



Evaluating Intel Virtualization Technology FlexMigration with Multi-generation Intel® Multi-core and Intel® Dual-core Xeon® Processors.

Executive Summary:

In today's data centers, live migration is a required technology for building an agile, dynamic data center based on server virtualization. It has not been possible, however, to perform successful live migration between servers based on different generations of processors, each with different instruction sets. This limited our ability to implement large resource pools, creating islands of servers and hindering the implementation of advanced data center capabilities.

Intel Virtualization Technology FlexMigration (Intel VT FlexMigration) assist and VMware's* Enhanced VMotion* are designed to overcome this limitation by enabling all servers to expose the same instruction set to applications, even if they are based on different processor generations from a single CPU supplier. In this case study we will showcase how these technologies allows enterprises to re-use and scale their existing resource pools by adding higher performing power efficient servers into the pool.

In this PoC, we created an enterprise reporting application workload representative of IT workloads. We then tested a variety of manual live migrations between host servers based on 3 generations of Intel® Core™ micro architecture with different instruction sets [Intel® microarchitecture, formerly codenamed Merom:SSE3, Intel® microarchitecture, formerly codenamed Penryn:SSE4.1, Intel® microarchitecture, formerly codenamed Nehalem:SSE4.2]. All migrations completed successfully without any failures in the workload.

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1 Proof of Concept [PoC] Overview

This PoC was conceived to showcase how Intel VT FlexMigration supports customers' hardware investment and helps future proof resource pools in a virtualized environment.

In this PoC, we created an enterprise reporting application workload representative of IT workloads. We then tested a variety of manual live migrations between host servers based on 3 generations of Intel® Core™ micro architecture with different instruction sets:

- A two-socket server based on Intel® Xeon® processor 5148 series with SSE3
- A two-socket server based on Intel® Xeon® processor X5365 series with SSE3
- A four-socket server based on Intel® Xeon® processor X7350 series with SSE3
- A two-socket server based on Intel® Xeon® processor X5450 series with SSE4.1
- A four-socket server based on Intel® Xeon® processor X7460 series with SSE4.1
- A two-socket server based on Intel® Xeon® processor X5570 series with SSE4.2

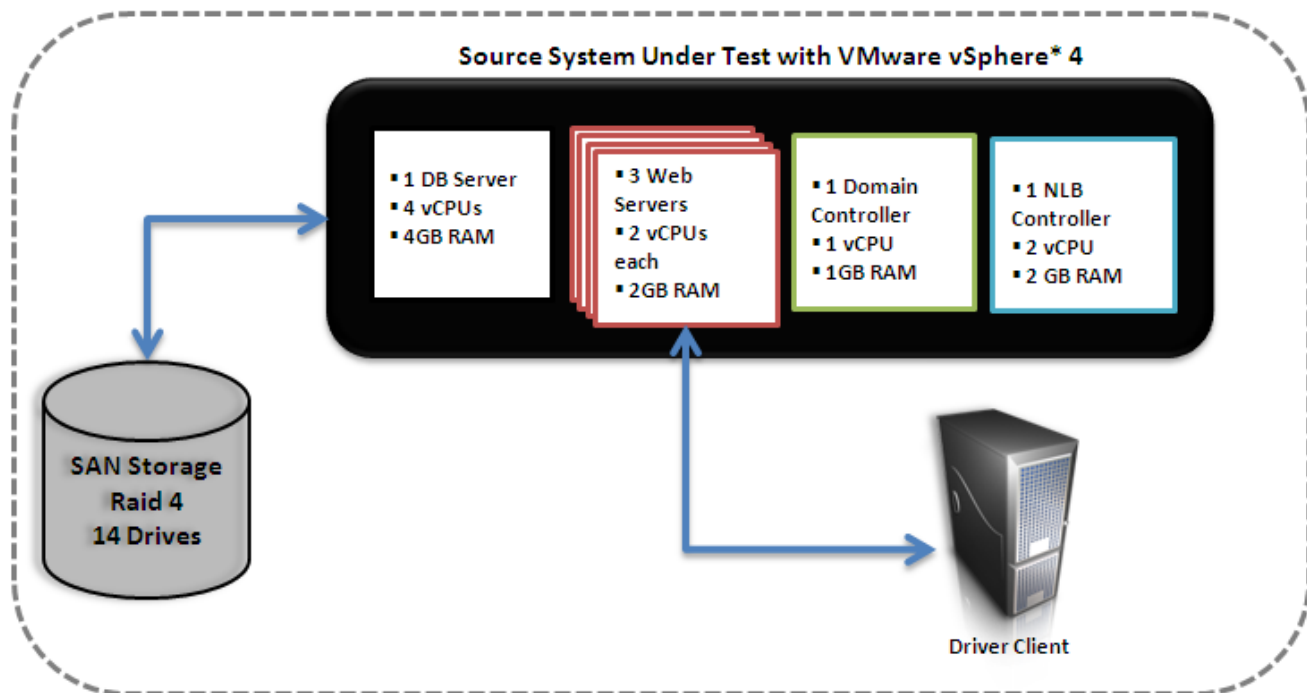
1.1 IT Business Reporting Overview

IT Business Reporting Application is a representative of a highly utilized set of enterprise reports served to a large number of users: financial reports, customer data, and so on. This workload has multiple aspects to not only provide compute workload, but also network workload. All web servers in this configuration are load balanced via Microsoft* network load balancing (NLB) with all requests generated and results recorded by an external physical test client. The workload also requires users to be authenticated and validated against a standard domain controller. This combination of Web traffic, computational workload, authentication and network load balancing provide an example of an Intel IT business reporting application based on Intel standard server builds and configurations.

Workload scalability is achieved via a variable number of concurrent users, which is configurable option in the Microsoft Application Test center tool that generates the load on the system. The primary metric of interest for this workload is requests/second and this is recorded for each individual test run undertaken. The workload that is generated is synthetic with no time delays between each request generated and sent to the workload.

The architecture and configuration of each component of the workload is described below. All the below VMs used the Virtual Machine 7 format that is supported starting with VMware vSphere* 4. Please refer to the appendix for details on the supported virtual machine formats.

Server	vCPUs	Memory (GB)	OS	Application
flexmigDC	1	1	Win 2K3, 64 bit	Domain Controller
flexsql1	4	4	Win 2K3, 64 bit	SQL Server 2005, Reporting Server
flexweb1	2	2	Win 2K3, 32 bit	NLB and SSRS controller
flexweb2	2	2	Win 2K3, 32 bit	Web Server
flexweb3	2	2	Win 2K3, 32 bit	Web Server
flexweb4	2	2	Win 2K3, 32 bit	Web Server

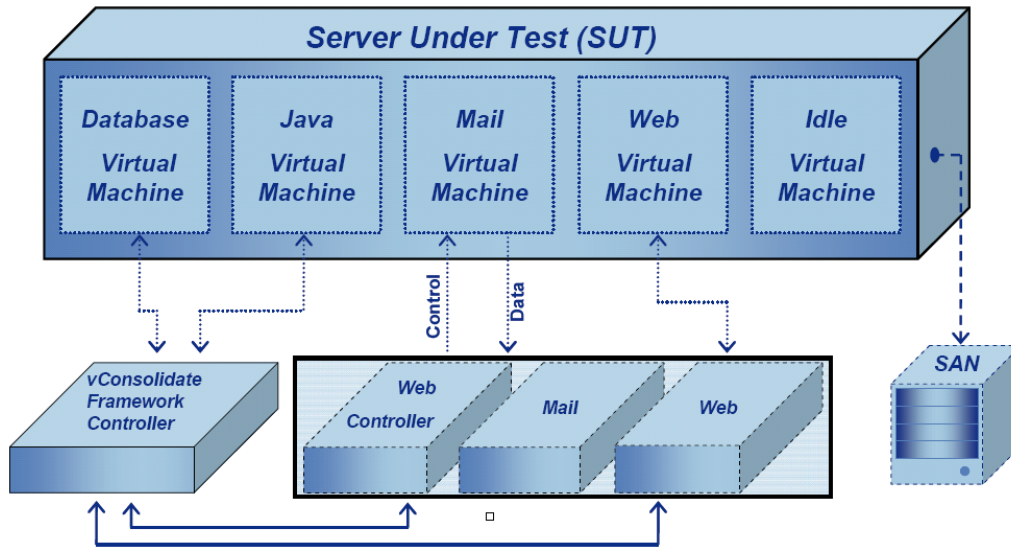


1.2 vConsolidate Workload Overview

The vConsolidate benchmark is a virtualization performance benchmark that simulates real server performance in a typical environment. vConsolidate is a consolidation benchmark comprised of four separate benchmarks that run simultaneously. There are benchmark components for database, web, Java* and mail. As this is targeted for a virtual environment, each component runs in its own separate Virtual Machine (VM), each with its own operating system. In addition to the four benchmark components there is a fifth VM not running any benchmark, which simulates an idle VM. These five virtual machines comprise a consolidation stack unit (CSU). To determine the full capabilities of a given system, more than one CSU may need to be added. The Figure below provides a high level architecture of the workload and the specific configurations of each of the virtual machines. Go to the [vConsolidate](#) link for detailed information.

All the below VMs in the vConsolidate workload used the Virtual Machine 4 format. Even though starting with VMware vSphere* 4, there is a support for the new Virtual Machine 7 format, the new version still supports the older version. Please refer to the appendix for further details.

Server	vCPUs	Memory (GB)	OS	Application
Web Server	2	1.5	Win 2K3, 32 bit	IIS
Mail Server	1	1.5	Win 2K3, 32 bit	Exchange
Database Server	2	1.5	Win 2K3, 64 bit	MS SQL
Java Application Server	2	2	Win 2K3, 64 bit	BEA JVM
Idle Server	1	0.4	Win 2K3, 32 bit	Web Server



1.3 POC Hardware

Below is the list of hardware that was used for testing the Intel VT FlexMigration feature.

