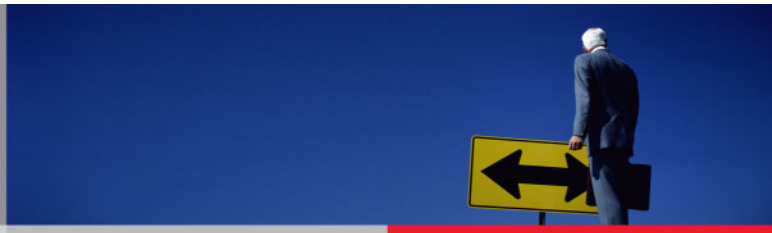
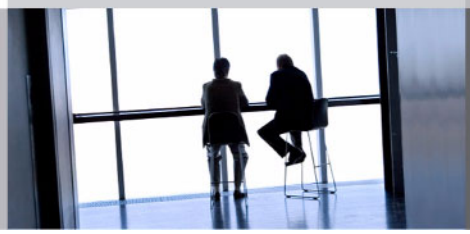
Consolidating Large Microsoft SQL Server Databases on the IBM System x3850 X5 with Microsoft Hyper-V





Redguides
for Business Leaders

Scott Smith
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- Shows how x3850 X5 and DS5000 make an ideal platform for consolidating large SQL databases
- Provides best practices for consolidating large databases through virtualization
- Reviews the latest enhancements from IBM, Intel, and Microsoft allowing for consolidation of large databases

Redbooks

Executive overview

An increasing number of customers are adopting server consolidation these days to curb the growing cost of managing and maintaining their IT infrastructure growth. IT administrators are increasingly faced with physical servers that run at low utilization levels. With significant and recent developments in server virtualization technology, customers are looking to implement a server consolidation strategy. This strategy can help many IT administrators solve multiple challenges associated with rapid and uncontrolled data processing growth:

- Maximize investment in server hardware
- Respond rapidly to changing IT needs
- Improve business continuity
- Simplify administration
- Save space and power

This IBM® Redguide™ publication is the second in a series of papers demonstrating Microsoft® SQL server consolidation using IBM System x® scale-up enterprise servers and IBM System Storage®. The first Redguide, *Consolidation of Microsoft SQL Server Instances on the IBM System x3850 X5 with Microsoft Hyper-V*, REDP-4661, highlighted consolidating large number of small SQL databases.

As an organization's IT environment becomes increasingly dynamic, IT administrators must find new ways to maintain and improve business continuity, and remain flexible and able to respond to the changing needs of the organization. Server consolidation has been aroundfor a long time, but is now taking a key role in helping IT staff maintain this dynamic environment.

The newest high-performance server from IBM, the System x3850 X5, uses a state-of-the-art design to maximize hardware acceleration in a virtualized environment. Using virtualization technology such as Microsoft Hyper-V, IT administrators can maximize their investment in System x server platforms, helping increase utilization to optimal levels for each hardware resource.

In this paper, we focus on consolidating large SQL database servers with up to 16 GB memory and a database size of over 100 GB. The IBM x3850 X5 4-socket server is well-suited to consolidate large databases because of the phenomenal performance and large memory configurations it supports. Coupled with the IBM System Storage DS5300 mid-range storage subsystem, which provides the IO capabilities needed for consolidating large SQL servers, this solution helps address the many challenges customers face with consolidating infrastructure and reducing costs.

There are several approaches to implementing a server consolidation strategy. This paper focuses on the consolidation of existing physical servers on IBM System x3850 X5 servers using Microsoft Hyper-V virtualization. Each SQL Server instance runs in an isolated virtual machine (VM) that is made highly available (HA) by configuring the host servers in a Microsoft HA cluster. With the ability to hold 1 TB of memory and 64 logical processors, the physical resources of the x3850 X5 can support the maximum allowable guest virtual machines per host. One viable solution for example, virtualizes multiple large Microsoft SQL Server systems, each running a 4–5 year old four-way server, onto a high-performance server such as the x3850 X5 running Hyper-V. This IT model provides several key elements, including flexibility, high availability, and standardized configuration.

The proof of concept depicted in this paper demonstrates Microsoft SQL Server running in 16 virtual machines on a pair of clustered x3850 X5 servers with 256 GB memory on each physical server. Each virtual machine is configured with four virtual processors and 15 GB of memory. The ability of the x3850 X5 servers to be configured with up to 1 TB memory and 64 logical processors provides the flexibility to consolidate a larger number of high performance database virtual machines with up to four virtual processors, and 64 GB or memory in an HA environment.

