Virtualization in the Enterprise

Today most organizations understand the importance of implementing virtualization. Virtualization plays an important role in increasing ROI through server consolidation. Virtualization vastly speeds up the delivery of new servers in the enterprise by eliminating the need to acquire and install new hardware for each new application. More importantly, virtualization abstracts the server workload from the physical hardware, which enables increased availability enhancing disaster recovery capabilities, as well as increased infrastructure flexibility.

Consolidating workloads from multiple servers onto a single server increases the ROI for your servers by driving up the hardware utilization rate. Studies by several organizations, including Microsoft and Gartner, have shown that the average
hardware utilization rate of a typical server ranges from 10-15%. Virtualization increases server utilization to 75-85% making much more efficient use of the computing resources that your organization has purchased. However, consolidating multiple workloads can present performance challenges as well – especially for I/O-intensive applications like SQL Server. In this Essential Guide, you will learn about some of the necessary techniques to get the most performance out of your virtual SQL Server instances and see how to leverage virtualization to increase the availability of your mission critical database applications.

**Hurdles to SQL Server Virtualization**

While virtualization is a vital component to most IT infrastructures, there can be hurdles to virtualizing database servers like SQL Server.

- **Performance** — It wasn’t that long ago that SQL Server was a workload that businesses thought couldn’t be virtualized. SQL Server was considered too resource-intensive and the previous generation of virtualization platforms didn’t provide the required levels of performance and scalability. This is no longer the case. Nowadays, it’s common for SQL Server workloads to be virtualized. Only the absolutely highest-demanding workloads can’t be virtualized. Both Microsoft and VMware have publicly demonstrated virtual machines that have exceeded 1 million IOPS. In addition, today’s virtualization platforms support highly scalable virtual machines. Both Windows Server 2012 Hyper-V and VMware vSphere 5.1 support virtual machines with up to 64 virtual processors and 1 TB of memory.

- **Vendor support** — While most software vendors do not have any restrictions about running their applications on a virtual server, there are still some vendors that will not support a virtual environment. This is typically due to support or management concerns. Very seldom are there any actual technical restrictions that would prohibit an application from running in a virtual machine. This issue will continue to disappear as
most organizations consider virtualization as the standard practice for implementing new servers.

- **Complexity** — While virtualization offers many benefits, it also introduces a level of complexity that not all organizations are able to deal with. Smaller organizations in particular may not have the technical expertise available to create and manage a virtual environment. For these types of organizations public cloud offerings like Windows Azure SQL Database are an alternative to on-premise virtualization.

While there are hurdles, there’s no doubt that virtualization and SQL Server virtualization are core IT technologies that will continue to grow. In 2011 Gartner Reach predicted that 50% of all workloads would be virtualized by the end of 2012, which would equate to about 58 million VMs. This trend is expected to grow. Gartner predicted that by 2015 80% of all workloads will be virtualized.

**Processor Best Practices**

In order to support bare metal virtualization platforms like VMware’s vSphere Server and Microsoft’s Hyper-V you need to make sure that the virtualization host uses a 64-bit x64 processor. This can be either an AMD or Intel processor. In addition, for a resource-intensive workload like SQL Server it’s vital that host process provides support for Second-Level Address Translation (SLAT). SLAT is known by different names depending on the CPU manufacturer. Intel calls it Extended Page Tables (EPT) while AMD calls it Nested Page Tables (NPT) and Rapid Virtualization Indexing (RVI).

Virtual machines must use physical host memory and SLAT is mechanism that enables the CPU to maintain the mapping between the memory used in the virtual machines and the physical memory in the virtualization host. If this memory mapping function isn’t performed by the CPU then it must be performed by the hypervisor. Microsoft studies have shown SLAT reduces the hypervisor processing overhead to about 2% and simultaneously drops the host memory
requirements by about 1MB per running virtual machine. Today most modern server platforms come equipped with x64 processors that have SLAT support. However, if you’re considering virtualizing SQL Server using older systems this may not be the case. Many older x64 systems are lacking SLAT support.

SQL Server is able to take advantage of multiple processors and many instances take advantage of today’s SMP systems. The virtualization platform you choose makes a difference if you are implementing a SQL Server virtual instance that requires a high degree of scalability. Windows Server 2008 and 2008 R2 Hyper-V were limited to 4 virtual CPUs so there is a limit to scalability that your virtual SQL Server instances can have on that on those platform. Windows Server 2012 lifts this limitation by boosting the virtual CPU support to 64 virtual CPUs. VMware vSphere 5.0 supports 32 virtual CPUs while the newer vSphere 5.1 also supports up to 64 virtual CPUs.