Server	Operating System	Configuration
Intel Xeon 5148 [wdc1.lab.epi-ind.com]	VMware vSphere* 4	2S, Dual-core 2.33GHz, 16GB RAM, 1.33GHz FSB, 4MB L2 cache [65nm, Intel® microarchitecture, formerly codenamed Merom]
Intel Xeon X5365 [cltn1.lab.epi-ind.com]	VMware vSphere* 4	2S, Quad-core 3.0 GHz, 16GB RAM, 1.33GHz FSB, 8MB L2 cache [65nm, Intel® microarchitecture, formerly codenamed Merom]
Intel Xeon X7350 [tgtn1.lab.epi-ind.com]	VMware vSphere* 4	4S, Quad-core, 2.93 GHz, 32GB RAM, 1.06GHz FSB, 8MB L2 cache [65nm, Intel® microarchitecture, formerly codenamed Merom]
Intel Xeon X5450 [hptn1.lab.epi-ind.com]	VMware vSphere* 4	2S, Quad-core, 3.0GHz, 32GB RAM, 1.33GHz FSB, 12MB L2 cache [45nm, Intel® microarchitecture, formerly codenamed Penryn]
Intel Xeon X7460 [dntn1.lab.epi-ind.com]	VMware vSphere* 4	4S, Hex-core, 2.67GHz, 32GB RAM, 1.06GHz FSB, 16MB L2 cache [45nm, Intel® microarchitecture, formerly codenamed Penryn]
Intel Xeon X5570 [nhm1.lab.epi-ind.com]	VMware vSphere* 4	2S, Quad-core, 2.93GHz, 32GB RAM, 1.33GHz FSB, 12MB L2 cache [45nm, Intel® microarchitecture, formerly codenamed Nehalem]
Intel Xeon X5365	Windows 2003 R2, SP2 vCenter Build: 140742 vSphere Build: 140742	2S, Quad-core 3.0 GHz, 16GB RAM, 1.33GHz FSB, 8MB L2 cache [65nm, Intel® microarchitecture, formerly codenamed Merom]
Intel Xeon E5345	Windows 2003 R2, SP2 Microsoft Application Center Test* 1.0.536.0	2S, Quad-core 2.4GHz, 8GB RAM, 1.33GHz FSB, 8MB L2 cache [65nm, Intel® microarchitecture, formerly codenamed Merom]
Intel Core™2 Extreme QX6800	Windows 2003 R2, SP2 vConsolidate Client	1S, Quad-core, 2.93Ghz, 4GB RAM, 1.06GHz FSB, 8MB L2 cache [65nm, Intel® microarchitecture, formerly codenamed Merom]

2 POC Setup and Configuration

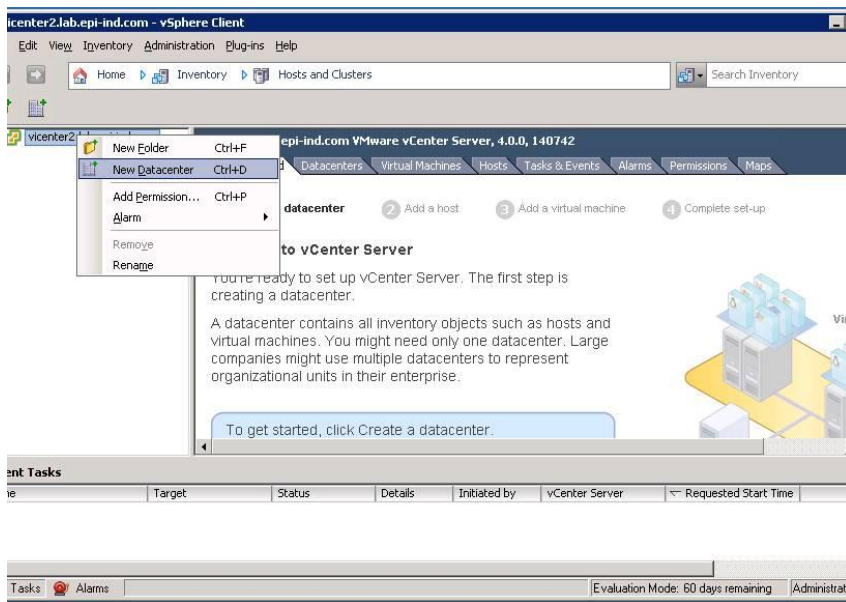
In this section we will go through the steps of creating a cluster and enabling the same to support Enhanced VMotion. Below are the pre-requisites that needs to be completed before proceeding further

- At least 2 hosts built with VMware vSphere* 4. With a single host we will not be able to test out the Intel VT FlexMigration functionality.
- VirtualCenter Server 4.0 installed on a system that meets the minimum requirements specified by VMware.
- Both hosts have “Execute Disable” and “Intel Virtualization Technology” bits in BIOS enabled. Note that enabling Intel Virtualization Technology bit requires an AC power cycle of the system.

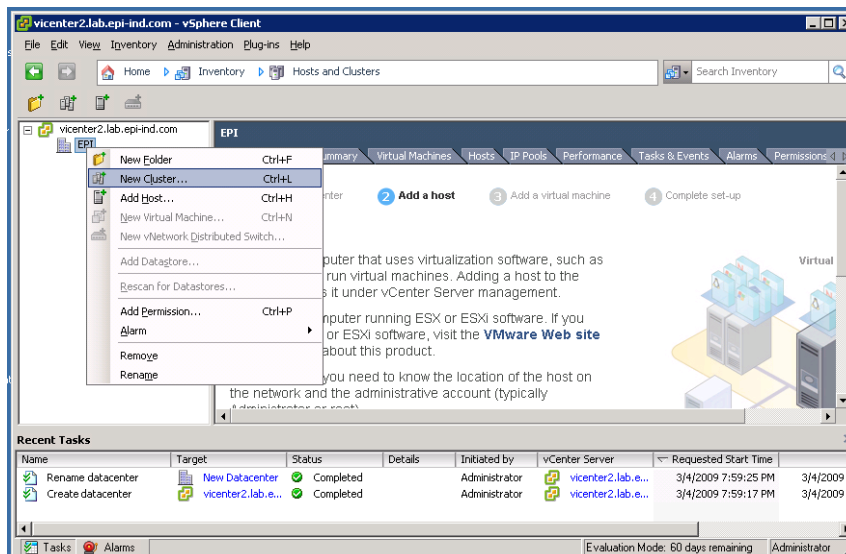
2.1 Cluster creation and enabling Enhanced VMotion

Below are the steps for the creation and configuration of the cluster:

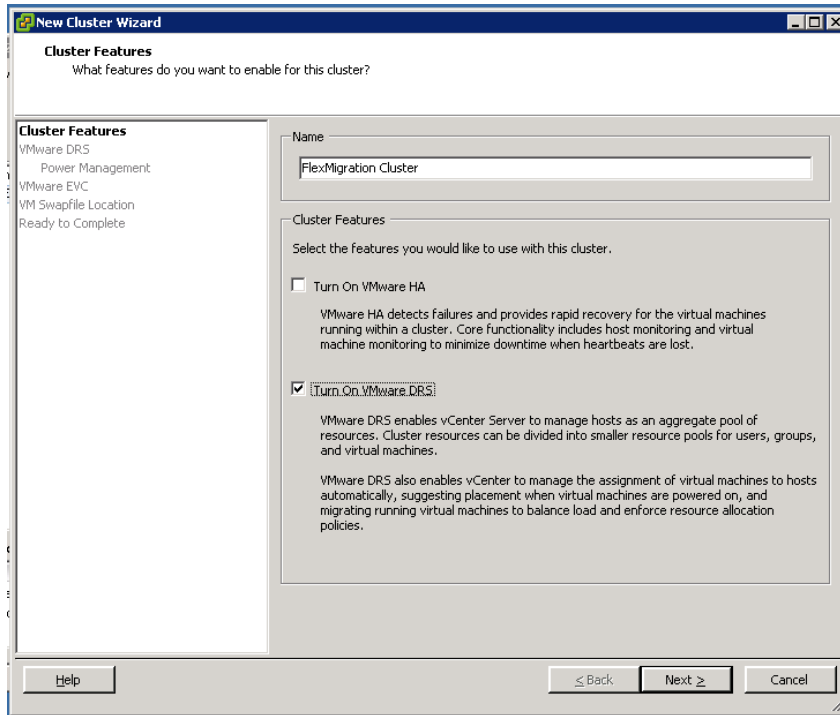
- After logging into the vSphere* client, first we need to create the high level Datacenter Node



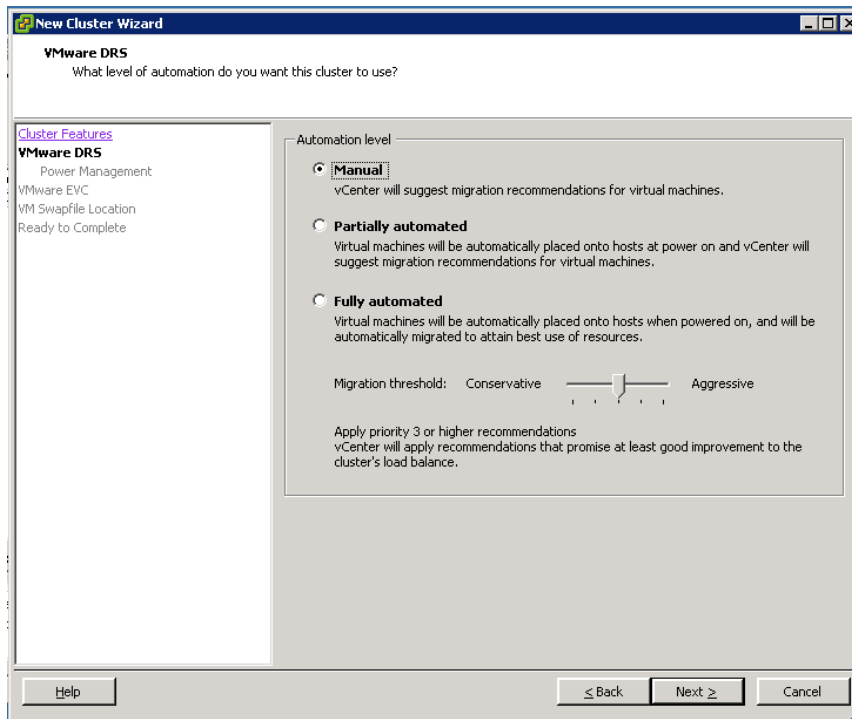
- After the creation of the Datacenter, the Cluster has to be created.