Introduction

A number of factors drive an organization's consolidation effort. The following key areas are typically seen in the industry:

- Improving business continuity and IT flexibility
- Maximizing capital investment in hardware
- Standardizing and centralizing compute resources
- Saving money on space, power and cooling

Migrating physical production servers into a virtual machine significantly eases tasks (such as moving databases between physical hosts, load balancing during seasonal demand spikes, or replacing old hardware as part of the IT life cycle). Many of these same benefits also lead to an improved disaster recovery (DR) plan allowing rapid redeployment of virtual machines in the event of catastrophic failure.

There are several methods to make use of server consolidation scenarios to improve system utilization, maximizing return on investment. However, finding the best method to place multiple compute tasks onto a single physical server has proven challenging for several years. Two common methods include creating application silos (placing similar applications onto a single server), or running multiple instances of a given application (such as SQL Server) on separate servers. Virtualization is the latest tool to give administrators the ability to run multiple virtual stand-alone servers with their own operating system instances, and providing applications an encapsulated and partitioned environment on a single physical server.

Some time ago, only smaller low-resource existing servers were virtualized. As experience with virtualization has grown, along with system capacity and virtual machine performance, more challenging workloads are now being virtualized (such as a Microsoft SQL Server database).

Two additional benefits of server virtualization can be quickly realized as well. First, centralized and standardized computing resources can improve manageability, simplify documenting procedures, and streamline training. Second, reducing the number of physical servers needed to support customer environments can result in significant savings in datacenter space with fewer physical servers to power and cool.

Why Database consolidation makes sense

Before servers with large numbers of processors and large amounts of memory became affordable, clients kept adding physical servers as their database needs increased, resulting in many low-capacity, underused SQL Server database servers being deployed throughout many companies. In time, *database sprawl* became evident in the following ways:

- Systems were not always highly available
- Many physical systems became difficult to manage
- Costs for hosting, powering, and cooling these systems increased

The solution methodology of consolidating these many servers on to one large, highly reliable, highly available server with plenty of processor and memory capacity helped address database sprawl. Consolidation is accomplished using one of several strategies:

- Single SQL Server instance running multiple databases
- Multiple SQL Server instances running multiple databases
- Running SQL Server instances in multiple independent virtual machines

The first method, *simple database consolidation*, involves running multiple databases under a single instance of SQL Server. This allows the highest level of consolidation, but requires all applications running within this instance to share the same SQL Server version, patch level, and service account. Due to the smaller number of SQL Server instances being run, significant savings can be achieved with reduced management and licensing costs. This strategy is also the least flexible consolidation approach.

The second method, *instance level consolidation*, involves running multiple databases on a single physical server running multiple instances of SQL Server. With each database contained within its own SQL instance, separation between each application can be maintained across various patch levels according to the requirements of the given application. However, because there is only one instance of Windows® OS, patching and maintaining is problematic, because you suffer downtime on all instances of SQL server during that time.

The third method, *SQL Server consolidation through virtualization*, involves a single physical machine running Windows Server 2008 R2 with Hyper-V enabled. Each SQL Server instance runs in a virtual machine, with its own system resources, and operating system instance. Each virtual machine is entirely isolated. Security and isolation are maintained because client access and communication between VMs is through the network only. In addition, these VMs can be made highly available with Microsoft Clustering and Hyper-V Live Migration. This method of consolidation provides the greatest degree of flexibility and business continuity.

Advantages of Microsoft SQL Server Virtualization

The following list details the advantages of virtualizing with SQL Server:

- Improved manageability

  Many small servers with software installed locally are difficult and expensive to manage and maintain due to the diverse and heterogeneous nature of the environment. Any required patches and updates to hardware and software must be applied to each server individually. Virtualizing workloads on a smaller number of large servers in a highly available configuration helps minimize this work. Fewer systems mapped to physical systems need updating, and the ability to live migrate running virtual machines to another server for maintenance windows helps improve uptime and minimize impacts to users. Having application servers encapsulated in virtual machines that can be easily backed up and restored can greatly improve recovery time in a disaster recovery strategy.