For best performance you should ideally aim for a one-to-one relationship between the total number of virtual CPUs and physical processor cores. While not strictly required, having a one-to-one ratio ensures each virtual machine will continually have available processing power which is typically what you want for a resources intensive production environment like SQL Server.

**Virtual Memory Best Practices**

Memory is a key factor in SQL Server performance, whether it is a physical system or a virtual server. Inadequate memory can significantly impede SQL Server’s performance. Plus, physical memory is a limitation to how many virtual machines you can have active at any one time. You need to be careful to only allocate the amount of memory that is required for each virtual SQL Server instance but not to over-allocate as that would take memory away from other virtual machines. Dynamic memory provides a great solution to SQL Server’s need for memory and the need to share the same physical memory between virtual machines.

In order for SQL Server to take advantage of dynamic memory the guest operating system must be able to recognize hot-add RAM. To use dynamic
memory with Hyper-V the host must be running Windows Server 2008 R2 SP1 or later. In addition, the guest OS must support the ability to hot-add RAM. The following guest OSs can utilize hot-add RAM:

- Windows Server 2012
- Windows Server 2008 R2 SP1
- Windows Server 2008 SP2
- Windows Server 2003 R2 SP2
- Windows 8
- Windows 7 SP1
- Windows Vista with SP1

To take advantage of hot-add RAM in the guest OS, you need to be running the Enterprise Edition of SQL Server 2008, 2008 R2 or 2012 or you need the Datacenter Edition of SQL Server 2008 or 2008 R2.

When a SQL Server workload causes the sqlserver.exe process to grow, SQL
Server will detect the added memory and grow to meet the workload demand. SQL Server checks OS memory every second and dynamically adjusts its memory according to the available memory and the max server memory setting.

If VM guest memory decreases, it’s possible that the guest OS can page out parts of the SQL Server working set. If this condition happens it has a very negative impact on SQL Server performance. To prevent this from happening, Microsoft recommends using SQL Server’s Locked Page Memory Model setting to insure that SQL Server memory is never paged out.

Taking advantage of dynamic memory is an effective tool to making more efficient use of your virtualization host’s available RAM to grow guest memory when it’s needed and shrink it when it’s not.

![Figure 2 – Dynamic Memory](image)

**Tuning Storage for Performance**

Storage may be the most critical component for scalable virtualized application performance. Multiple virtualized SQL Server systems create a lot
of I/O contention on the host. When you create virtual machines that are intended to run SQL Server database instances there are some essential best practices that you need to follow.

Virtual Hard Disk Recommendations
There are three basic types of virtual hard disks that you choose for use with your virtual machines. This is true whether you’re using VMware vSphere or Microsoft Hyper-V. The three types of virtual hard disks are:

- **Dynamic** — The virtual hard disk is initially sized according to the actual guest operating system’s storage requirements and it can expand dynamically in response to increased storage requirements until it reaches its maximum allocated size.
- **Fixed** — The virtual hard disk is initially sized and allocated at its maximum size.
• **Differencing disks** — The virtual hard disk is initially created using a base image which serves as a parent. Then different child disks can be created that use the parent as a base and incrementally add different components.

Fixed virtual hard disks are the best choice for virtualized SQL Server systems that run a production workload. Fixed disks provide the best performance. Dynamic virtual hard disks are a good choice for labs, test environments or noncritical production workloads. Dynamic virtual hard disks use less disk space but they do not provide the same level of performance as a fixed hard disk. In addition, workloads running on dynamic virtual hard disks can experience occasional pauses when the dynamic disk needs to be extended. Differencing disks are really best suited for lab environments where disk space is at a premium. They use far less storage but they also have much lower levels of performance.

Another storage option that exists for virtual machines is to use Pass-through or Raw disks. Pass-through disks dedicate a portion of the host’s storage to the virtual machine. The storage can either be a physical disk internal to the host server or it can be on a Storage Area Network (SAN) Logical Unit (LUN) mapped to the virtualization server. Pass-through disk offer the highest level of performance for virtual machines storage. However, they don’t have the flexibility of a fixed virtual hard disk. Pass-through disks cannot be moved without incurring downtime and they do not support virtual machine snapshots.