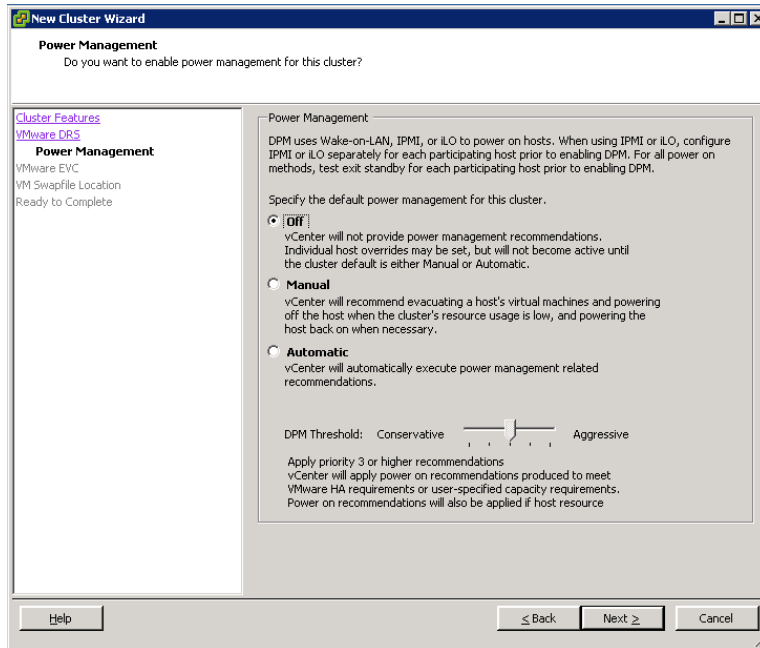
- Depending on the requirement, appropriate flags need to be enabled for HA and DRS. This setting can be changed at any point of time later by editing the settings of the Cluster. For this POC we will enable the DRS feature.



- Since the DRS feature was enabled, additional settings for the DRS need to be provided. Note that the number of live migrations depends on this setting. For example, if the mode is set to 'Fully Automated' and 'Aggressive', then depending on the workload, if there is lot of variation, you would see lot of migrations happening to balance the cluster.



- Dynamic Power Management [DPM] is a new feature in VMware vSphere* 4. This was introduced earlier in ESX 3.5 as a test feature. Depending on the requirement, enable or disable this option. Note that there is additional hardware required to enable this option, which is specified in the screen shot below.



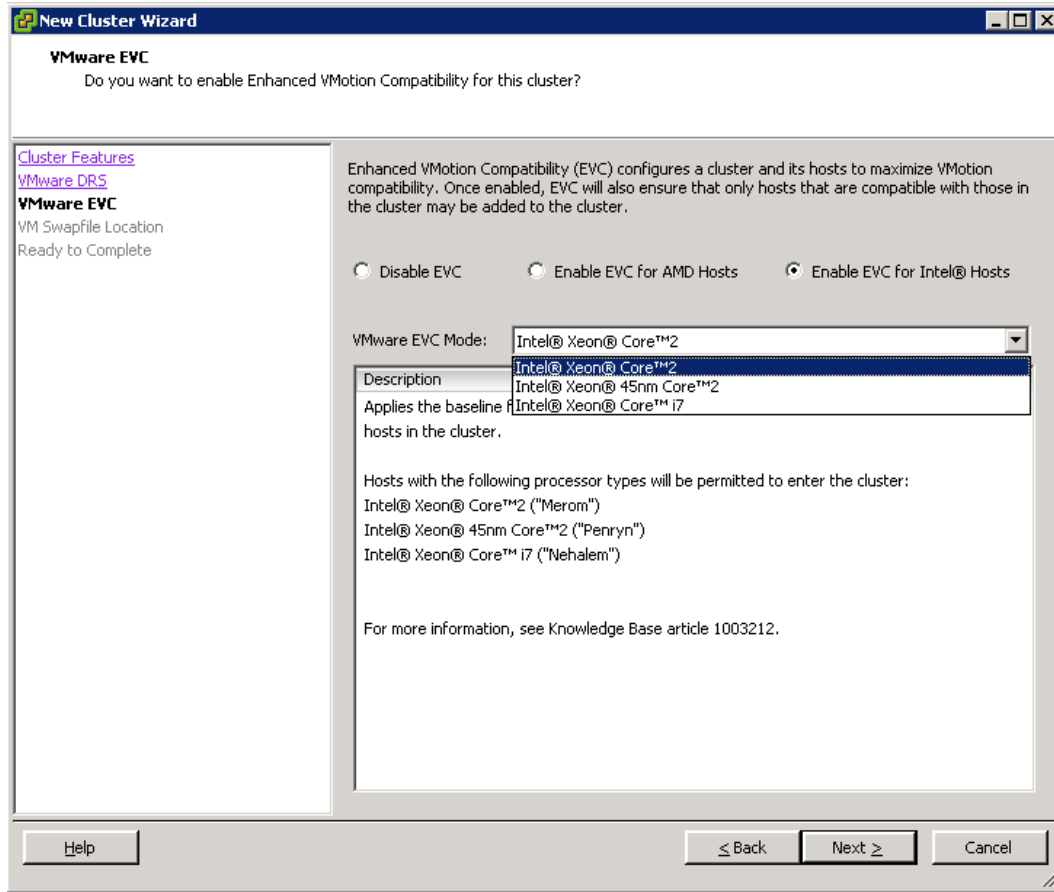
- Enhanced VMotion Compatibility [EVC] configuration setting depends on the different kinds of hardware the ESX hosts have that are need to be added into the cluster. Table below summarizes the settings based on the hardware of the ESX hosts present in the cluster. Additional details on each of the micro-architecture can be obtained by clicking on the hyperlink.

Intel® microarchitecture	EVC Setting for Cluster	Example
Intel® microarchitecture, formerly codenamed Merom + Intel® microarchitecture, formerly codenamed Penryn + Intel® microarchitecture, formerly codenamed Nehalem	Intel® Xeon® Core 2	X5365, X5450 & X5570
Intel® microarchitecture, formerly codenamed Penryn + Intel® microarchitecture, formerly codenamed Nehalem	Intel® Xeon® 45nm Core 2	X5450, X7460 & X5570
Intel® microarchitecture, formerly codenamed Nehalem	Intel® Xeon® Core i7	X5570

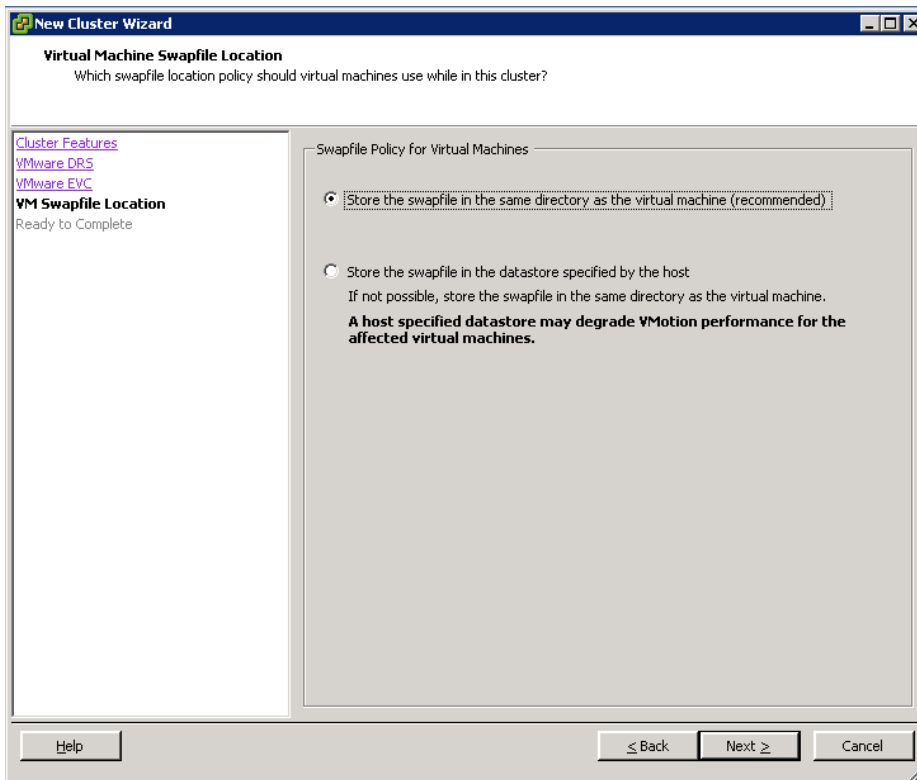
Note: If all the servers in the cluster belong to the Intel® microarchitecture, formerly codenamed Nehalem family, and the EVC setting is set to “Intel® Xeon® Core 2”, then the applications running on the server within the virtual machines will not be able to utilize the new instructions present in the Intel® microarchitecture, formerly codenamed Nehalem processors. Please see the FAQ section in the document to understand the implications of changing this setting.

Below is the high level summary of the instructions present in these families of processors.