- Power savings

  Running multiple servers at low use levels is not a good use of power when compared to running a single server at a higher utilization level. The CPUs, disks, memory, and I/O devices consume a minimum level of power that begins when the server is turned on, which compounds energy use requirements. In addition, the IT industry has experienced significant improvements in server power supply technology and efficiency.

  The IBM System x3850 X5 system has new highly efficient power supplies. The power supply performance achieves a peak efficiency of over 94%, and greater than 90% over the entire nominal operating range (power supply loads of 10% to 100% output power). Server consolidation through virtualization helps maximize customer returns per unit of power consumption.

- Isolation and security

  With server virtualization, each database server operates in its own operating system instance, providing the benefits of increased security and the ability to tightly control access to the host platform.

Consolidation Components

Our consolidation solution contains the key components discussed in the following sections.

Server

The latest IBM System x3850 X5 server release marks another significant advance in server technology. These new systems incorporate the latest in hardware acceleration and scalability, providing resource configurations that push the boundaries of x86/x64 based systems and providing industry-leading flexibility by offering the most amount of memory on similar x86 configurations.

Figure 1 shows the IBM System x3850 X5.

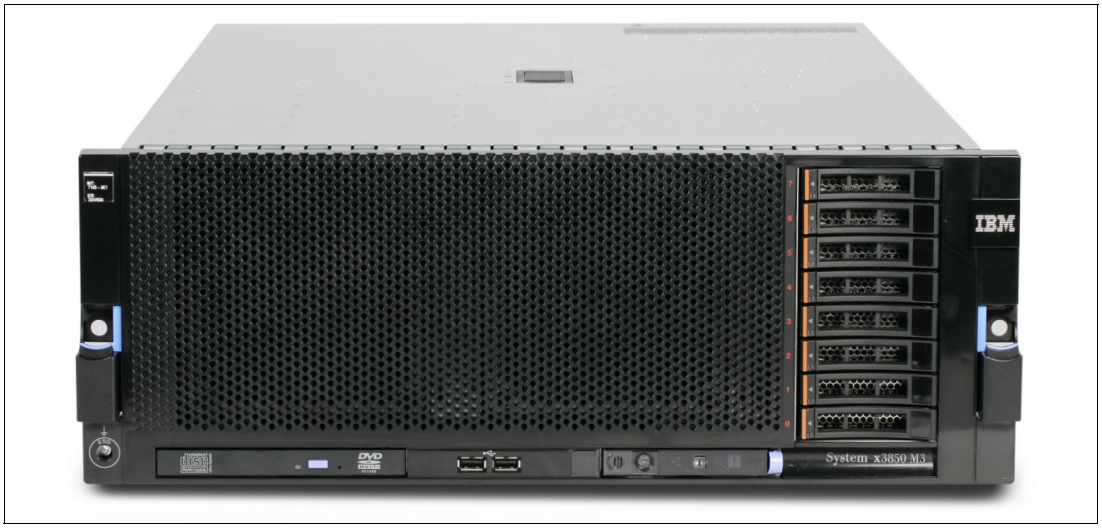

Figure 1 IBM System x3850 X5

The x3850 X5 is powered by the highly intelligent and massively scalable Intel® Xeon processor 7500 series. Built to handle the most demanding applications, the Intel Xeon® processor 7500 series helps deliver a quantum leap in enterprise computing performance. The Intel Xeon processor 7500 series features Intel Advanced Reliability Technology that provides automatic detection and correction of errors, dynamic reassignment of workloads across processors; interconnect error detection and recovery, and individual virtual machine recovery in virtualized environments.

The 4-socket server IBM System x3850 X5 now offers up to 32 cores or 64 logical processors with Intel Hyper-Threading Technology and up to 1 TB of memory per chassis. These scale-up servers with improved reliability and availability now make it well-suited for consolidating large SQL databases, providing the reliability and high availability needed for the most demanding virtualization requirements.

Virtualization has matured in recent years. Hypervisors have significantly improved in terms of performance, resource use, and guest machine support. The newest is Microsoft Hyper-V, which is capable of running virtual machines with up to four virtual processors and 64 GB of memory per virtual machine.