The best practice is to use fixed virtual hard disks unless you absolutely must have the slight extra performance that’s afforded by pass-through disks. Dynamic disks are only suitable for test or non-mission critical workloads.

**SQL Server Guest Storage Configuration**

Just like the disk configuration in a physical server, the disk configuration in a virtual server can make a huge impact on performance. Improper virtual disk configuration is a common hurdle to the performance of virtual
SQL Server instances. If you accept the default configuration that’s offered by either VMware’s vSphere or Microsoft’s Hyper-V you’ll end up with a poor performing virtual SQL Server instance. This is because the default configuration only uses a single virtual hard disk for storage. If you accept this configuration your operating system files as well as SQL Server data and log files would all end up on the same virtual hard drive. This configuration would only be suitable for smaller low transaction types of SQL Server instances. Most production workloads with higher transaction rates would immediately run into disk contention issues.

For high-performance production virtual SQL Server instances it’s important that you separate your operating system, data file and log files on to different VHDs or pass-through disks. If you’re using a shared storage solution it is also important that you be aware of the physical disk implementation and make sure that the disks used for the SQL Server log files are separate for the disks used for the SQL Server data files.

Reducing Storage Maintenance with Automated Storage

One of the biggest factors that impacts application performance is the storage architecture and configuration. One of the challenges to maintaining high-performance is adapting the storage configuration to changing

Figure 4 – Example SQL Server virtual instance storage configuration
workloads and demands. Traditionally, SQL Server SAN storage was set up using a manual tiering process where the database objects with heaviest I/O like the transaction logs and tempDB were stored on high-performance drives while database objects like the SQL Server database files themselves were stored on higher capacity lower performance drives. Initially, this type of tiering setup requires significant storage usage analysis and over time demands change. This is particularly true in virtualization environment where there can be multiple virtual SQL Server workloads running all sharing the same backend storage. To maintain performance levels you need to perform an ongoing process where you analyze the storage requirements manually move objects to different tiers as required.

Technologies like automated storage tiering can dynamically maintain your storage performance levels without any manual intervention. Automated storage tiering technologies can automatically redistribute hot and cold workloads onto different levels of storage. For instance, your storage array might contain a combination of Flash and SATA drives. Automated storage tiering technologies can dynamically move your hot I/O intensive workloads to your high-performance Flash drives while the cooler workloads would be automatically moved to the lower performance SATA drives. Automate storage tiering dynamically adjusts the workload to the optimum storage making sure performance levels. EMC studies of their Fully Automated Storage Tiering (FAST) show that it can reduce database storage setup and deployment time by approximately 80% by automating the usage analysis and management tasks.

Utilizing High-Performance Server-Based Flash Storage

Server-based flash storage is another vital storage technology that can improve the performance of virtualized SQL Server instances. Disk rotational latency is one of the main issues database systems like SQL Server attempt to cache all of the data that they can. Accessing cached data (data in memory) is far faster that access data that’s stored on disk. Memory
access times are measured in microseconds while disk access times are measured milliseconds. Server-based flash storage technology can address this issue by treating flash media like an extension to system memory yet allowing applications to access it like standard block storage. This gives applications a significant performance boost by enabling them to access disk objects with in-memory speed. Because flash storage products are typically implemented using PCIe adapters they sit right in the system bus and bypass all networking overhead. The high IOPS performance delivered by flash storage makes is optimal for boosting the performance of database OTLP and reporting workloads. While flash storage can deliver extremely high IOPS to applications it is more limited in size than traditional disk storage. Because the data on the flash storage is not stored on any permanent disk storage it is usually best used for temporary data or data that is protected by mirroring. EMC’s XtremSF server-based flash storage product has been measured at providing up to 785,000 IOPS with data access latency as low as 30 microseconds. For organizations that want to maximize performance with server-based flash storage while still providing mission critical application protection EMC provides their XtremSW Cache software solution. When combined with XtermSF you can get the performance of flash storage combined with the ability to write the data through to persistent storage. EMC’s XtremSF soltuion is supported in Windows, Linux and VMware environments.