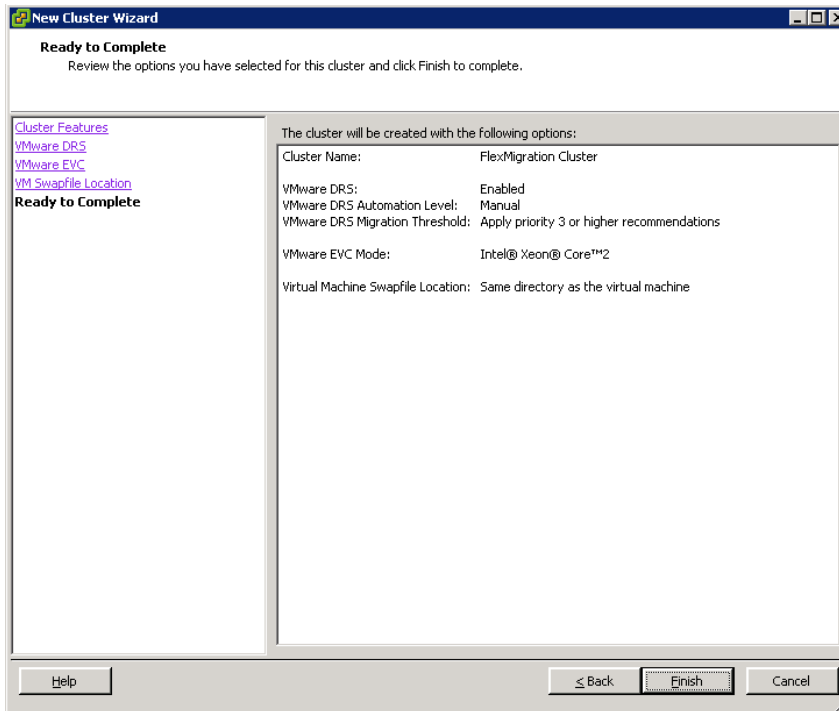
Intel® microarchitecture	Instruction Set
Intel® microarchitecture, formerly codenamed Merom	Baseline that includes x87, SSE, SSE2, SSE3, SSSE3, MMX etc.
Intel® microarchitecture, formerly codenamed Penryn	Baseline + SSE4.1 [40+ media/video instructions]
Intel® microarchitecture, formerly codenamed Nehalem	Baseline + SSE4.2 [7 instructions (POPCNT, CRC32, PCMPGTQ, STTNI)]



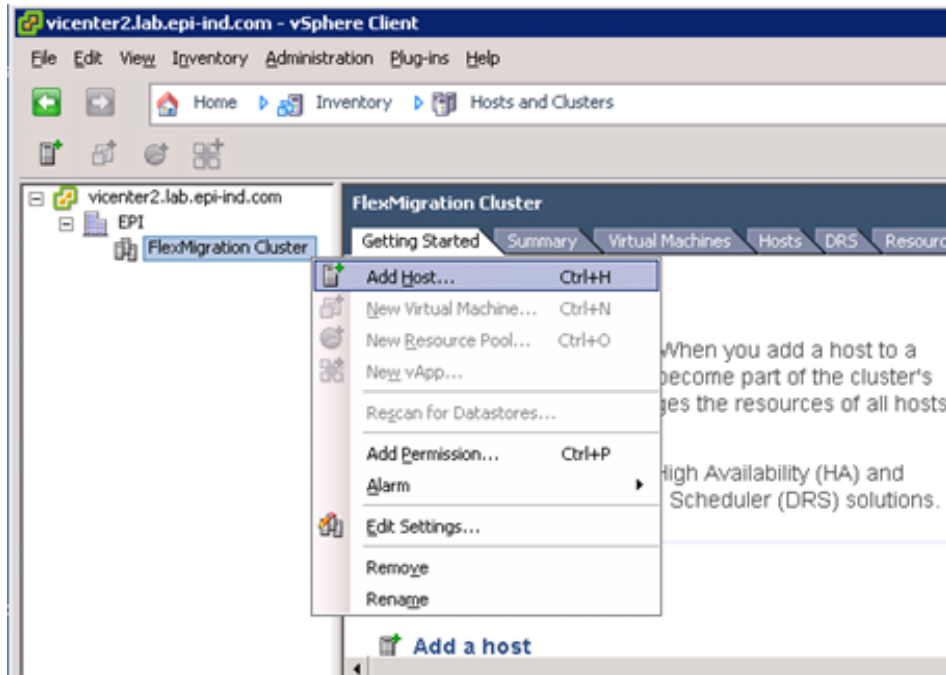
- For optimal performance keep the recommended option of storing the swap file in the same directory as the virtual machine.



- Ensure all the settings are correct and complete the creation of the cluster.

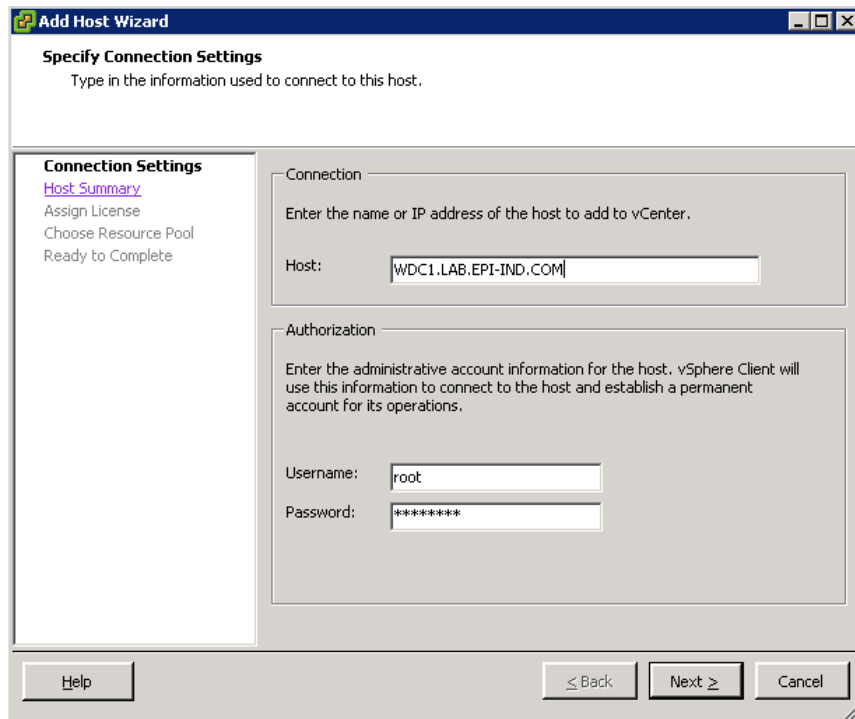


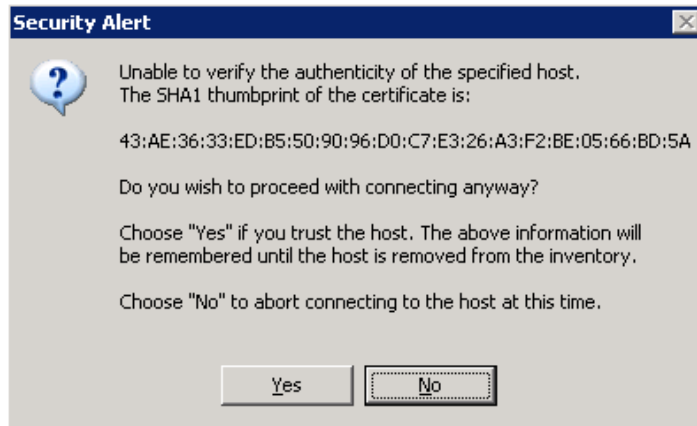
- After the cluster has been created, we can start adding hosts into the cluster. If the hosts have already been added to the Datacenter directly, they need to be moved into the cluster. But make sure all the VMs in the hosts are shut down and the BIOS settings mentioned at the start of the section are enabled.



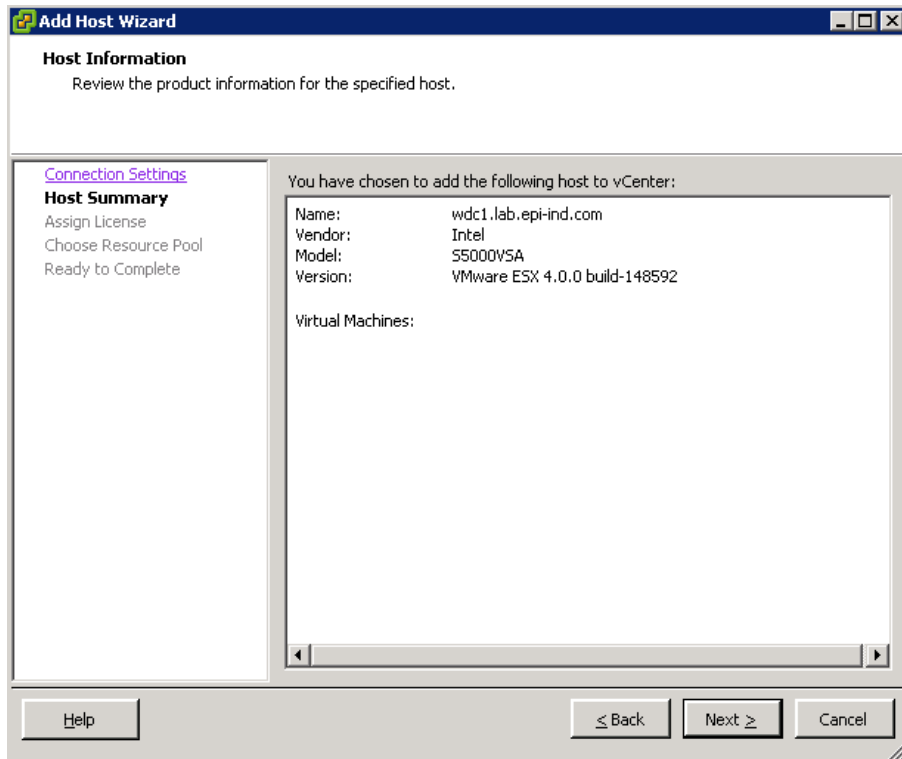
- Specify the connection string for the host, which can either be an IP address or a FQDN. If there are any conditions that are not met, like BIOS changes, appropriate errors/warnings would be generated.

