Considerations to Consolidate and Virtualize Microsoft® SQL Server® on Dell™ PowerEdge™ Servers and Dell EqualLogic™ Storage

A Dell Technical White Paper

Database Solutions Engineering

By Anthony Fernandez

Dell Product Group

July 2009

Executive Summary

This white paper provides guidance and recommendations to help customers design a consolidation and virtualization strategy for deploying Microsoft® SQL Server® software on the latest Dell™ PowerEdge™ servers and Dell EqualLogic™ iSCSI storage arrays.

The goal of this white paper is to introduce consolidation and virtualization strategies, describe benefits and limitations of each strategy, and to provide a reference in which system architects can design and implement a successful deployment. It includes considerations and recommendations for the configuration and deployment process at the server and backend storage levels.

The tests detailed in this white paper reveal potential bottlenecks that may arise in a consolidated or virtualized environment and provide best practices recommendations to mitigate the effects of these bottlenecks, including recommended server and virtual machine configurations as well as workload sizes supported by the server and storage configuration.

CONTENTS

Introduction

In today's economic climate, enterprises are taking a closer look within their IT organizations to identify potential areas in which cost-saving strategies can be implemented to help reduce operating expenses. One of the challenges that IT organizations face today is how to develop an infrastructure that allows flexibility, redundancy and high-availability, ease of management, security, and access control while at the same time reducing costs, hardware footprints, and complexity.

Not all cost-savings strategies are created equal. Some require an upfront investment of hardware and software while others can be implemented organically, in other words using existing resources over a longer period of time, each with an associated cost. One of the keys to designing and applying a successful strategy that meets business goals is to gather as much relevant data as possible upfront and create a strategy model. The development of the strategy should be projected over a period of time and the projected outcome analyzed to verify that it corresponds to the business goals. The strategy model or business goals should then be modified as needed.

This white paper discusses the key points to consider when designing a cost-saving strategy. The lessons learned in this white paper are the result of evaluating and implementing various strategies at the Dell Database Engineering Lab.

Audience and Scope

This white paper is intended for customers, partners, solution architects, storage administrators, and database administrators who are evaluating, planning a consolidation and/or virtualization strategy. It provides an overview of various considerations and reference architectures for consolidated and virtualized SQL Server 2008 deployments.

Today's Challenges

IT organizations face an enormous challenge to keep operations running around the clock with increasing demand and growing complexity, to the point that it becomes difficult for employees to request resources to fulfill their tasks. This has lead to circumventing the IT standards and procedures to get the job done faster, which in turn has lead to server sprawl especially at the database tier. Databases are the engines that provide data to applications in a typical three- or four-tier environment; web-tier, application-tier, database-tier, and an optional storage-tier. With the advent of standardized hardware, a tiered architecture allowed compartmentalization of applications and separation of resources. Hardware at each tier provides a specific function and requires a specific set of tools to manage and maintain. All of the components are connected via a network, in most cases Ethernet. This separation of resources provides an easy way for employees to bypass and deploy database servers for test and development without the IT department's oversight and management.

The apparent benefit of ease of deployment and development can easily be overshadowed by potential challenges such as incompatibility issues that may arise during deployment to production, thus delaying time to market. Security vulnerabilities may also be introduced to the organization due to un-patched systems. Over time, however, servers that were deployed for a specific project that is no longer active still remain in the organization just in case a need arises to continue testing and quality assurance (QA). In the meantime, CPU cycles are lost to idle systems that consume valuable wattage, adding to the bottom line of the business costs.

It very quickly becomes apparent that unmanaged server-sprawl can potentially grow very complex, adding to the data center footprint and the costs for management, security, power, and cooling.

Developing a Strategy

The first step to developing a successful strategy is to identify the current challenges. With the increase of user and application demand, the datacenter footprint typically also increases as more hardware is added. This results in an increase in power and cooling costs as well as management complexity.

Developing a comprehensive inventory of all hardware and application software, along with all its dependencies, is essential to developing business goals based on the areas needing improvement. For example, an inventory may reveal that a large number of hardware resources are not efficiently utilized or that too many unmanaged servers exist that may lead to security risks. This information helps shape the business goals such as, increasing server utilization, reducing security risks, and lowering power and cooling costs in the data center. In turn, meeting these goals will help simplify and streamline IT operations.

Figure 1 below shows a high-level view of the process of developing a strategy to help IT organizations meet their goals.

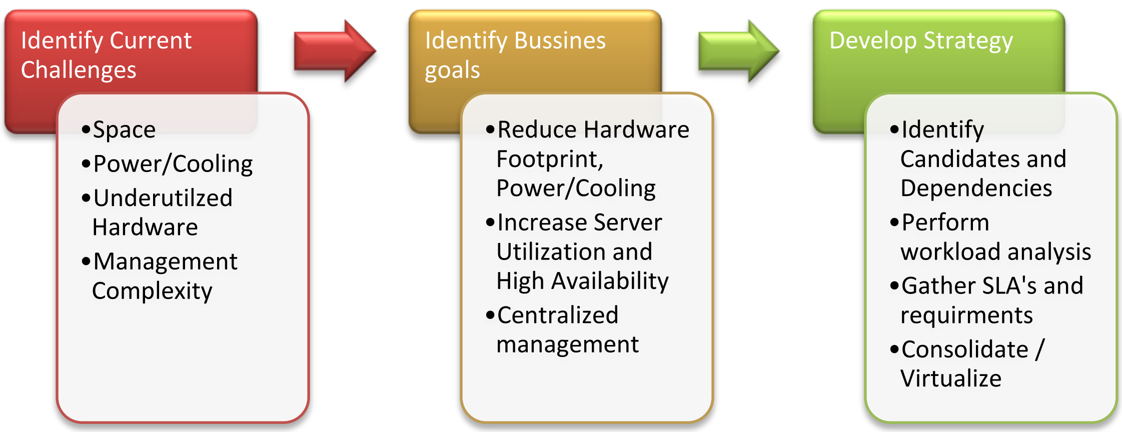

Figure 1: Process Flow

Once the challenges and the business goals have been identified, developing a strategy requires more in-depth analysis of the current environment, focusing on the challenging areas of the organization. This analysis should reveal all aspects of how the hardware and software are being used as well as the internal and external dependencies that exist around the system. Understanding exactly how the system is being used, by which applications and users, the expected service level agreements (SLAs) of those users and applications, and at what times it is being accessed will help determine if the system is a candidate for a consolidated or virtualized environment. This also helps in sizing the correct target configuration in which to consolidate databases or virtualize servers.

