Why Hyper-V for VDI?

Microsoft Corporation

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Abstract

This whitepaper demonstrates why organizations should choose Microsoft® Hyper-V™ as their hypervisor when designing and implementing a Virtual Desktop Infrastructure (VDI) solution.

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Executive Summary

Choosing a hypervisor for deploying a VDI solution involves a number of important considerations, each of which can be fulfilled by using Microsoft's Hyper-V 2008 R2 SP1 hypervisor-based virtualization technology. When implemented together with the Microsoft System Center family of products and desktop virtualization technologies from partners like Citrix, organizations can build integrated VDI solutions that can meet the needs of your business while keeping costs under control. One factor important for ensuring a cost-effective VDI solution is the maximum VM density supported by the hypervisor.

Results from internal benchmark testing demonstrate that Microsoft Hyper-V 2008 R2 SP1 enables at least 40% higher VM density levels than Microsoft Hyper-V 2008 R2 for VDI environments having Windows 7 SP1 64-bit guests and a single virtualization host running on hardware from HP or Dell. Additional test results for VDI environments point to even higher VM density levels being achievable when Windows 7 SP1 32-bit guests are used instead of Windows 7 SP1 64-bit guests.

VDI was also tested using Windows XP SP2 guests with fixed amounts of memory assigned since Windows XP guests are not able to take advantage of the Dynamic Memory feature of Microsoft Hyper-V 2008 R2 SP1. The ability of Windows 7 SP1 guests to take advantage of Dynamic Memory provides a compelling reason for choosing Windows 7 instead of Windows XP as the guest operating system for VDI.

Test results were also obtained for VDI environments built using joint technologies from Citrix and Microsoft. The very high VM density levels achieved in the VDI environment clearly demonstrate the superior ability of integrated Citrix/Microsoft VDI even when running on minimal hardware. Finally, comparison with the behavior of third-party hypervisors demonstrates first, that Hyper-V provides a superior out-of-box experience with minimal tuning required; and second, that Hyper-V allows much faster recovery of the VDI user environment after a sudden and unexpected shutdown of the host.

The best hypervisor for VDI is one that allows IT to implement VDI solutions that are easy to engineer, easy to tune, easy to manage and support, and cost-effective to deliver. Based on the results obtained from internal testing and because VM density has a significant influence on datacenter cost structures; an integrated Citrix/Microsoft VDI solution that includes Microsoft Hyper-V 2008 R2 SP1 and System Center delivers unique end-to-end business value for organizations planning on implementing VDI.

The How and Why of VDI

Virtual Desktop Infrastructure (VDI) is an alternative approach to centralized desktop computing that allows users access to virtualized desktop computing environments ("virtual desktops") running on servers ("virtualization hosts") located in a data center. These virtual desktops can provide users with either pooled (shared) or personal (one-per-user) working environments depending on how the VDI solution is implemented.

Compared with a traditional PC deployment, VDI can provide your business with significant benefits, especially when centralized desktop management and security/compliance are key considerations for your business. For example, VDI can simplify desktop management by using a centralized desktop delivery architecture that centralizes the storage, execution and management of Windows desktops within the data center. And VDI can enhance security by providing users with completely isolated work environments while keeping sensitive business data safely located in the data center. VDI can also increase your business agility as by allowing users to access their desktop applications and user state (personal settings and data) from any connected endpoint device, managed or unmanaged, including standard PCs, thin clients, tablets/slates or mobile smartphones. VDI can also enhance business continuity and simplify disaster recovery, for should a user's device fail or be lost or stolen the user's virtual desktop remains available in the datacenter to be quickly accessed from another device.