If the host is being added to the cluster for the first time, an alert to confirm the authenticity of the server is displayed.

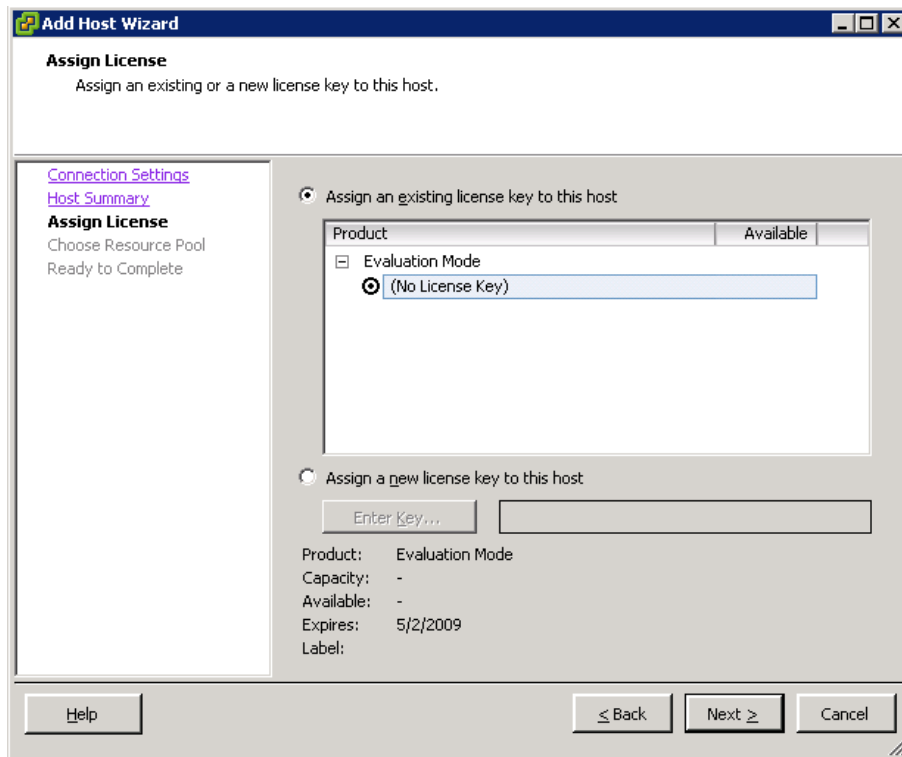




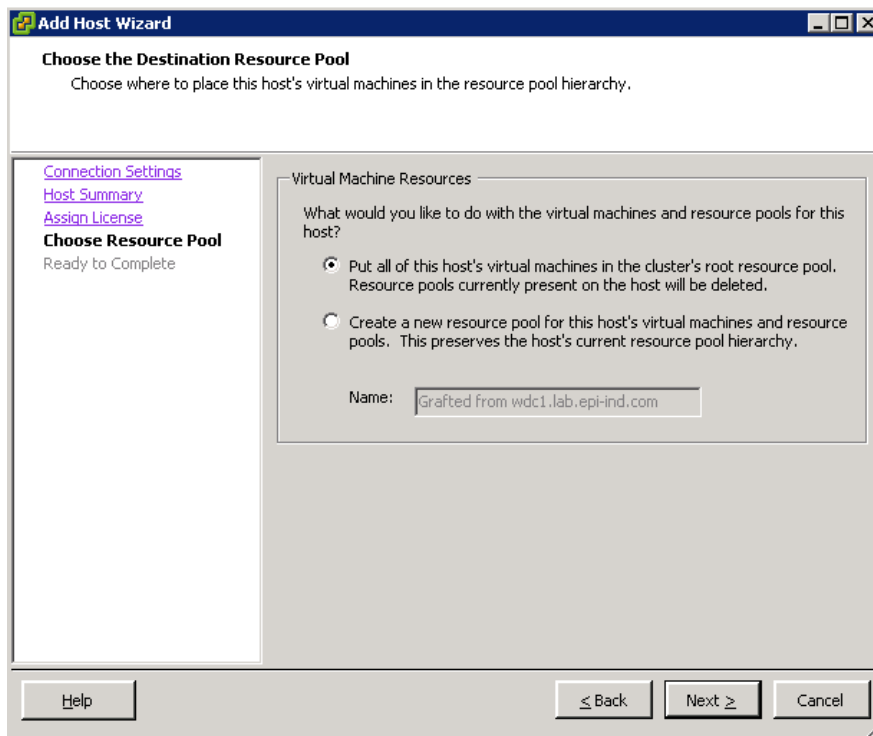
- Confirm the host creation settings and go the next screen.

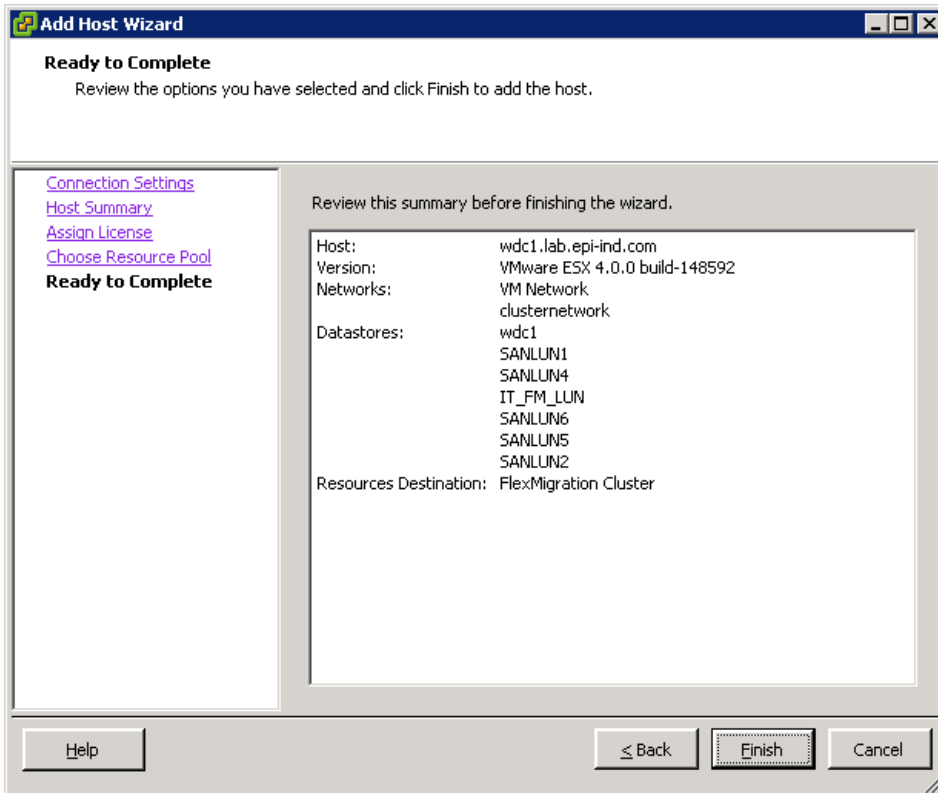


- Enter the license information if you have or continue with the next step for using the host under the evaluation mode



- Based on the requirements choose the Resource Pool configuration and complete the final step of the host creation. Repeat the steps for adding additional hosts into the cluster.





3 Results

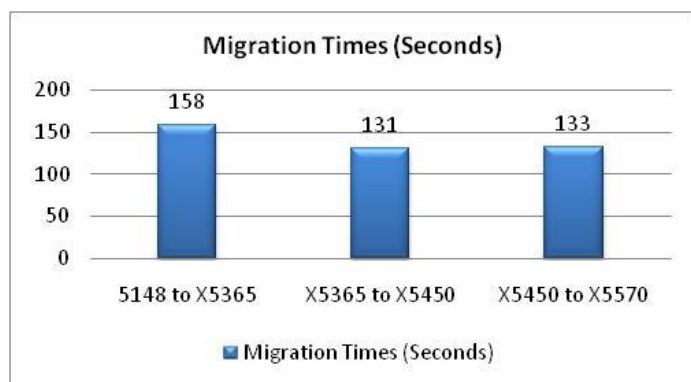
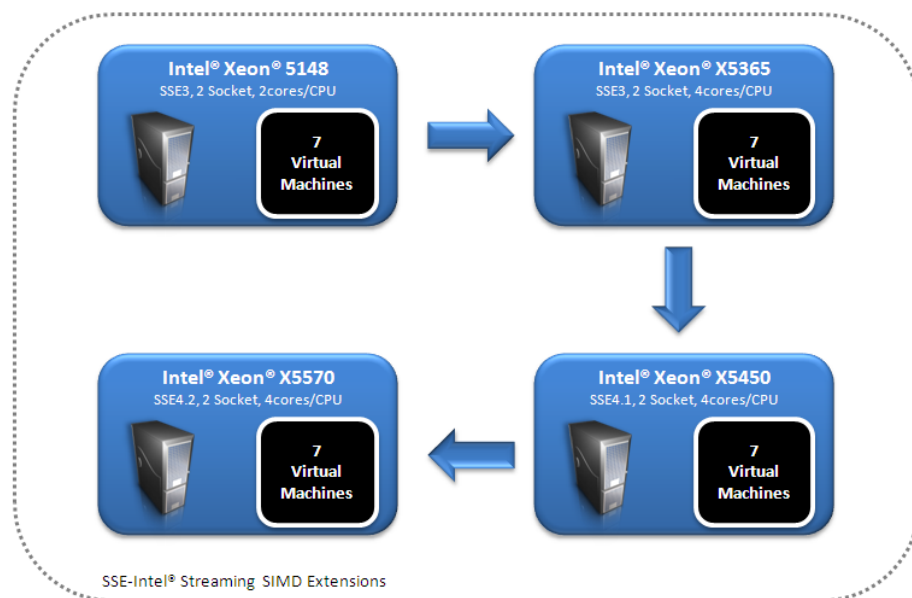
We designed our PoC to test a wide variety of configurations and migration scenarios representative of our production IT environment:

- Intel IT standard 64-bit and 32-bit Microsoft Windows* builds were used.
- VMs were virtualized servers based on IT-standard configurations for database servers, reporting services, network load balancing, and Web servers.
- We tested heavily loaded 32-bit and 64-bit VMs.
- We used manual and automated migration modes across two different platform architectures (two-socket and four-socket) and three processor generations [Intel® microarchitecture, formerly codenamed Merom, Intel® microarchitecture, formerly codenamed Penryn & Intel® microarchitecture, formerly codenamed Nehalem].