Considerations for Consolidation and Virtualization

Based on the analysis gathered from the candidate systems, the choice between consolidating databases onto a single physical server or creating virtual machines that host independent containers for databases will vary depending on the goals of the organization, number of databases, the SLAs, and workload analysis, to name a few.

Server Consolidation

Enterprises are embracing the *scale-up* strategy to consolidate SQL Server instances onto fewer physical servers. The scale-up strategy involves adding as much memory and as many CPUs as possible to one physical system and consolidating multiple databases or instances. For example, a single PowerEdge R900 with 256 GB of RAM and four six-core processors can host a large number of instances and databases. The benefit of this strategy is that it reduces licensing costs and management. The challenge with this configuration is to provide high availability for planned and unplanned downtime for a large set of databases. Clustering and mirroring provide ways to mitigate this problem; however, implementing a high-availability solution can prove difficult for administrators, since all the databases must failover when there is downtime.

In a *scale-out* strategy, smaller systems are deployed with enough memory and CPUs to drive workload with a small number of databases. The benefit of this strategy is that it avoids the single point of failure that can occur when one system holds all the databases. With less expensive, standards-based hardware, this strategy is widely implemented today to mitigate large monolithic systems that hold the data of the entire company. This model poses a challenge since it requires a large number of smaller physical servers, increased complexity, maintenance overheads, and additional power and cooling. The term used to refer to server expansion is called server sprawl. Over time, the costs associated with this model can outweigh the benefits of the scale-out model.

Server Virtualization

Virtualization offers an innovative solution that allows multiple instances of operating systems to run on the same physical hardware, unlocking the capabilities of the hardware. In the past, if a new system was needed, hardware had to be purchased or repurposed, power requirement had to be accounted for, and each server was deployed with a fresh operating-system image. The hardware allocation process could take days, weeks, or even months, depending on the availability of hardware. With virtualization technologies, the allocation process of a new virtual machine can take minutes to hours. In addition, virtualization technology has multiple benefits—for example, maximizing hardware-resource utilization and providing logical separation of applications running on the same hardware. It also increases system availability and reduces management and downtime associated with data centers that manage information in silos.

The table 1 below compares some key considerations for each strategy side by side:

Table 1 Consolidation/Virtualization Considerations

	Consolidation	Virtualization
Disaster and Recovery	Needs to be implemented at each level (hardware, software, instance, databases). Full hardware redundancy is required and additional server for failover capabilities by use of MSCS and/or SQL Server mirroring. Scheduling of backups to disk and tape for short- and long-term archiving and retrieval.	Hardware virtualization decouples the guest operating system from the physical hardware. VM snapshots can be scheduled to quickly restore the state of the operating system and databases.

Minimize Downtime	Patching and upgrade can be accomplished by performing a restart failover to passive node in cluster.	Entire VM can be moved seamlessly to separate hardware, allowing for hardware maintenance and upgrades.
Testing and Development	Server reboots as a result of test and development affects other databases and users on the same system. Sharing the hardware can be a challenge if multiple users are hosted, but server parameters need to be modified. Performance tuning needs to be catered to all databases that are hosted.	Since VMs are compartmentalized, developers can have complete control to modify operating system parameters to test database impact, perform reboots, etc. without other downtime to other users on the same host.
Dynamic Deployment	Rigid environment. It requires hardware setup, software installation, migrating or creating of databases. Even slight variations in hardware configuration can force multiple images to be created. Strict account management for all logins, such as database users and system users.	Cloning and templates allow for quick VM deployment. When users require a new system for development, training, testing, etc., administrators can quickly provide a VM with operating system and applications to users.
Licensing Costs	Reduces operating system and application licensing costs by consolidating physical servers onto fewer servers.	May add additional costs for the hypervisor license and also for each virtual-machine operating system and application license, depending on version edition, number of virtual machines, and licensing schema. Refer to Microsoft's licensing website at: http://www.microsoft.com/licensing/about-licensing/virtualization.aspx.
Recommendations	Ideal for production environments where the hardware and operating system are completely protected from application users and database administrators.	Ideal for dynamic environments in which users require complete control of database and operating system, quick deployment and de-allocating of virtual systems.

As virtual machines proliferate in enterprise environments, the complexity of the underlying storage does as well—potentially eliminating gains achieved through increased server-hardware utilization and power and cooling reductions. With EqualLogic iSCSI storage virtualization technology, customers can realize similar gains at the storage layer.

The benefits of EqualLogic iSCSI storage include:

- Virtualized storage enables seamless rebalancing as array members are added.
- By leveraging Ethernet infrastructure, no specialized hardware is required for storage traffic.

- Ease-of-management and high-availability features are included by default.
- Complete integration with the Microsoft Volume Shadow Copy Service (VSS) framework simplifies creating snapshots and clones.

Figure 2 below shows instance consolidation on physical hardware.