But while VDI can bring significant benefits in some business scenarios, there are other scenarios where VDI is clearly not the best approach. For example, in task worker environments where users need access to a limited set of applications with minimal personalization, Remote Desktop Services (formerly Terminal Services), a mature technology included in Windows Server 2008 R2, provides a more cost-effective solution than pooled VDI because of its greater scalability.[1] Because VDI requires constant network connectivity between users' endpoint devices and the data center, VDI is also not suitable for mobile workers who require offline mobility. Instead, other desktop virtualization technologies such as Citrix XenClient, Microsoft Enterprise Desktop Virtualization (MED-V) or Microsoft Application Virtualization (App-V) can be implemented if mobile workers need access to virtualized desktops or applications when their endpoint devices are disconnected from the corporate network. Choosing the best approach to meet the specific needs of your business requires understanding the different types of desktop virtualization solutions available.

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[1] For a detailed comparison of the scalability of pooled VDI vs. Remote Desktop Services, see the whitepaper "Achieving Business Value through Microsoft VDI Together with Session Virtualization" available from http://www.microsoft.com/downloads/en/details.aspx?displaylang=en&FamilyID=391c0118-56f7-4026-8283-d5689d25518f.

Desktop Virtualization and VDI

Desktop virtualization refers to decoupling the different layers of the Windows desktop environment from the underlying hardware. With standard PCs for example, the system hardware and installed software are tightly bound together into a package that must be deployed and managed as a single unit. Desktop virtualization however is able to separate the user's operating system, applications and user state (personal settings and data) from the PC hardware, which can improve your business agility by enabling new models for providing services to users and by simplifying desktop and application deployment.

Desktop virtualization solutions can be implemented in several different ways depending on the needs of your business:

- **Server Hosted** - This approach to desktop virtualization is server-based and is the method used by VDI. Server hosted desktop virtualization can be a good choice for your business when centralized desktop management and security/compliance are key requirements. Depending on your choice of hypervisor, server hosted desktop virtualization can also be a viable alternative to standard PCs when users require a media-rich experience with a high level of personalization.
- **Session Virtualization** - This older server-based approach to desktop virtualization lets users access either entire Windows desktops or individual applications running remotely on data center servers. Session virtualization can be a good choice for businesses that need to support a large number of task workers. It can also be a good choice when you need to support contract workers given the ease of provisioning and isolation.
- **Client Hosted** In this approach to desktop virtualization, hypervisor-capable endpoint devices are used to host virtual desktops that are centrally stored and managed on datacenter servers. Client hosted desktop virtualization can help businesses resolve application-to-OS compatibility issues and provide their users with a secure personal space on their corporate PCs. It can also be used for supporting mobile workers and can be a good choice for development, test and demo scenarios.
- **Application virtualization** Application virtualization refers to a set of technologies that provide a way of running an application in isolation from other applications. With application virtualization, the application runs inside a virtual "sandbox" environment on the user's PC instead of needing to be locally installed on the PC. The result is that applications can no longer conflict because the underlying file system and registry settings on the user's PC are never changed—the user's operating system remains in a pristine condition. The ability this approach to dynamically stream applications to a user's PC can increase flexibility, speed deployment, and greatly reduce the IT labor needed to deploy and update applications.

Citrix/Microsoft Integrated Solutions

Regardless of which form of desktop virtualization you decide to implement, Citrix® and Microsoft together provide a wide range of integrated solutions that can help meet the needs of your business.

Citrix is the market leader in application delivery infrastructure and provides end-to-end delivery solutions that use desktop, application, and server virtualization to enable customers to increase the agility, performance, and security of Windows-based applications, while significantly lowering operating costs. And Microsoft is the market leader in desktop computing and offers technologies for virtualizing desktops, applications and user state to enable a broad range of different desktop virtualization scenarios including VDI. Key among Microsoft's technologies for implementing desktop virtualization is the Microsoft Hyper-V™ hypervisor, which has been enhanced in Service Pack 1 for Windows Server 2008 R2 and Microsoft Hyper-V Server 2008 R2 with two new features:

- **Dynamic Memory** lets you pool available physical memory on the host and dynamically allocate that memory to virtual machines based on workload needs. By enabling more efficient usage of physical memory resources, Dynamic Memory allows more VMs to be running simultaneously on a virtualization host without noticeable performance impact. This is important for the VDI scenario because it means fewer hypervisor-capable servers are needed in the datacenter for hosting large numbers of virtual desktops.
- **Microsoft RemoteFX™** is a feature of the Remote Desktop Services (RDS) server role. RemoteFX lets you provide users with a rich user experience when accessing virtual desktops from a broad range of endpoint devices. For example, using RemoteFX in a VDI environment, users can work remotely in a Windows Aero™ desktop environment, watch full-motion video, enjoy Silverlight animations, and even run 3D applications from any endpoint device.

Depending on the specific desktop virtualization scenario you plan on implementing, other Microsoft technologies you might use can include Microsoft Application Virtualization (App-V) for dynamically delivering Windows applications on-demand to endpoint devices; Microsoft Enterprise Desktop Virtualization (MED-V) for centrally managing and deploying client-hosted virtual desktops, Folder Redirection and Roaming User Profiles; Windows features that allow users to access personal data and application settings from any connected device; and Remote Desktop Session Host (RDSH), a role service of RDS that can provide users with access to RemoteApp™ programs and session-based desktops. For more information about Microsoft virtualization technologies and solutions, see www.microsoft.com/virtualization.

Citrix, a key partner of Microsoft in a relationship that has spanned more than 20 years, also offers a broad range of technologies for desktop, application and user state virtualization. Key among these is Citrix XenDesktop™ which lets you deliver media-rich virtual desktops and applications on-demand to connected endpoint devices using Citrix High Definition User Experience (HDX™) technology. Depending on your desktop virtualization scenario, other Citrix technologies you might use can include Citrix XenApp™ to deliver Windows applications over the network to endpoint devices; Citrix Receiver for provisioning virtual desktops/applications on any type of device; Citrix User Profile Manager for centralizing user personalization data and settings; and Citrix XenClient™ for provisioning client-hosted virtual desktops. For more information about Citrix solutions and technologies, see www.citrix.com.

Tying together all these different desktop virtualization technologies from Microsoft and Citrix is the Microsoft System Center family of products that can provide your business with a "single pane of glass" for managing both your physical and virtual infrastructures. System Center can meet a broad range of business needs, including:

- **Virtual desktop and application management** System Center Configuration Manager provides asset, application, usage, and desired configuration management for personal physical and virtual desktops.

- **End-to-end management of VDI infrastructure** System Center Operations Manager monitors state, health, and performance to ensure uptime and reduce overall cost of management.

- **Management of third-party VDI** For organizations with Citrix VDI solutions, System Center Virtual Machine Manager manages virtual machines and server utilization across the datacenter. Virtual Machine Manager integrates with Operations Manager to provide enhanced management for VDI scenarios, allowing performance and resource based allocation of virtual machines.

- **Compliance insight** System Center Service Manager and its IT GRC Process Management Pack use information collected from Configuration Manager, Operations Manager, and Active Directory to provide unified reporting and visibility of compliance in VDI environments.

For more information about the System Center family of products, see www.microsoft.com/systemcenter.

Choosing the Best Hypervisor for VDI

Since the hypervisor is a core component of any VDI solution, choosing the right hypervisor is a key consideration when planning a VDI solution for your business. To be suitable for VDI, the hypervisor platform should:

- Allow implementation of VDI solutions that are secure, scalable, and highly available.
- Perform well on a broad range of hardware and be able to take advantage of the advanced capabilities of the latest high-end processors.
- Provide high-speed access to virtual machine storage and high network throughput.
- Provide users with a full-fidelity virtual desktop experience across a wide range of endpoint devices in a way that closely mirrors what users are familiar with on standard PCs.
- Work out of the box with an optimal experience that does not require additional configuration to achieve high density and performance.