The IBM System x3850 X5 is the fifth generation of scalable architecture from IBM, built on over forty years of innovation and virtualization experience. The following list details key features:

- Integrated Management Module, which supports out-of-band management and connectivity
- Industry-leading predictive failure analysis on all major components, which allows administrators to address reported issues before actual system failure occurs.
- Chipkill and ECC memory, which provides better memory reliability for the high demands of virtualization by detecting and correcting multiple-bit memory DIMM errors.
- IBM Memory ProteXion Redundant Bit Steering, which uses unused bits in memory as *hot spares* independently of the operating system (a benefit included at no additional cost).
- Memory mirroring and sparing technologies, which increases uptime and flexibility on scheduled maintenance windows.

A single x3850 X5 chassis consists of the following elements:

- Four Intel Xeon x7500 series processors with up to a total of 32 cores and 64 threads
- 64 DIMM slots that can be populated with 1, 2, 4, 8, or 16 GB DDR3 1066 MHz RDIMMS
- Seven PCIe 2.0 slots, one full-length x16, five x8, and one x4.

Storage

The IBM System Storage DS5000 sets new standards for performance, scalability, reliability, availability, and flexibility for midrange storage systems. As the most powerful IBM midrange storage system, the DS5000 is well-suited for virtualized environments that can keep pace with business growth.

Figure 2 shows the IBM System Storage DS5000.

Figure 2 IBM System Storage DS5000

Organizations can buy only the capacity needed, and can, without any system downtime, dynamically upgrade and reconfigure additional capacity and features to meet changing business requirements.

The DS5000 supports IT environment virtualization and consolidation by delivering industry-leading performance and is adept at supporting transactional applications (such as databases and On-Line Transaction Processing [OLTP] environments). The DS5000 is designed to provide the highest levels of reliability and availability, allowing it to meet the most demanding service level agreements (SLAs) based on the following technologies:

- Dual redundant controllers
- Two performance levels (DS5100, DS5300) with ability to field upgrade.
- Flexible host interface options are 8 Gb Fibre channel and iSCSI ready
- Up to 16 host interfaces and 448 FC/SATA drives using EXP5000 drive expansion units
- Up to 32 GB of dedicated data cache per controller
- Support of RAID 0, 1, 3, 5, 6, 10
- Remote volume mirroring and FlashCopy® premium features for Volume Shadow Copy (VSS) supported backups and flexible DR scenarios.
- Full Microsoft MPIO support through a custom device-specific module (DSM)
- Management support through Microsoft System Center Operations Manager (available 3Q10)

Microsoft Hyper-V

Microsoft Hyper-V is a native hypervisor, first released in September 2008, and significantly updated with the release of Windows Server 2008 R2. Hyper-V uses a 64-bit operating system environment running as one of the installed roles in the Windows Server 2008 R2 product in either GUI or Core configurations. It is also shipped as a stand-alone console-based hypervisor in the Microsoft Hyper-V Server 2008 R2 product. It is available for download from the following web page:

http://microsoft.com/hvs

Hyper-V can support the following host resources:

- Up to 8 processor sockets
- 64 cores or logical processors
- Up to 1 TB of memory (Standard Edition limited to 32 GB)

Virtual machines hosted by Hyper-V can support up to four virtual processors and 64 GB of memory, depending on the operating system loaded. Each virtual machine has its own operating system instance and is completely isolated from the host operating system and from other virtual machines.

HA features (such as Live Migration, Cluster Share Volumes, and VM Failover) are options available with the Enterprise or Datacenter Edition of Windows Server 2008 R2 with Microsoft Clustering installed.

The version of Hyper-V used for this paper is included in the RTM version of Windows Server 2008 R2 Enterprise Edition. The HA features (such as Live Migration, and VM failover) that rely on Microsoft clustering are only found the Enterprise and Datacenter versions of the product.

There are several significant improvements in this latest Hyper-V release that are key to this solution:

- Live Migration

  This provides the ability to move running VM between physical hosts.

- Cluster Shared Volumes

  This provides the ability for storage LUNs to be accessed by multiple physical hosts simultaneously.

- Second Level Address Translation

  This provides the ability for VMs to have direct access to their respective memory segments.

Proof of Concept

A proof of concept was conducted to validate the performance of large SQL servers consolidated using virtualization running Hyper-V on a pair of clustered IBM System x3850 X5 system attached to an IBM System Storage DS5300 SAN controller as host platforms. Sixteen virtual machines were created running Windows Server 2008 R2 operating systems. Each operating system instance ran SQL Server 2008 R2 executing an OLTP workload. Sufficient resources were reserved on the servers to allow for the ability to relocate all virtual machines to a single server if needed.