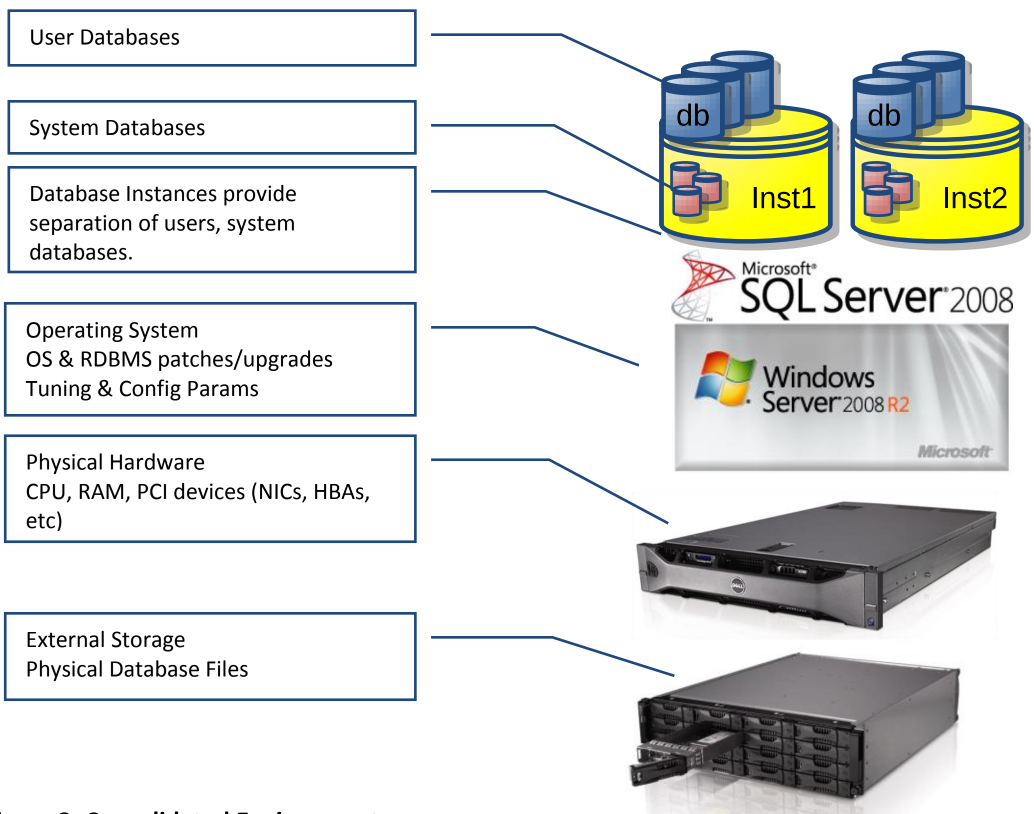

Figure 2: Consolidated Environment

Figure 3 below shows a virtualized environment with two separate virtual machines.

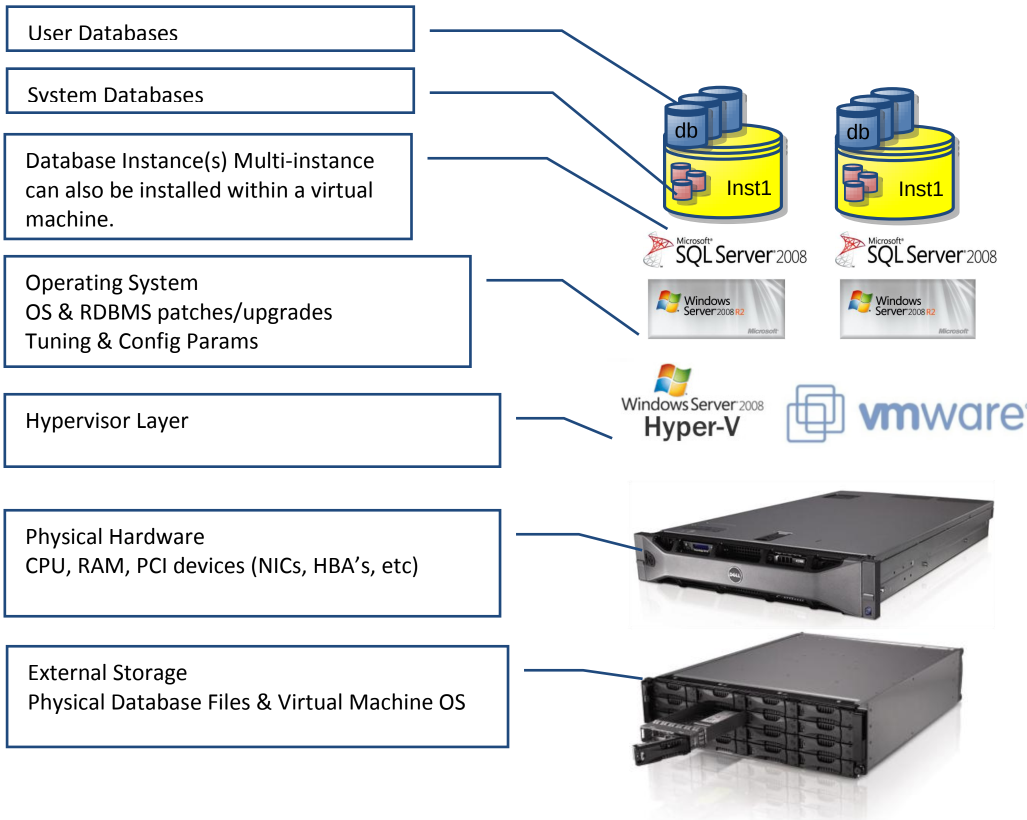

Figure 3: Virtualized Environment

Consolidation/Virtualization Process

This section describes an example of a consolidation/virtualization process performed at the Dell Database Engineering Lab. Using the processes described above, we first identified the challenges our lab was facing and produced a table with a high level overview of the current status of the data center. Based on the inventory results, we can now develop a list of goals to drive the implementation process.

It is recommended that a development strategy be divided into multiple phases or cycles. During phase one of our exercises, using the inventory results and business goals described above we can begin to develop a strategy to meet the goals. The table below describes the high level challenges, inventory of the entire organization hardware and proposed goals for each category.

Table 2 Inventory Collection and Goals Table

Challenges	Inventory Results	Goals
Space	Rack space is limited. Four 42-U Racks 95% full.	Maintain lab footprint. Reduce rack utilization capacity to 55%.