If we examine Microsoft Hyper-V 2008 R2 SP1 in detail, we see a close correlation between Microsoft Hyper-V 2008 R2 SP1 capabilities and VDI hypervisor requirements:

Requirement: *Allow implementation of VDI solutions that are security enhanced, scalable, and highly available.*

Microsoft Hyper-V 2008 R2 SP1 satisfies this VDI hypervisor requirement as follows:

- For greater security and easier maintenance, the Hyper-V role is available in the Server Core installation option of Windows Server 2008 R2. The Server Core option provides a minimal footprint environment that provides enhanced security by reducing the attack surface and lessens maintenance requirements by requiring fewer updates.
- For improved scalability, Hyper-V in Windows Server 2008 R2 supports for up to 64 logical processors in the host processor pool. Together with the new Dynamic Memory feature of Windows Server 2008 R2 SP1, this now enables significantly higher virtual machine (VM) densities to be achieved on your Hyper-V hosts.
- For increased availability, Hyper-V in Windows Server 2008 R2 supports hot plug-in and hot removal of Virtual Hard Drive (VHD) files and pass-through disks while a virtual machine is running. This allows you to quickly reconfigure virtual machines in order to meet changing workload requirements for your environment. Hyper-V in Windows Server 2008 R2 also supports Live Migration, which lets you move a virtual machine between two virtualization hosts with no interruption in service. Live Migration can use Cluster Shared Volumes (CSV), a new feature of Failover Clustering in Windows Server 2008 R2 that supports dynamic I/O redirection to improve cluster node connectivity fault tolerance for virtual machines running on the cluster.

Requirement: *Perform well on a broad range of hardware and be able to take advantage of the advanced capabilities of the latest high-end processors.*

Microsoft Hyper-V 2008 R2 SP1 satisfies this VDI hypervisor requirement as follows:

- For improved performance, Hyper-V in Windows Server 2008 R2 provides increased virtual machine performance on high-end servers that support Second Level Address Translation (SLAT). Virtual machines also consume less power because of the new Core Parking feature in Windows Server 2008 R2. And to ensure mobility across a broad range of hardware, the new processor compatibility mode for Hyper-V in Windows Server 2008 R2 allows you to perform live migrations across different processor versions within the same family, for example from Intel Core 2 to Intel Pentium 4 or from AMD Opteron to AMD Athlon.

Requirement: *Provide high-speed access to virtual machine storage and high network throughput.*

Microsoft Hyper-V 2008 R2 SP1 satisfies this VDI hypervisor requirement as follows:

- Windows Server 2008 R2 includes a number of performance improvements in storage solutions that can directly impact solutions built on Hyper-V. For example, Windows Server 2008 R2 provides improved performance when multiple paths exist between servers and storage; improved connection performance for iSCSI attached storage; improved storage I/O process performance; and reduced processor utilization to achieve "wire speed" storage performance.

- Hyper-V also leverages new networking technologies in Windows Server 2008 R2 to improve overall virtual machine networking performance. For example, the new Virtual Machine Queue (VMQ) feature increases network throughput and reduces CPU utilization on the host through a combination of reduced routing overhead and direct memory access (DMA), especially for 10 GbE networks.
- Hyper-V also provides support for up to 12 single processor virtual machines per logical processor when using Windows 7 SP1 guests.

Requirement: *Provide users with a full-fidelity virtual desktop experience across a wide range of endpoint devices in a way that closely mirrors what users are familiar with on standard PCs.*

Microsoft Hyper-V 2008 R2 SP1 satisfies this VDI hypervisor requirement as follows:

- The new RemoteFX feature introduced with Service Pack 1 for Windows Server 2008 R2 and described previously above can be used to implement VDI solutions that provide users with full-fidelity virtual desktops similar to what they experience on standard PCs running Windows 7. RemoteFX extends the benefits of VDI and session virtualization to a wide variety of endpoint devices ranging from high-end desktop PCs to extremely low-cost clients such as LCD display devices. The result greater flexibility and more choices for how businesses can use server-hosted desktops to meet the needs of their users.