**Flash-Based Storage Arrays**

Another important storage technology that can have a huge impact on the performance of virtual SQL Server systems are flash-based storage arrays. Traditionally, storage arrays are optimized to provide efficient and high-performance storage access and in the past the storage has been mainly composed of disk drives. Newer storage arrays have provided a mix a high-performance SSD drives and larger capacity disk drives. The availability of larger capacity SSD drives has provided a foundation for an all new type
of 100% flash-based storage array. All flash-based storage can potentially provide far greater levels of performance than a traditional disk based storage array. The new all-SSD based arrays require very different mechanisms to efficiently read and write data than older disk based arrays. SSD drives utilize random I/O rather than the sequential I/O used in rotational drives. This means the new all flash arrays must be resigned for the ground up to optimize the random I/O. In addition to performance they also need to support many other features that enterprise have come to depend on like snapshots, deduplication cloning, thin provisioning and replication. One new example of this type of flash-base storage array is EMS’s XtremIO solution. EMC’s XtremIO is all flash scale-out storage array that was designed from the ground up to take advantage of SSD storage to provide an extremely high-performance and still provide enterprise features. XtremIO provides all of the capabilities like snapshot, deduplication and thin provisioning that you would expect in an enterprise storage array. Its scale-out architecture is built out of highly available, high-performance SAN appliances called X-Blocks. You can add multiple X-Blocks together with linear scalability. The scale-out array can deliver higher functional IOPS to OLTP applications like SQL Server that require high levels of random I/O performance. EMC tests showed the XtremIO system exceeds 150K functional 4K mixed read/write IOPS, and 250K functional 4K read IOPS for each X-Brick and over 1.2 million functional 4K mixed read/write IOPS, and 2 million functional 4K read IOPS when scaled out to a cluster of eight X-Bricks

Virtualization and Availability

One of the most important advantages in virtualizing your SQL Server systems is to ability to increase availability and provide flexible and fast disaster recovery capabilities. Virtualization can enhance SQL Server’s built-in availability methods plus VMs have additional capabilities that can enhance the business continuity of your mission critical database servers.
AlwaysOn Availability Groups

Arguably the most important new feature in SQL Server 2012 is the new AlwaysOn Availability Groups. SQL Server 2012 AlwaysOn Availability Groups addresses all the main limitations that are found in Database Mirroring. Database Mirroring was limited to a single database and two servers and you had to pick whether it operated synchronously for high availability or asynchronously for disaster recovery. AlwaysOn Availability Groups provides support for one primary replica and up to four secondary replicas where each replica is a separate SQL Server instance running on a Windows Failover Cluster node. More importantly, AlwaysOn Availability Groups can contain multiple databases all of which can be automatically failed over as a unit. This means that AlwaysOn Availability Groups can protect multiple related databases and fail them over simultaneously. It can provide both high availability and disaster recovery for multiple SQL Server databases. AlwaysOn Availability Groups works with both physical and virtual SQL
Server instances. For virtual instances those SQL Server systems can be on the same host or they can span multiple hosts and even multiple sites.

**Using Live Migration and VMotion to Reduce Planned Downtime**

Microsoft’s Live Migration and VMware’s VMotion let you move VMs between virtualization hosts with no downtime. These technologies enable you to perform planned maintenance on your virtualization hosts without any interruption of end user activities. You can be running multiple queries on a SQL Server system that’s being vMotioned or Live Migrated with no interruption of service—the queries will run to completion. Using Live Migration or vMotion you can move the VMs from the physical host that needs maintenance to another host. You can perform whatever hardware or software maintenance that the host requires and then migrate the virtual machines back to the original server when you’re done. Both vMotion and Live Migration can work with any version of SQL Server. The latest releases of Hyper-V and VMware have eliminated the requirement of having shared storage on the host and can perform live migration when the VMs are stored...
on file shares or even if there’s no common file shares between the hosts. vMotion and Live Migration significantly reduce planned downtime for virtualized SQL Server instances.

**Summary**

Virtualizing SQL Server provides many benefits over physical implementations. Consolidating multiple servers as virtual machines increases the ROI of your hardware platforms by increasing the utilization of the physical resources. It also reduces management overhead well as your IT infrastructure’s power, cooling and rack space requirements. Further, virtualization provides availability and disaster recovery features that are unavailable to physical SQL Server instances.

While SQL Server was once thought to be impossible to virtualize, advances in virtualization technology and today’s modern hardware platforms enable virtualized SQL Server systems to deliver performance levels that rival physical server instances. Virtual machines now support up to 64 virtual CPUs with up to 1TB of RAM providing scalability that’s able to meet all but the very most demanding workloads. Storage technologies like automated storage tiering, server-based flash and flash-based storage arrays can help you reduce storage management requirements, as well as significantly boost the performance of your virtualized SQL Server instances.
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