Power/Cooling Costs	105,120 kWh / year	Reduce by 25% to 80,000kWh / year

Hardware Inventory	• Total 30 servers
	  ○ 13 database servers (25 instances, 140 databases).
	    ▪ 6 db servers Production
	    ▪ 4 db servers QA Test
	    ▪ 3 db servers Development
	  ○ 6 infrastructure servers (DHCP, DNS, DC, etc.)
	  ○ 5 Application Test/Dev servers
	  ○ 4 QA servers
	  ○ 2 backup servers
	• Storage
	  ○ Fibre Channel SAN (CX700 + 3 DAEs)
	  ○ 3 direct attached storage enclosures (DAS)
	  ○ 50% of servers on SAN
	  ○ 20% of servers on DAS
	  ○ 30% other (internal storage)
		Phase out and consolidate legacy hardware onto 11th Generation PowerEdge Servers.
		
		Attain a 40% hardware reduction to 18 physical servers while maintaining SLAs and high utilization rates.
		
		Consolidate storage for increase security, management, high availability.

Under-Utilized Resources	Under-Utilized 20%: 6 servers running <5% Low Utilization 60%: 18 servers running at 10%-20%. Medium Utilization 14%: 4 servers running 20%-50% High Utilization 6%: 2 servers running at 50%-70%	Implement a consolidation strategy on servers with less than 5% utilization.
Management Complexity	The core of operations relies on database servers. Increasingly more difficult to manage high number of servers.	Reduce physical server management and introduce standardization.

It was identified that as much as 20% of hardware resources were under-utilized and as much as 60% had low utilization patterns. Even though the goal is to reduce under-utilized systems, not all under-utilized systems could be candidates for either a consolidated or virtualized environment. In some cases, under-utilization was a result of sizing hardware for a specific database server. The sizing process to allocate hardware for databases takes into account projected growth over time. For databases that are projected to grow rapidly and have a high resource utilization patterns will not be candidates for consolidation or virtualization during the first phase of implementation. If during future phases it is determined that the anticipated growth rate or utilization patterns have not been met, the database server could become a candidate for consolidation or virtualization depending on features required.

Figure 4 below shows a flow diagram with the strategy development process.

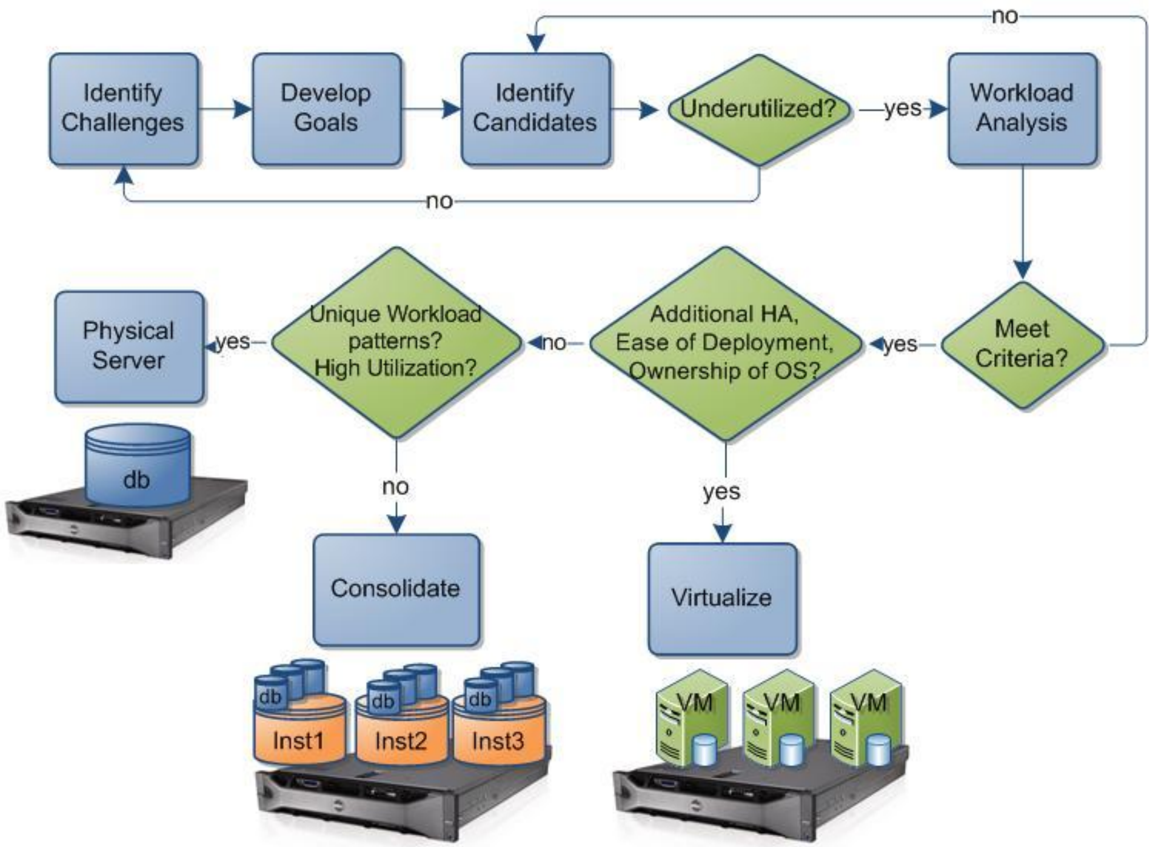

Figure 4: Strategy Development Flow

Once the candidate systems have been identified, the next step is to gather comprehensive performance information during the workload analysis phase. The table below describes the statistics and system information gathered for a PowerEdge 2850 server.

Table 3 Candidate Legacy Configuration

PowerEdge Server	PowerEdge 2850
Processors	Single Dual-Core Intel Xeon 2.66GHz 800MHz front side bus, L2 2MB processors
Memory	4GB (2x 2GB DDR2)
Internal Hard Drives	Two 7K 36GB RAID1 for the operating system
External Storage	Varies. Some PE2850 servers use internal storage for databases, while others have external storage such as SAN or Direct Attached.