Requirement: *Work out of the box with an optimal experience that does not require additional configuration to achieve high density and performance.*

As the benchmark testing and analysis described in the next section demonstrates Microsoft Hyper-V 2008 R2 SP1 satisfies this VDI hypervisor requirement as well.

VM Density Testing for VDI Using Microsoft Hyper-V 2008 R2 SP1

The remainder of this paper focuses on one specific but very important hypervisor requirement for VDI solutions: achieving the highest VM density on the host, which assists in driving down the cost per user metric. This hypervisor requirement is particularly important for VDI since more virtual desktops per host can mean fewer host machines required, which usually translates into lower costs for implementing the solution. To demonstrate that Hyper-V excels in this area, the section that follows provides evidence in the form of internal benchmark testing concerning the maximum achievable VDI densities

on Microsoft Hyper-V 2008 R2 SP1 hosts for both low- and high-complexity VDI solutions based on Citrix/Microsoft technologies.[2]

Overview of Testing Methodology

In order to determine the scalability of different hypervisors for VDI, Microsoft engineers set up a proof of concept full-scale lab environment and performed a series of tests on hardware from different vendors. Hyper-V tests were performed using Windows Server 2008 R2 SP1 Release Candidate running on identical hardware so that comparisons of maximum achievable VM density could be performed.

Two basic types of VDI test environments were set up in the lab. First, multiple environments each having a single virtualization host were used for testing the scalability of different hypervisors. The hypervisors tested in these environments included Microsoft Hyper-V 2008 R2 SP1 and third-party hypervisors from other vendors. Second, a single high-complexity environment consisting of eight Microsoft Hyper-V 2008 R2 2008 SP1 hosts, System Center Virtual Machine Manager, Citrix Desktop Delivery Controller, Citrix Provisioning Server, Citrix Web Server and Citrix License Server was set up for studying the scalability of a joint Microsoft/Citrix VDI solution.[3]

Initial testing was performed in each test environment to establish an optimal hypervisor configuration. Increasing workload testing was then performed until the targeted VM density was either achieved or not achieved under full workload stress. The test methodology used for measuring maximum achievable VM density relied on validation using the following tools:

- **Login VSI v 2.1.2**, a VDI workload generating tool from Login Consultants, was used to launch each VDI session and initiate a scripted workload that simulates actual use of each virtual desktop until either system saturation was achieved or the scripted workload completed. This particular tool was chosen for these tests because much of the industry now accepts this tool as the de-facto standard for user workload generation. A newer version of this tool having a slightly different workload profile was available in beta at the time our tests were performed, however many vendors still used version 2.1.2 for performing their tests and our goal was to be consistent with others in the industry. Full details concerning the workload used for these tests are outlined in Appendix A at the end of this whitepaper.
- **Performance Monitor**, a tool included in Windows Server 2008 R2 SP1, was used to measure key performance counters relevant to Hyper-V host and virtual machine performance.