Figure 3 shows our test configuration.

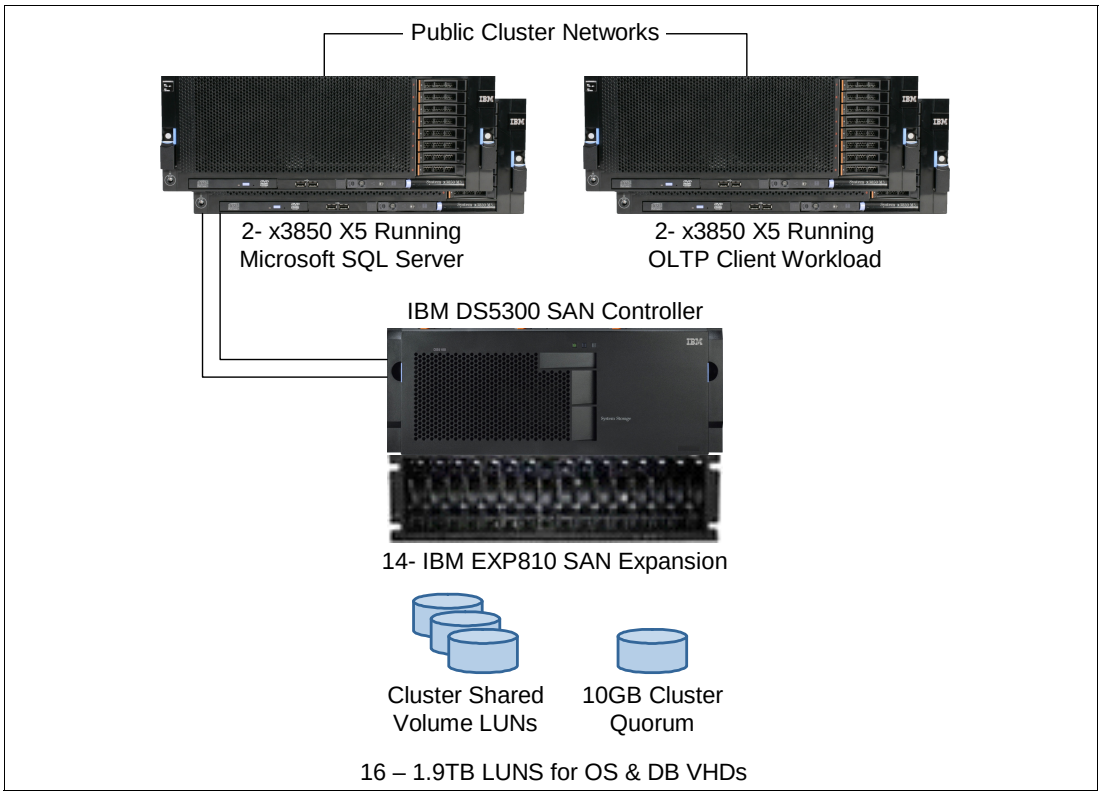

Figure 3 Host configuration

Tested consolidation environment

Our test configuration was made up of the following components:

- Two x3850 X5 servers in a 2-node (active/active) cluster:
  - Four Intel Xeon x7560 processors running at 2.26 GHz with 32 cores and 64 threads
  - 256 GB memory with 4 GB DDR3 106 6 MHz RDIMMs
  - One Emulex 8 Gb Fibre Channel Dual-Port HBA
  - 12 Gigabit Ethernet ports, supplied by:
    - One Broadcom dual-port Gigabit Network Interface Card (NIC) onboard
    - Five Intel Gigabit dual-port adapters
- One IBM System Storage DS5300 controller and fourteen EXP810 disk enclosures with 224 300 GB 15K RPM Fibre Channel drives
- 16 Hyper-V VMs with 4 virtual processors and 15 GB of memory

Eleven network connections were enabled (leaving one of the 12 ports unused):

- 8 ports for public cluster networks for SQL transactions (each port shared by two VMs)
- 1 port for the private cluster heartbeat network
- 1 port for the private cluster Live Migration network
- 1 port for the Hyper-V management network

Workloads

The 16 VMs were configured to run a typical OLTP workload. Several metrics (including CPU use, batch requests per second, and IO data) were measured as the load was scaled up from 1 VM to 16 VMs.