Operating System	Microsoft Windows Server® 2003 Standard Edition
Database	SQL Server 2005 Standard Edition
Number of Database Instances	1
Number of User Databases	10
Application Dependencies	2 non-production application servers rely on these databases to store/retrieve data for online application. If databases are down, end users accessing web front end will get a page not found 404 messages.
Administration Requirements	Developers do not require operating system access.
Risk Assessment	Low. A low number of users accessing web application during business hours. None during off hours.
Aggregate Database Size	250GB
Workload Pattern	OLTP
Average Power Consumption	276 Watts
Input Current	2.52amps (110 AC input voltage)
Average CPU Utilization	<5%
Average Disk IOPS	200-500 (8-KB IO size for data files)

Using the Microsoft Performance Monitoring tool (Perfmon), the following counters were collected during a period of 24 hours. We can quickly verify that the system CPU, memory, and IO resources are under-utilized.

Table 4 Performance Statistics

Perfmon Counters	Minimum	Maximum	Average
Memory – Pages/sec	0	303	10
Memory – Available Bytes	54	59	55
Physical Disk –% Disk Time	36%	52%	44%
Physical Disk – Avg. Disk sec/Read (_Total)	0.000	0.004	0.003
Physical Disk – Disk Reads/sec (_Total)	91	125	104
Physical Disk – Average Disk Queue Length	0	5	3

Processor – % Processor Time	2%	12%	5%
System – Processor Queue Length	0	1	0.223
SQL Server Buffer – Buffer Cache Hit Ratio	98.502%	99.789%	99.586%
SQ Server General – User Connections	4	40	20

Note: For a description of each perfmon counter refer to Appendix C.

Six servers were identified as potential candidates with statistics patterns similar to the one shown in the tables above. Based on the total utilization for all six servers, it was determined that a single R710 system would be an ideal candidate to consolidate the current load. Table 4 below describes the target server for consolidation.

Table 5 Target Consolidation Configuration

PowerEdge Server	PowerEdge R710
Processors	Two Quad-Intel® Xeon® X5550, 2.66Ghz, 8-M Cache, 6.40 GT/s QPI, Turbo, HT
Memory	48-GB (12x4GB), 1066-MHz Dual Ranked RDIMMs for 2 Processors, Optimized
Internal Hard Drives	Two 15K 146-GB RAID1 for the operating system Six 15K 146-GB RAID10 for Logs orTempdb
External Storage	Two EqualLogic PS6000 (15K 146-GB RAID10).
Operating System	Microsoft Windows Server® 2008 Enterprise Edition x64
Database	SQL Server 2008 Enterprise Edition x64
Number of Database Instances	3
Number of User Databases	60
Application Dependencies	12 non-production application servers rely on these databases to store/retrieve data for online application.
Aggregate Database Size	1,500 GB
Workload Pattern	OLTP
Average Power Consumption	365 Watts
Input Current	3.4 amps (110-AC input voltage)

Average CPU Utilization	30%
Average Disk IOPS	1,200 (8-K IO size for data files)

Consolidation Test

The goal of this test is to consolidate six PowerEdge PE2850 servers that were identified in the previous step onto an 11th Generation PowerEdge server R710. In addition to the target server, two extra servers were included to provide high availability features to mitigate the concerns of a large number of databases potentially going off-line in case of a server failure. In order to protect the system from hardware failure, a two-node cluster was configured as active/passive and sharing the same storage enclosure. Optionally, a third server was configured as a SQL Server Mirroring partner to provide a failover mechanism of individual databases to protect from storage failure.

Figure 4 below shows a diagram of the legacy and the target configurations. SQL Server Mirroring is implemented to provide high availability at the database level and optionally, Microsoft Clustering is implemented to provide high availability at the server level.