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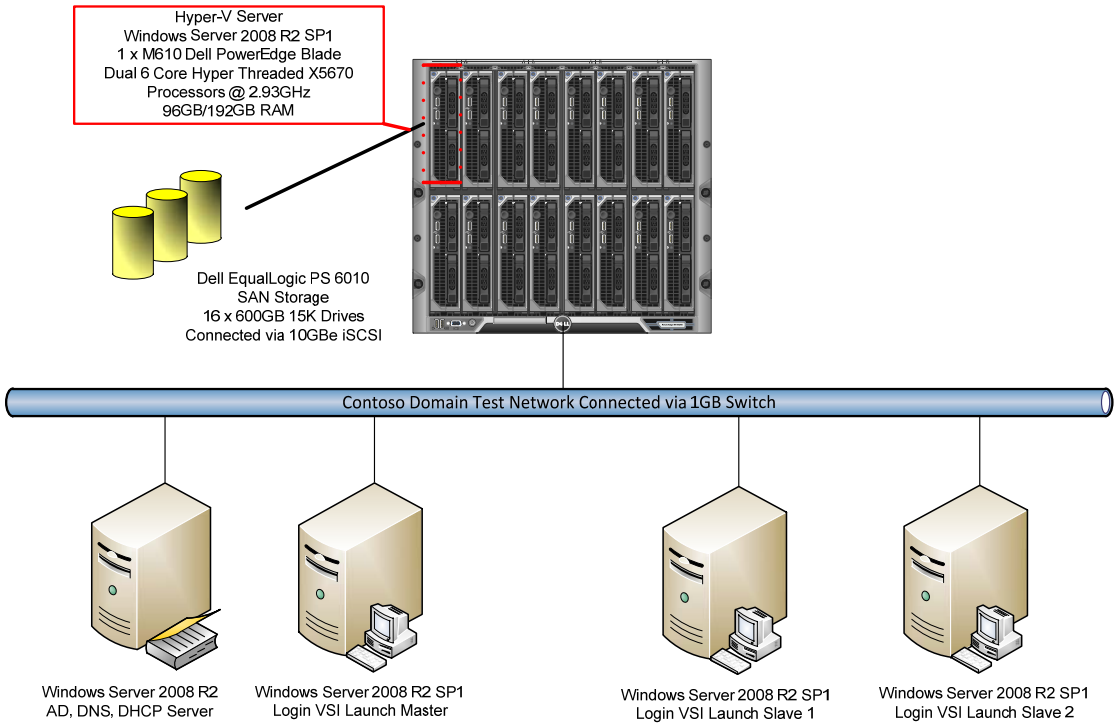
[2] Benchmark testing in a lab environment does not represent “real world” analysis. Microsoft bears no responsibility for any actions you may take based on the benchmark data included in this paper and recommends you perform your own benchmark testing and analysis as you approach the pilot phase of your VDI deployment.

[3] For comparison purposes, an additional environment was set up to measure the scalability of a session virtualization solution based on Windows Server 2008 R2 SP1 Remote Desktop Session Host, but the results of these tests are not relevant for this present whitepaper.

- **Dell SAN Headquarters SNMP Monitoring**, which was used to analyze performance directly at the SAN. This tool provided an understanding of disk IOPs, queue length and also helped to understand iSCSI network performance. This tool was only used during the Dell hardware testing.

The results presented below are for tests performed with the Microsoft Hyper-V 2008 R2 SP1 VDI environments.[4] The primary reason for focusing on these tests is that the results clearly demonstrate how Dynamic Memory can benefit VDI solutions by enabling significantly greater VM densities per host than Microsoft Hyper-V 2008 R2 RTM is able to support.

Figure 1 shows the setup used for determining maximum achievable VM density in a Microsoft Hyper-V 2008 R2 SP1 VDI environment. Initial testing was performed on an HP DL 380 G6 server with dual quad hyper-threaded (Nehalem) processors configured with 96 GB and connected via iSCSI to a 42 disk storage array configured as RAID 0 for maximum read/write throughput. Subsequent tests were performed using a single Dell M610 server blade connected via iSCSI to a Dell EqualLogic SAN where the virtual hard disks for the virtual machines are stored. Figure 1 shows the details of the VDI environment used for testing Microsoft Hyper-V 2008 R2 SP1 VM density using the latter hardware platform.



[4] Future whitepapers from Microsoft may focus on the results of the other VDI test environments studied.

Figure 1: Details of the VDI environment using Microsoft Hyper-V 2008 R2 SP1 as hypervisor.

In Windows Server 2008 R2 Hyper-V (RTM), the minimum supported memory per VM in a VDI environment for both 32-bit and 64-bit Windows 7 guests was 1 GB. In practice this meant that a virtualization host having 96 GB RAM like the ones used here could run at most around 85 to 87 concurrent VMs, allowing for spare capacity for the host itself. Using Dynamic Memory on Microsoft Hyper-V 2008 R2 SP1 and Windows 7 SP1 guests however, VMs can now be configured and supported with as little as 512MB of memory which can then utilize dynamic memory as needed. For comparison purposes, separate tests were performed using VMs running 32-bit and 64-bit versions of Windows 7 Enterprise with Service Pack 1 as the guest operating system.