Host software

For the purposes of this proof of concept, each host used a version of Windows Server 2008 R2 Enterprise Edition installed, along with the Hyper-V role, and the clustering features enabled. The Public network cluster was connected to an Active Directory domain controller to support cluster operations, and a second Private network clusterwas configured to offload live migration traffic. Before the actual cluster was created, the Cluster Validation wizard was run from the Failover Cluster Manager tool to validate that the systems, storage, and networking met Microsoft requirements to support a cluster. The necessary Multi-Path IO (MPIO) drivers were also installed. Cluster Shared Volumes were enabled on the cluster to simplify LUN management.

Host configuration setup

Running SQL databases on clustered servers running Windows Server 2008 R2 with Hyper-V provided an HA environment with a reduced number of physical machines to manage. The active database servers were moved between nodes using Hyper-V Live Migration with no loss of connections or transactions. This capability greatly increases the database environment's flexibility, availability, and security in the following ways:

- Allows rapid provisioning of database servers as needed
- Provides a highly available environment with the ability to move servers among cluster nodes with ease, including
- Support for load balancing
- Maintenance support of physical machines
- Enables each server to maintain a degree of isolation.

Results

Using the IBM System x3850 X5 helps maximize HA processing capability with enough logical processors, memory, and I/O to host high-performance database VMs in a clustered environment. The physical Microsoft SQL servers were easily virtualized on the two x3850 X5 servers, leaving plenty of memory headroom (up to 1.5 TB with MAX5) for future growth. The proof of concept also demonstrated sufficient capacity to allow all VMs to be migrated to a single system if needed, resulting in fewer physical systems to manage, coupled with improved reliability, availability, and flexibility.

Figure 4 displays the linear scaling seen when placing all VMs on a single server and increasing the OLTP workloads across these VMs.

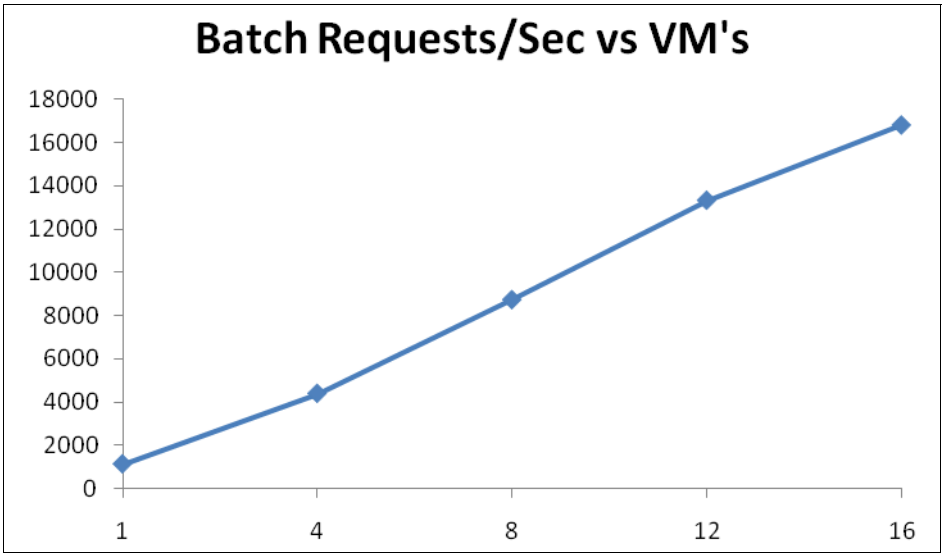

Figure 4 Total SQL Trans/Sec as number of VMs increased

Figure 5 displays this same linear scaling from an IOPS perspective.