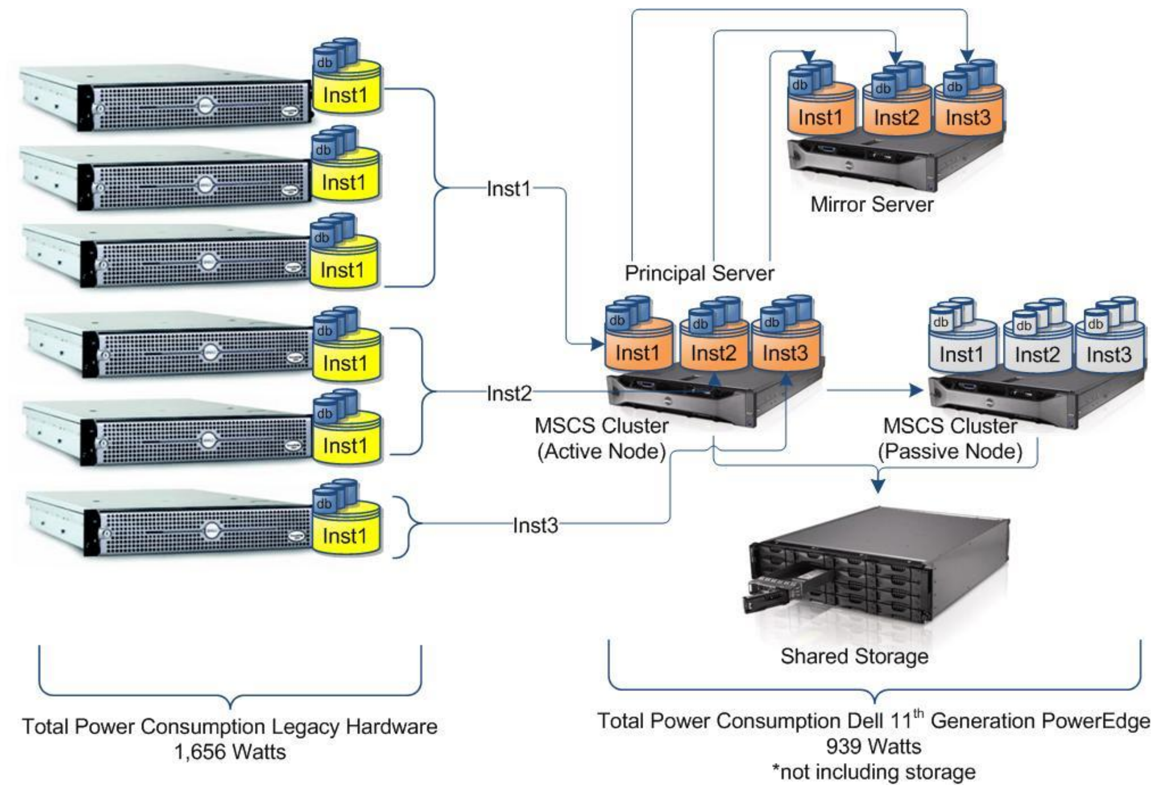

Figure 4: Consolidation to physical server implementing SQL Server Mirroring and Microsoft Cluster Server (MSCS) Clustering

Consolidation Test Methodology

The first test we performed was a scale-up test to find out how the R710 system performs in a consolidated environment.

We developed a set of SLAs for each of the candidate databases to consolidate, such as transactions per second, query response times, and high availability. The first step is to migrate each database one at a time and to record their performance with a simulated user load to match the actual user load. After we attained the results for the first test run or baseline, the subsequent test runs added an additional database and a baseline for that database was recorded. Once all databases had been consolidated, statistics were gathered to verify against each database baseline to ensure that no system bottlenecks caused performance degradation.

Consolidation Results

Figure 5: Legacy and Consolidated Results below shows the transactions per hour and average time of IO to complete for each of the legacy PE2850 servers. It also shows the performance after all six PE2850 systems were consolidated onto a single PowerEdge R710 server. The average transactions per hour remained constant as the same average number of users log in to the system to gather data from the databases. The biggest gain was achieved at the average response time. Notice that after the consolidataion, we have only a 6 millisecond per IO transfer and not the sum of each of the legacy servers sec/transfer.

The legacy server and storage configuration varied greatly. Some legacy servers used only internal drivers for database data files and some external storage.

The target storage configuration for the consolidated and virtual environment consists of two Dell Equallogic iSCSI storage arrays each with fourteen 15K drives in a RAID10 configuration.

This graph also is indicative of that each of the servers hosting a small number of databases was under-utilized.

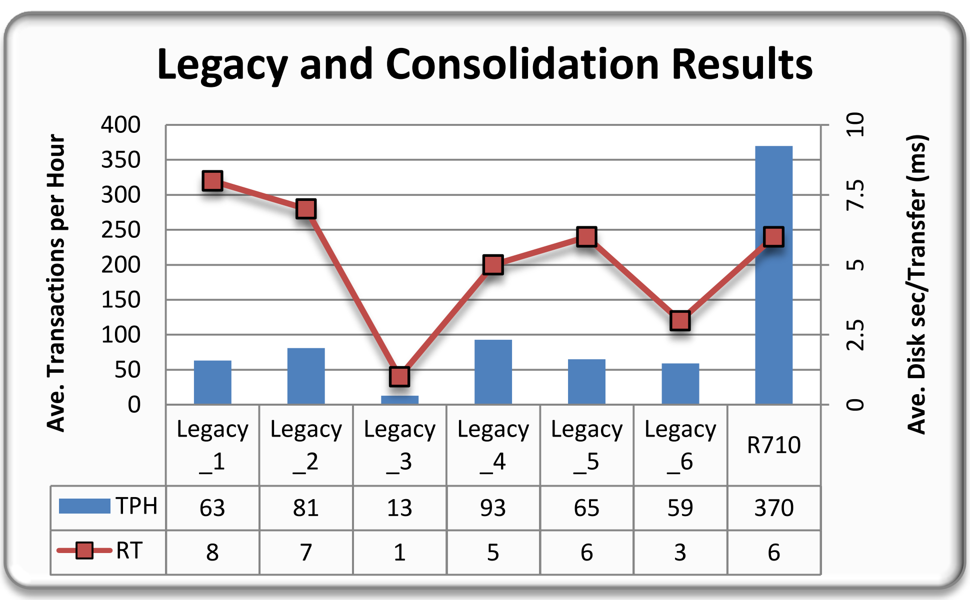

Figure 5: Legacy and Consolidated Results

The overall CPU utilization on the target system reached an average of 20%-30%. The target R710 system was configured with 48 GB of RAM; however, the combined memory usage patterns of the legacy systems for the database was only 12 Gb. More tuning can be performed to take advantage of a larger memory space and perhaps consolidate more databases.

Figure 6 below shows the total power consumption of the six legacy PE2850 systems versus a two-node cluster with mirroring partner. The figure also shows the power consumption of only the two nodes either for the mirror partner or the passive cluster node.