3.1 Test Case # 1: Manual Migration of VMs between DP systems

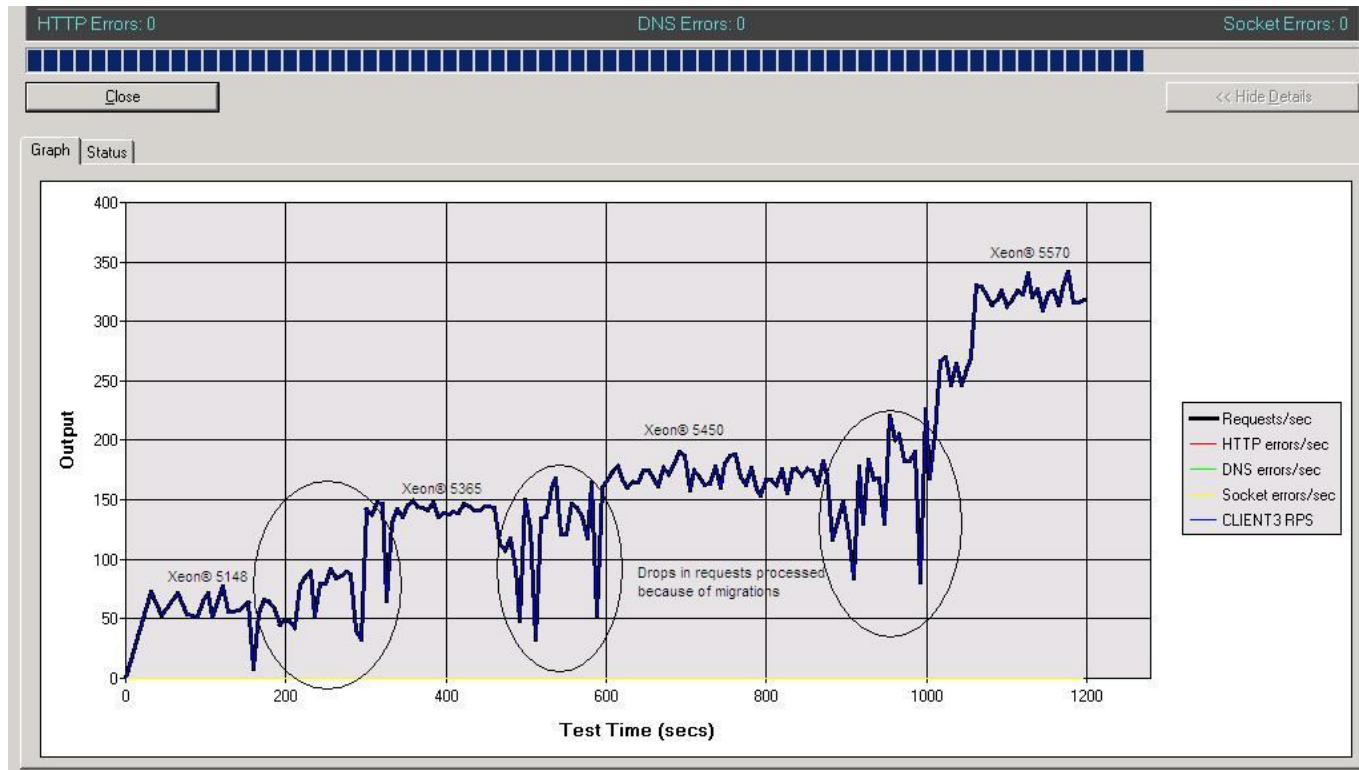
In this test case, we started the IT Business reporting workload (7 VMs) on a system using an Intel Xeon processor 5148 series. Using the Microsoft Application Test center, a load of 14 concurrent users was generated.

As shown in the figure below, we started the workload on the system using an Intel Xeon processor 5148 series. The workload was run on the system for about 3-4 minutes before migrating manually to the next server. All the migrations completed successfully without any errors in the workload.



The Microsoft Application Test center screenshot below captures the performance of the workload as we manually move the VMs from older generation servers to the later generation ones. The tool plots Requests/second that was processed by each of the servers.

Note: *Even though there are drops in the requests that were processed during the actual migrations, there are NO errors generated.*



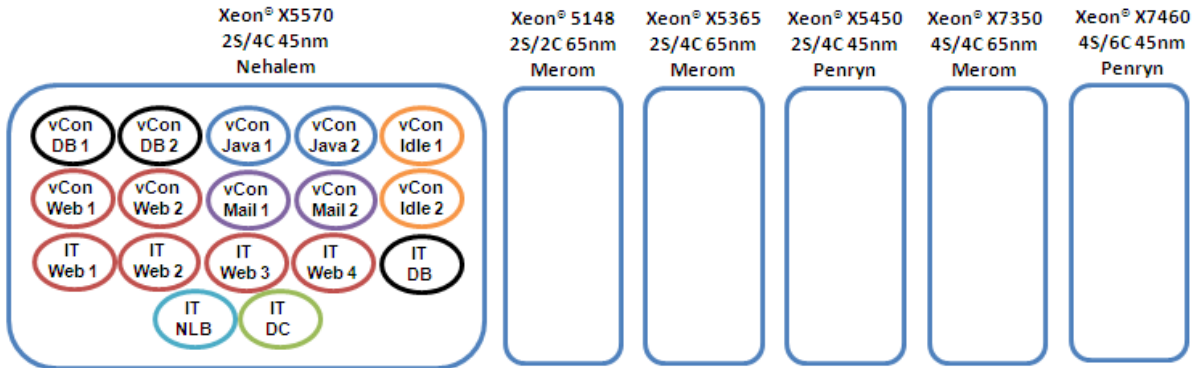
3.2 Test Case #2: Migrations using DRS from Intel Xeon Processor X5550 series System

For this test, we added systems using a multi-socket Intel Xeon processor X7350 series and Intel Xeon processor X7460 series into the cluster to showcase that Intel VT FlexMigration works across 2-socket (DP) and 4-socket (MP) systems. Along with the IT Business Reporting workload, we added additional workload of vConsolidate benchmark application consisting of 10 VMs.

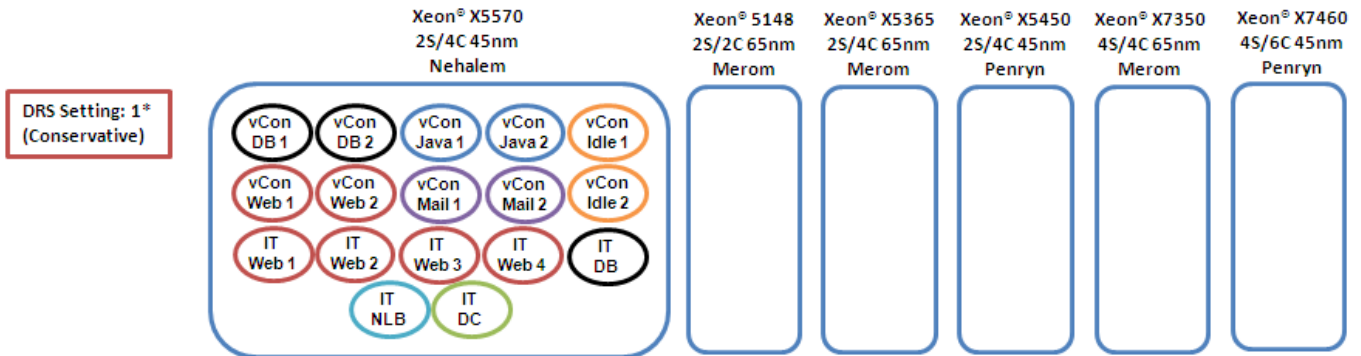
The focus of this test is to showcase that virtual machines could be migrated from a system using an Intel Xeon processor X5550 series to various other DP/MP systems across generations. Also this test showcases how DRS feature of ESX handles the migrations depending on the configuration. **Note:** Higher DRS setting is not indicative of a better performance. Rather it tries to create a more load balanced cluster. Optimal setting of DRS has to be evaluated for the individual workloads.