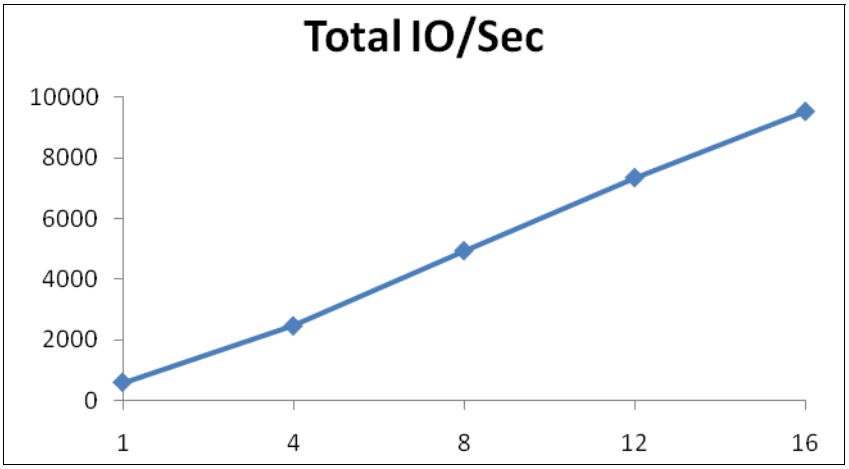

Figure 5 Total I/Os performed as number of VMs increased

Creating a high-performance VM environment is a new step for many enterprises. Experience in server consolidation can provide helpful familiarity with creating VMs, but might also encourage less beneficial habits. A high-performance VM environment can be set up using basic guidelines. Follow these guidelines using input gathered by profiling the physical systems being replaced, and by using input from the customer that is dependent on the VM.

Recommendations

As a result of our proof of concept, we can make basic recommendations for high-performance VMs such as Microsoft SQL Server:

- Minimize over-commitment of the logical processors on the host system.

  Traditionally, server consolidation for existing servers over-committed processors often ranging from three to four times each processor's capacity. These over-committed processors pay a performance penalty as they are switched between VMs, and have an even larger impact on high performance applications. For VMs running Microsoft SQL Server try to keep the number of virtual processors limited to 1–2 times the number of physical processors in the system depending on your workloads.

- Do not over-commit memory.

  In addition to memory allocated to the VMs, host systems need memory reserved to support virtualization operations. A good rule of thumb is to leave a minimum amount of spare memory equal to (`2 GB + number of VMs * 32 MB`) for the host OS. Reserve memory to support any additional VMs that might need to be migrated. If there is not enough physical memory for all the VMs, migration fails.

- Install the operating system for the VM on a dedicated fixed virtual hard disk

  Attach this virtual hard disk to the virtual IDE controller presented to the VM. Ideally, the virtual disk is backed by a fault-tolerant physical disk.

- Install applications on one or more dedicated fixed virtual disks

  Attach these virtual hard disks to a virtual SCSI controller presented to the VM, again backed by a fault-tolerant physical disk. Your I/O requirements help determine the number of spindles required to sustain operations at the desired throughput or latency levels.

- Allow for sufficient network I/O or even consider dedicated NICs for particularly heavy workloads.

  Physical NICs are used to create virtual network switches on the host, and can be assigned to VMs on an as-needed basis.

- Use a dedicated network for live migration

  Configure this as a second Private network in a cluster to keep live migration traffic off the cluster's Public network, and reducing the chance of cluster interruption.

- Configure storage arrays as RAID 10 to obtain best overall performance.

Summary

The IBM System x3850 X5 provides the processing power and reliability needed for consolidating large Microsoft SQL Server databases without compromising the performance of SQL database instances. Only with the release of the x3850 X5 can such servers handle the high demands on memory and I/O subsystems for such workloads.

System x3850 X5 server helps maximize the performance of highly available SQL Server VMs running under Hyper-V. The proof of concept depicted in this paper showed Microsoft SQL Server 2008 R2 running in 16 virtual machines with up to four virtual processors and 15 GB of memory each. These x3850 X5 servers can be configured with up to 1 TB memory (1.5 TB with MAX5) to enable you to consolidate much larger database VMs. For example, with this much memory, you can configure eight 64 GB VMs per host or 64x 16 GB VMs per host.

More information about IBM System x can be found at the following web page:

http://www.ibm.com/systems/x/

IBM System Storage DS5000 systems provide excellent performance, availability, and scalability for the most demanding Microsoft SQL Server applications. Additional guidance on deploying SQL Server on IBM System Storage products can be found at the following web page:

http://www.ibm.com/systems/storage/solutions/isv/#microsoft

Running Microsoft SQL Server in a VM might be well-suited for a large number of database server consolidation scenarios. A virtualized SQL environment can add reliability, can be easier to manage, and can reduce cost by using fewer physical servers, which in turn require less power, cooling, and physical space.

The team who wrote this guide

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