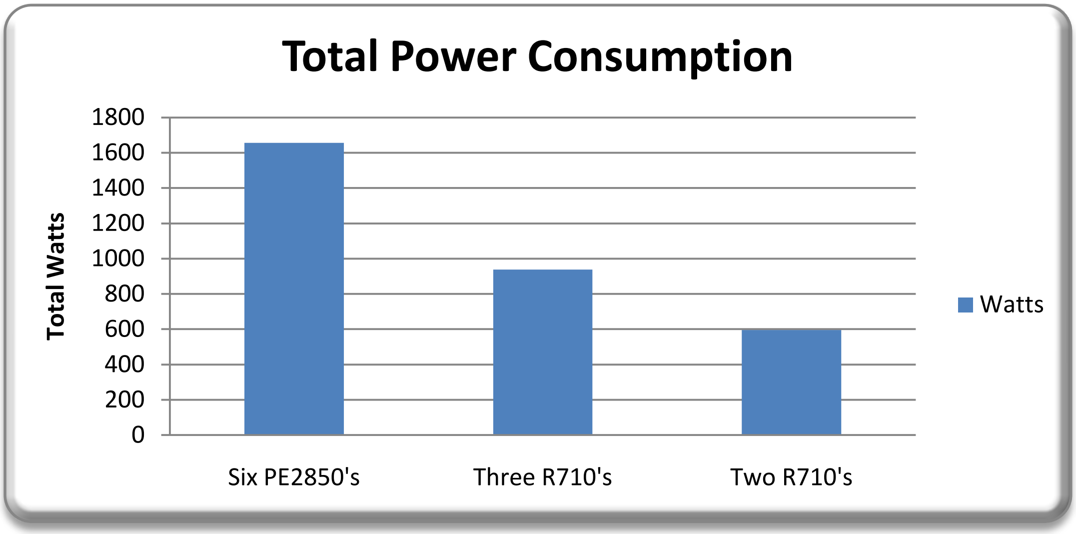

Figure 6: Total Power Consumption

Virtualization Test

The goal of this test is to deploy a virtual environment with multiple virtual machines in which to consolidate the databases hosted on the six candidate PowerEdge PE2850 servers identified in the previous step onto an 11th Generation PowerEdge Server R710. In addition to the target server, one extra server was installed with a hypervisor to provide high availability features such as virtual machine failover or migration.

Figure 7 below shows a diagram of the legacy and target configuration.

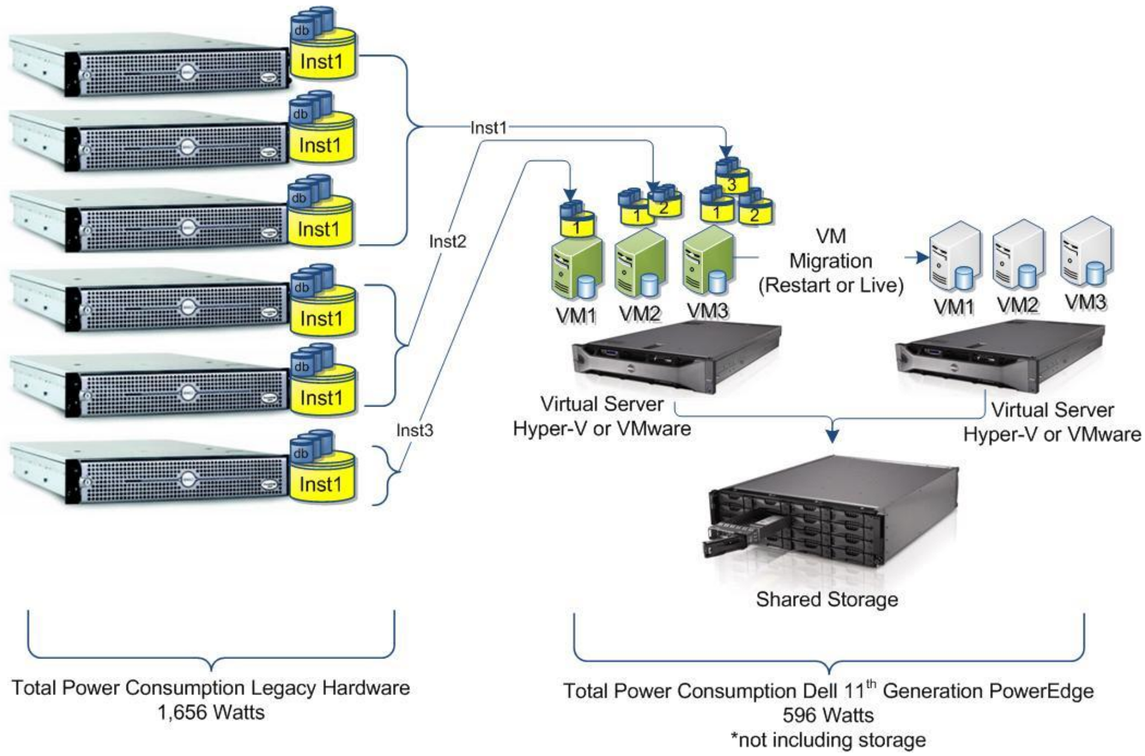

Figure 7: Legacy and Target Configuration

Virtual Environment Test Methodology

The second test performed was a scale-out in a virtual environment test to find out how the R710 system performs in a virtual environment.

The legacy servers' database workload was grouped into three categories depending on various factors such as workload patterns, usage requirements, user access, and so forth. Three Virtual Machines were created to host each of these three categories. For instance, VM1 only hosts a single instance due to the fact that the developer needs constant reboots for operating system tuning, while the group instances hosted on VM3 do not require operating system access, and hence each developer can share the same virtual machine. This consolidation helps reduce Virtual Machine sprawl. Table 5 below describes the configuration for each virtual machine.

Table 6 Virtual Machine Configuration

	Virtual Machine 1	Virtual Machine 2	Virtual Machine 2
Virtual Processors	One vCPUs	Two vCPUs	4 vCPUs
Virtual Memory	8GB	12GB	24GB
Guest Operating System	Windows Server 2008 Standard Edition x64	Windows Server 2008 Standard Edition x64	Windows Server 2008 Standard Edition x64

Database	SQL Server 2008 Standard Edition x64	SQL Server 2008 Standard Edition x64	SQL Server 2008 Standard Edition x54
Number of Instances	1	2	3

We developed a set of SLAs for each of the candidate databases to consolidate, such as transaction per second, query response times, and high availability. The first step was to create each virtual machine and to migrate each database instance one at a time and record their performance with a simulated user load to match the actual user load. After we attained the results for the first test run or baseline, the subsequent test runs added an additional database and a baseline for that database was recorded. Once all databases had been consolidated, statistics were gathered to verify against each database baseline to ensure that no system bottlenecks caused performance degradation.

Virtualization Results

Both the Average Transaction per Hour and Average Response Time were equal to the consolidated test. From the end-user perspective, the queries completed as fast as the consolidated environment.

Figure 8 below shows the overhead associated with running multiple operating systems on a single physical machine.