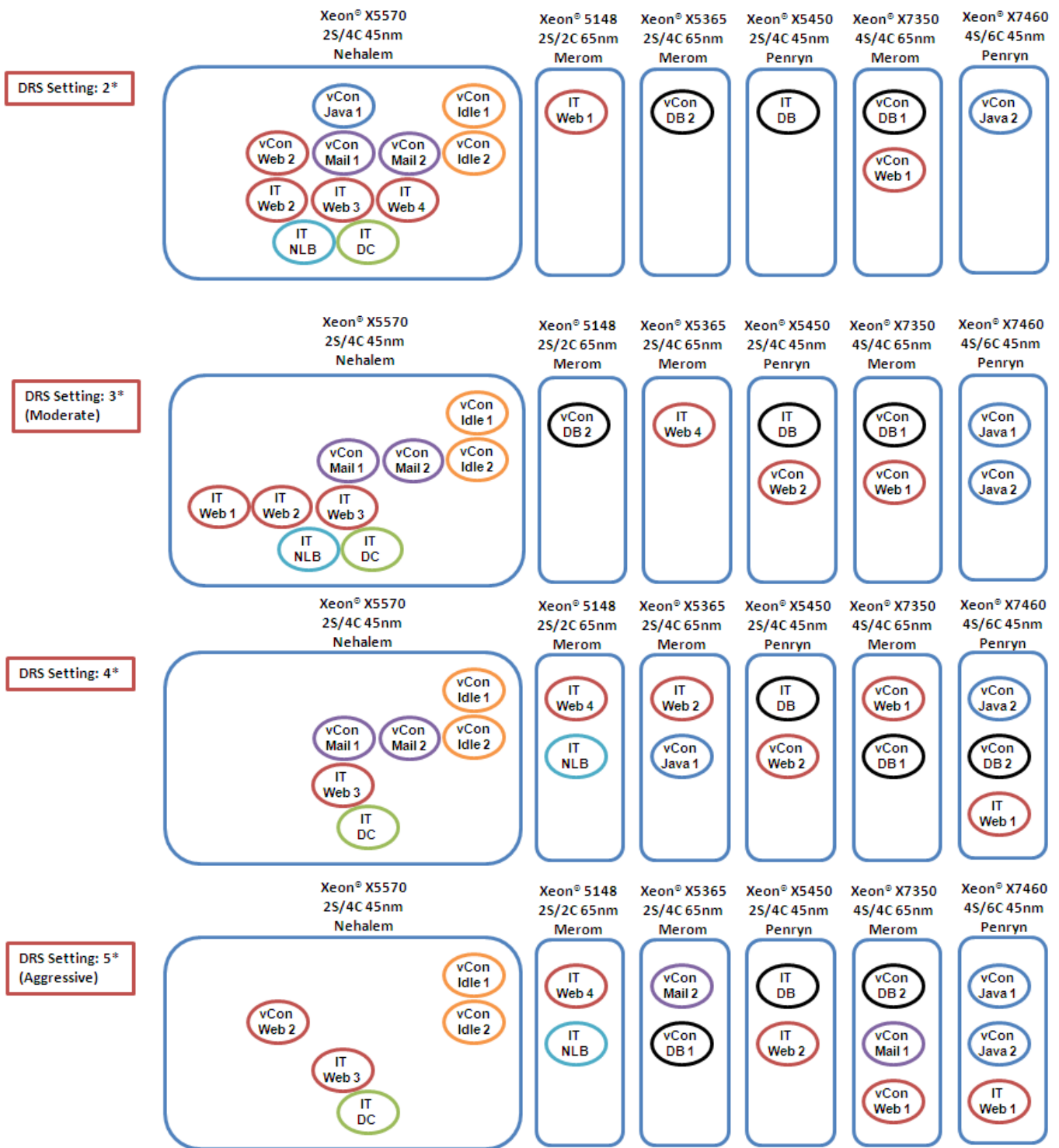
The diagrams below indicate the VM migrations for the various different DRS settings of the cluster. As we move to more aggressive setting, the distribution of VMs across the various DP/MP hosts is more uniform.

▪ **Before Enhanced VMotion***

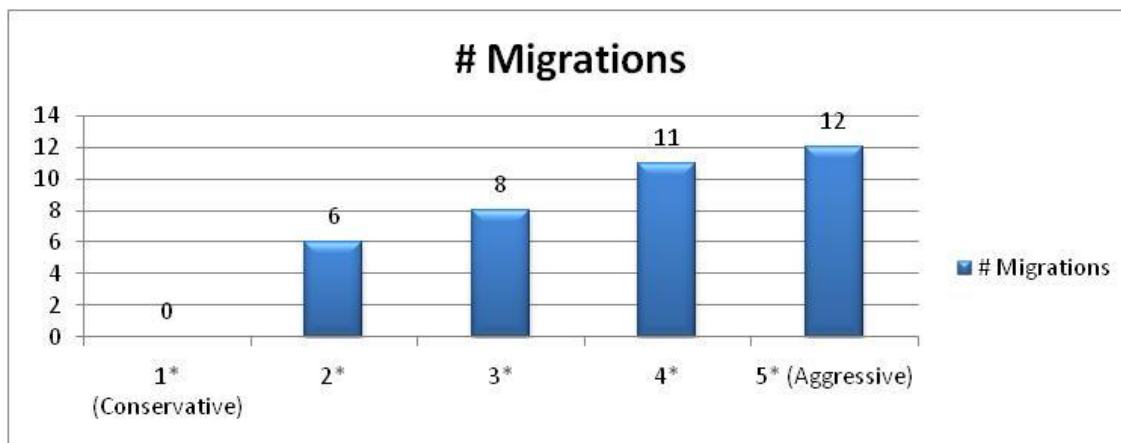


▪ **After Enhanced VMotion***





In this case we tested the DRS functionality with various different settings of the “Full Automation” level. The graph below shows the number of migrations based on the settings of DRS. For all the cases both the IT workload and vConsolidate workload were started on the server using an Intel Xeon processor X5570 series. The workloads executed successfully without any error.

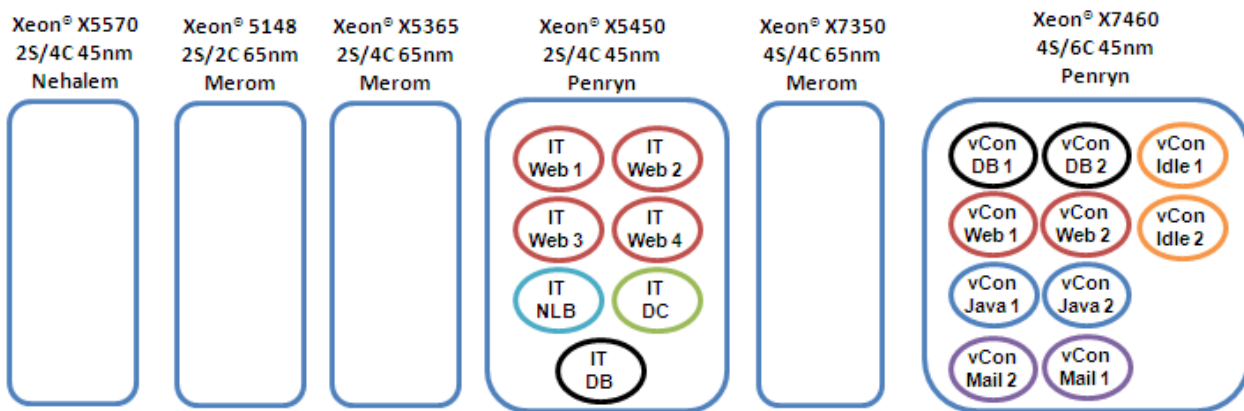


3.3 Test Case 3: Migrations using DRS to Systems using Intel Xeon processor X5550 series

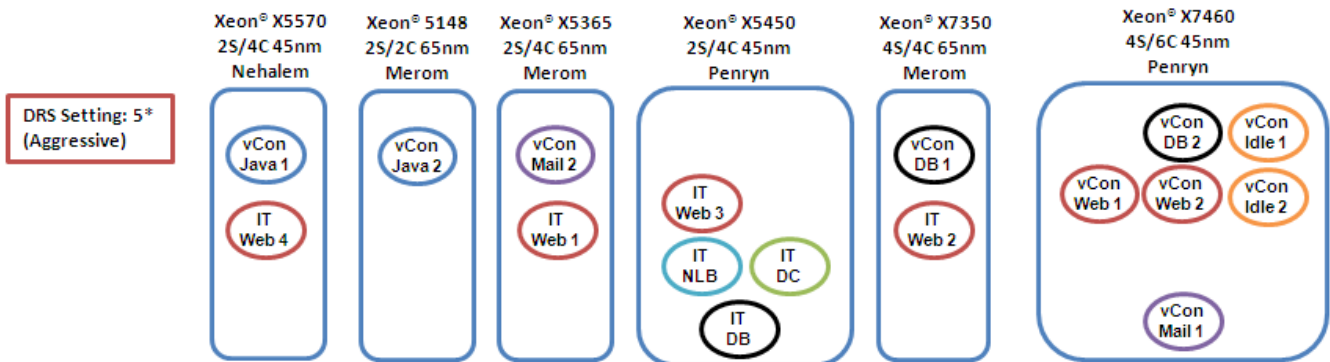
The focus of this test case is to show that VMs could be migrated from older generation DP/MP systems to systems using the latest generation Intel Xeon processor X5550 series. In this scenario, all the 7 VMs of the IT workload were started on a server using the 2-socket Intel Xeon processor X5450 series, and the vConsolidate benchmark workload was started on a server using the 4-socket Intel Xeon processor 7460 series.

Note: As mentioned earlier, more aggressive DRS setting is not indicative of a better performance. Rather it tries to create a more load balanced cluster. Optimal setting of DRS has to be evaluated for the individual workloads. In this test case the aggressive setting (5*) was used to showcase higher numbers of VM movement to all the different hosts in the cluster.

▪ **Before Enhanced VMotion***



▪ **After Enhanced VMotion***



4 Key Learnings

4.1 Intel VT FlexMigration Performance

Intel VT FlexMigration assist along with VMware’s Enhanced VMotion is a robust solution and performed flawlessly within the cluster consisting of 3 different generations of Intel’s DP/MP systems. The multi faceted IT business reporting workload and the virtualization benchmarking vConsolidate workload executed successfully without any errors providing scalable and consistent performance.

The above technologies allow enterprises to re-use and scale their existing resource pools by adding higher performing, power efficient, latest generation servers into the pool. Intel VT FlexMigration helps provide investment protection and future proofing of resource pools.

4.2 FAQs

- *What are the differences in instruction sets from Intel® microarchitecture, formerly codenamed Merom to Intel® microarchitecture, formerly codenamed Penryn to Intel® microarchitecture, formerly codenamed Nehalem?*

Below table summarizes the instruction support in the above micro-architectures. For additional details on the instructions please click on the links.

