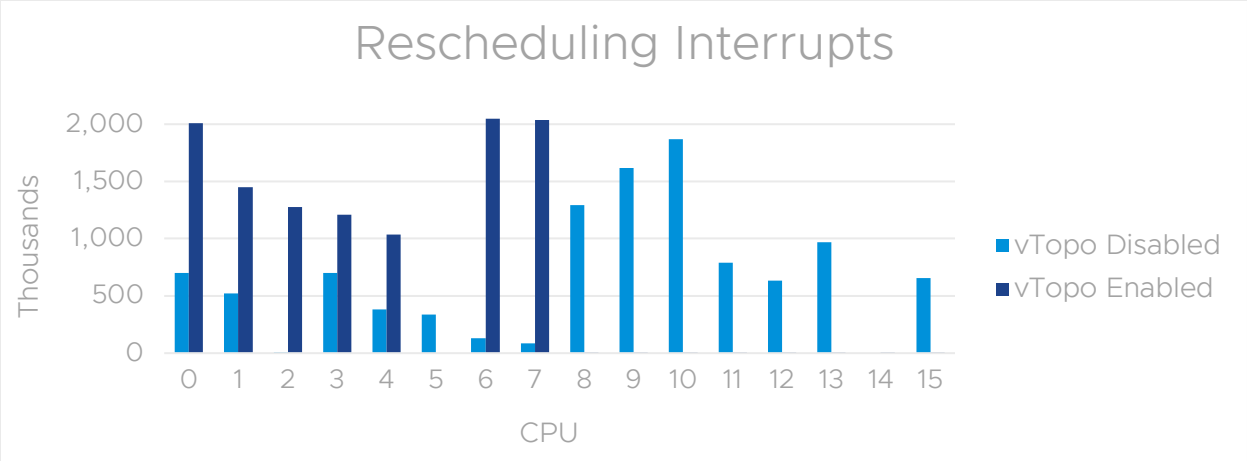


Figure 14. Rescheduling interrupts among CPUs—only a subset of the cores were active

The following components made up the testbed:

- Server: Dell PowerEdge R740xd
- CPU: 2 Intel Xeon Gold 5120 Processors @ 2.20GHz with 14 cores
- Hyper-Threading (HT): Yes
- Memory: 192GB
- Adaptor: Mellanox Technologies MT27700 Family (ConnectX-4)
- VM Configuration: 16 vCPU, 32GB memory

Conclusion

Virtual topology simplifies virtual machine settings and provides the optimal configuration to match the physical hardware. We have seen performance improvements in several workloads. We also noticed some microbenchmark workloads suffer degradation due to guest operating system behavior or application design choices. These microbenchmark degradations can be mitigated by either staying in a previous hardware version or manually setting cores per socket to 1. We expect that performance will be unchanged or improved using virtual topology for most typical customer workloads.

Appendix

At VMware, we use the following terminology:

- **CPU:** The CPU, or processor, is the component of a computer system that performs the tasks required for computer applications to run. The CPU is the primary element that performs computer functions. CPUs contain cores.
- **CPU Socket:** A CPU socket is a physical connector on a computer motherboard that connects to a single physical CPU. Some motherboards have multiple sockets and can connect multiple multicore processors (CPUs).
- **Core:** A core contains a unit containing an L1 cache and functional units needed to run applications. Cores can independently run applications or threads. One or more cores can exist on a single CPU.
- **Hyper-Threading (HT), Simultaneous Multithreading (SMT):** Processor technology that allows two logical cores (threads) to run on a single physical core.
- **Virtual NUMA (vNUMA):** vNUMA exposes non-uniform memory access (NUMA) topology to the guest operating systems, allowing NUMA-aware guest operating systems and applications to make the most efficient use of the underlying hardware's NUMA architecture.

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