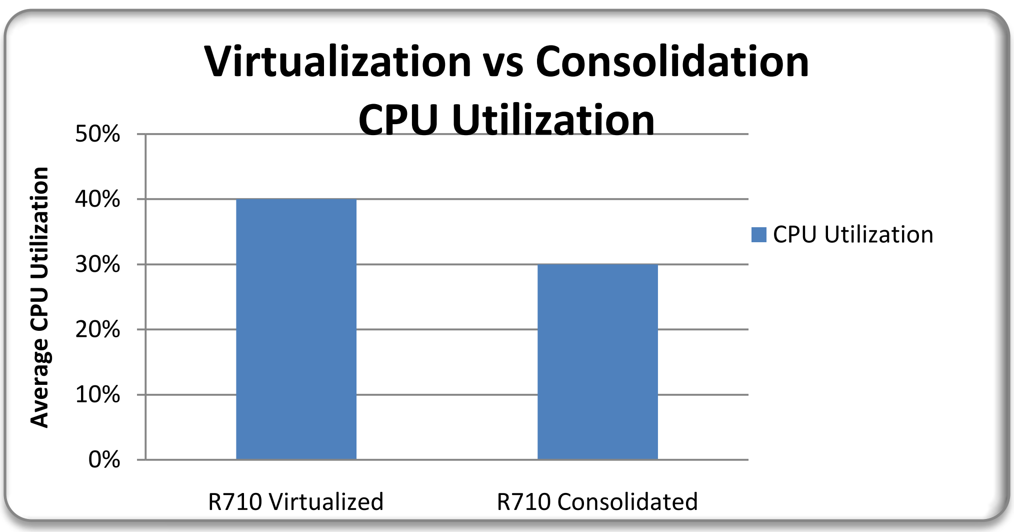

Figure 8: Virtualization vs. Consolidation — CPU Utilization

The overhead associated with running virtual machines depends on the workload and the number of virtual machines running on the same host. The costs of higher CPU utilization in a virtualized environment, provides some of the benefits discussed in this paper such as high availability and separation of resources and workloads. Careful analysis is recommended when deciding to virtualized servers.

Conclusion

This study provides an overview of considerations to develop a strategy to maximize hardware utilization and reducing costs associated with database sprawl.

It describes the strategies and reference architectures as a starting point to consolidate SQL Server on the latest Dell hardware using a building block approach to design, configure, and deploy using best practice recommendations to simplify IT.

To simplify the design and deployment of a virtualized infrastructure, Dell offers Solution Architectures bundles for PowerEdge blade servers, VMware, Microsoft Hyper-V, and EqualLogic. The bundles provides configuration and best practices to achieve full redundancy—with no single point of failure, scalability, and ease of management.

Since a large portion of database servers require external storage for high throughput workloads, careful planning and design is required in a Fibre Channel SAN for LUN creation to achieve separation of data. This could add management overhead as more and more databases need to be deployed. Dell EqualLogic Virtualized iSCSI SAN helps simplify the creation and management of volumes, thus increasing productivity.

The tests performed in Dell labs showed that significant gains can be achieved by developing a strategy to maximize hardware utilization, reducing sprawl, power and cooling costs by consolidating and virtualizing SQL Server on the latest Dell PowerEdge servers, VMware, and EqualLogic storage while providing the performance to meet the most demanding customers' workloads.

Appendix

Below is a description of Perfmon counters that are useful when analyzing workloads. In addition, refer to the References section for additional resources.

Perfmon Counters	Description
Memory – Pages/sec	Shows the rate at which pages are being swapped in and out of memory.
Memory – Available MBytes	Shows the level of free physical memory
Physical Disk – % Disk Time	Percentage of how busy the individual logical disks are.
Physical Disk – Avg. Disk sec/Transfer (_Total)	This shows the average time it is taking for data to be transferred between disk and memory, and includes both Disk Reads and Disk Writes. If disk transfers are taking consistently longer than 50 milliseconds, a disk bottleneck may be developing.
Physical Disk – Disk Reads/sec (_Total)	The rate at which read requests have been sent to each logical disk.
Physical Disk – Average Disk Queue Length	This shows the average number of I/O requests that were queued for each logical disk. Disk Queue Length indicates how heavily loaded a disk subsystem is. High queue lengths mean the disks are struggling to process the I/O load being put on them.
Processor – % Processor Time	The percentage of elapsed time that the processor spends to execute a non-Idle thread.
System – Processor Queue Length	Shows the number of threads (program execution units) that are waiting to run on each processor. A high number of queues may indicate processor bottleneck.
SQL Server Buffer – Buffer Cache Hit Ratio	Percentage of pages that were found in the buffer pool without having to incur a read from disk.
SQ Server General – User Connections	Number of users connected to the system.

References

Dell Solutions Engineering

- http://www.dell.com/sql
- http://www.dell.com/virtualization

Dell Services

- http://www.dell.com/services

Microsoft SQL Server 2005 Virtualization in the Dell Scalable Enterprise

- http://www.dell.com/downloads/ap/POWERSOLUTION/CN/PowerJanuary2007/January07_66_70.pdf

Top SQL Server 2005 Performance Issues for OLTP Applications

- http://sqlcat.com/top10lists/archive/2007/11/21/top-sql-server-2005-performance-issues-for-oltp-applications.aspx

TOP 10 SQL Server 2005 Performance Issues for Data Warehouse and Reporting Applications

- http://sqlcat.com/top10lists/archive/2007/11/21/top-10-sql-server-2005-performance-issues-for-data-warehouse-and-reporting-applications.aspx

OLTP Blueprint – A Performance Profile of OLTP applications

- http://blogs.msdn.com/sqlcat/archive/2006/06/23/Tom-Davidson-SQLCAT-Best-Practices.aspx

SQL Server Perfmon (Performance Monitor) Best Practices

- http://www.brentozar.com/archive/2006/12/dba-101-using-perfmon-for-sql-performance-tuning/