Intel® microarchitecture	Instruction Set
Intel® microarchitecture, formerly codenamed Merom	Baseline that includes x87, SSE, SSE2, SSE3, SSSE3, MMX etc.
Intel® microarchitecture, formerly codenamed Penryn	Baseline + SSE4.1 [40+ media/video instructions]
Intel® microarchitecture, formerly codenamed Nehalem	Baseline + SSE4.2 [7 instructions (POPCNT, CRC32, PCMPGTQ, STTNI)]

- *What are the requirements from the hardware perspective to enable Intel VT FlexMigration and Enhanced VMotion?*
 - Hosts should have virtualization supported Intel Xeon processors.
 - “Intel® Virtualization Technology FlexMigration” and “Execute Disable Bit” should be enabled in the BIOS.
- *What are the requirements to have hosts having ESX 3.5 U2 or higher and VMware vSphere* 4 in the same cluster?*

Hosts having the above ESX versions can co-exist in the same cluster without any issues. One thing to keep in mind is that VMs which are built using Virtual machine version 7, which only the VMware vSphere* 4 supports, cannot be migrated to earlier versions of ESX. This will limit the VMs ability to migrate to any host in the cluster, which in turn might unbalance the cluster.

Note: Hosts having ESX 3.5 U1 or below does not support Intel VT FlexMigration.

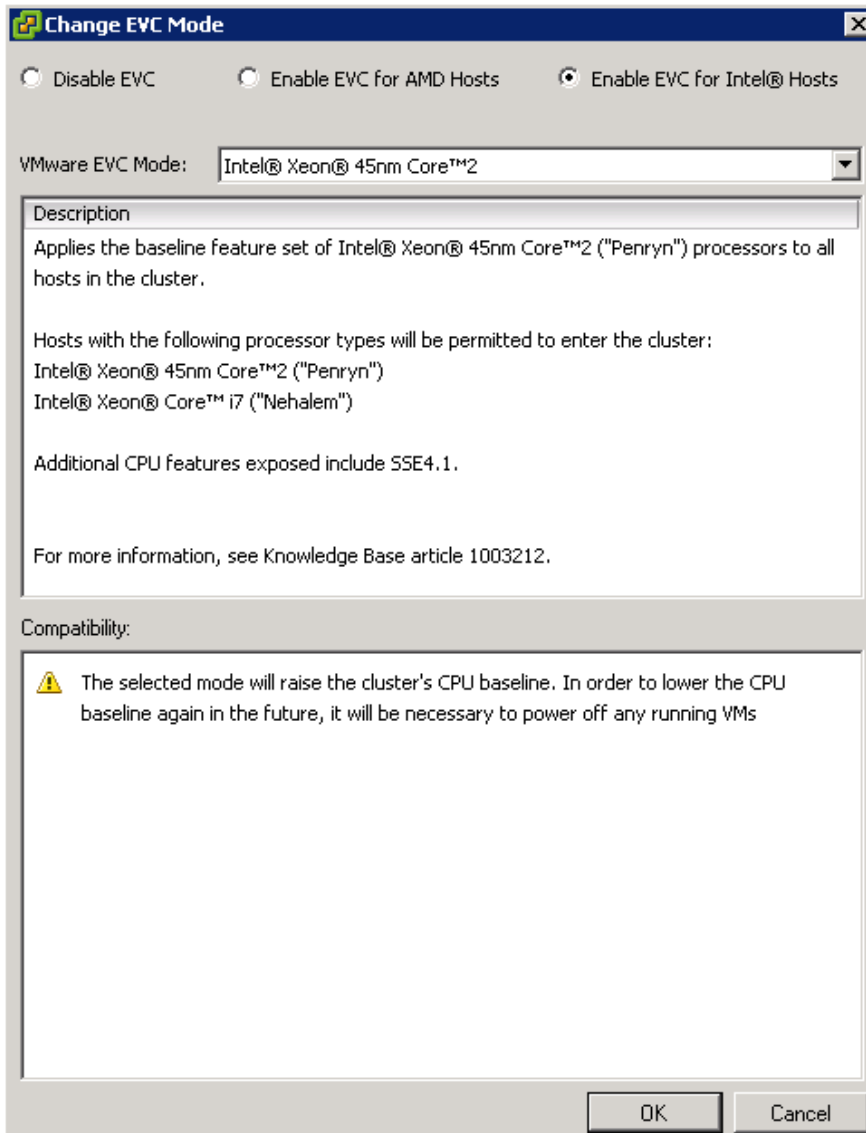
- Can I add a new host into a cluster that is already EVC enabled?

Yes, an ESX host can be added into a cluster that is already enabled. The only constraint is that either the VMs should be migrated out of the host or shutdown before it is added. You also need to ensure that the proper BIOS settings are updated as mentioned earlier.

- *What happens when I retire the last box of the Intel® microarchitecture, formerly codenamed Merom generation from the EVC pool? Do I have to reboot all of the VMs to use the Intel® microarchitecture, formerly codenamed Penryn instruction set or do they somehow automatically know?*

No reboot is required. All you need to do is update the cluster settings for it to use the Intel® microarchitecture, formerly codenamed Penryn instruction set as the base line. Having said that it really depends on the application as to whether it can see this change dynamically or not even though ESX allows it.

But if you are trying to add an ESX host that belongs to the Intel® microarchitecture, formerly codenamed Merom generation when all the existing ESX hosts belong to the Intel® microarchitecture, formerly codenamed Penryn family, then in order to lower the cluster settings to use Intel® microarchitecture, formerly codenamed Merom instruction set, a reboot of all the VMs are required. See the screen shot below that mentions this warning.



5 Summary

Intel VT FlexMigration is designed to enable seamless migrations among current and future Intel processor-based servers, even though newer systems may include enhanced instruction sets. With this technology, hypervisors can establish a consistent set of instructions across all servers in the migration pool, enabling seamless migration of workloads. The result is a more flexible and unified pool of server resources that functions seamlessly across multiple hardware generations. This provides more flexibility in dynamically allocating resources to meet business needs and makes it easier to add new server technology without creating islands of compute resources.

Our POC experiments have showcased that live migration of VMs using Intel VT FlexMigration and VMware's* Enhanced VMotion works successfully and can be used to host Intel IT business applications in a virtualized production environment.

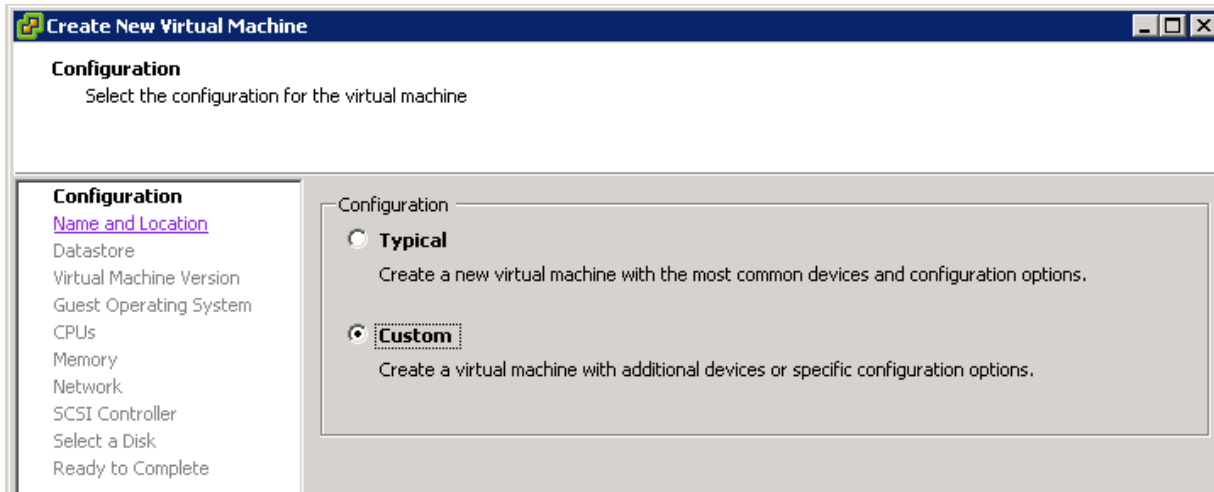
Intel® VT FlexMigration and VMware Enhanced VMotion technologies allows enterprises to re-use and scale their existing resource pools by adding higher performing power efficient servers into the pool and also provides investment protection and future proofing of resource pools.

6 Appendix

6.1 Changes in Virtual Machine format

Starting with VMware vSphere* 4.0, VMware is supporting a new Virtual Machine version 7, which is more optimized to take advantage of the new features of VMware vSphere* 4.0. If all the hosts in the cluster are 4.0, then it is recommended to have the VM's with version 7 for optimal performance.

By default all the VMs that will be created using Virtual Center 4.0 will be using Virtual Machine version 7. In order to change it, please choose the "Custom" option as shown below during the creation of VM.























Note: The VMs with virtual machine format 7 cannot be migrated to ESX 3.x hosts. If you need backward compatibility with versions of ESX prior to VMware vSphere* 4.0, keep the VMs in virtual machine 4 version.

6.2 Hardware Status

In VMware vSphere* 4.0, all the hardware sensors for the hosts can be monitored centrally from the Virtual Center server. Appropriate alarms are generated for any hardware issues. Screen shot shows the high level components that could be monitored.

Note: Even though alarms are generated because of hardware issues, the system continues to run without any issues.

Sensor	Status	Details
+  Processor	 Normal	
+  Memory	 Normal	
+  Fan	 Normal	
+  Voltage	 Normal	
+  Temperature	 Normal	
+  Power	 Normal	
+  Network		
+  Storage	 Normal	
+  Software Components		
+  Watchdog	 Normal	
+  Other	 Normal	

6.3 References

- [First the Tick, Now the Tock: Next Generation Intel® Microarchitecture \(Nehalem\)](#)
- [Intel® Microarchitecture \(Nehalem\)](#)
- [IT@Intel Testing Live Migration with Intel VT FlexMigration white paper](#)
- [A Superior Hardware Platform for Server Virtualization](#)

Acronyms

CSU	Consolidated Stack Unit	NLB	Network Load Balancing
HA	High Availability	POC	Proof Of Concept
DRS	Distributed Resource Scheduler	SSE	Intel® Streaming SIMD Extensions
EVC	Enhanced VMotion Compatibility	VM	Virtual Machine

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