Test Results for Windows 7 SP1 64-bit Guests

While the VM running Windows 7 SP1 64-bit would start successfully on 512MB of RAM, when the tests executed it was determined that each, on average, utilize about 725MB of system memory running under full workload when Dynamic Memory is enabled per VM. To allow for proper functioning of the host therefore, the following calculation was used to determine the initial VM density goal for Windows 7 SP1 64-bit:

96GB (system memory) – 9GB (for headroom) = 87GB (available for VMs)

87GB /725MB = 120 VMs (estimated)

Figure 2 shows the Login VSI response results for a test of 120 Windows 7 SP1 64-bit guests. The graph shows the minimum, maximum and average response time as more and more "users" successively log onto their virtual desktops and perform their "work" (both user and work are simulated using the Login VSI tool). The blue line in the graph is an index generated by the tool that measures response time, which reflects the latency users experience when executing their workload. Response time is measured in milliseconds and ranges from zero to a maximum of nearly 2000 milliseconds. The maximum acceptable response time (VSImax) for these tests was defined as 2 seconds.[5] If VSImax is reached more than six times during a test run, Login VSI considers the host to be saturated and the target VM density not to have been achieved.

[5] Login VSI uses 2000 msec for VSImax by default. In real-world VDI, the acceptable level of user latency will depend on expected user workload and will need to be established during pilot deployment.

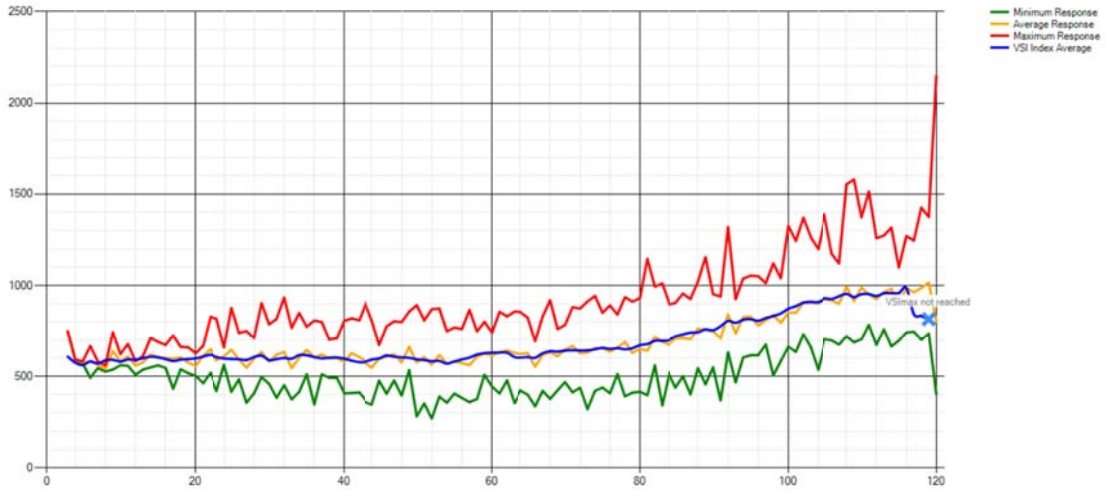


Figure 2: Login VSI results for a test of 120 Windows 7 SP1 64-bit guests.

As Figure 2 above illustrates, the response time is relatively stable and increases only gradually as more and more users log on to their virtual desktops, steadily increasing the load on the host. The Figure clearly demonstrates that the target VM density of 120 VMs running 64-bit Windows 7 SP1 virtual desktops has been easily achieved, which represents a greater than 40% improvement in maximum VM density resulting from using the new Dynamic Memory feature of Microsoft Hyper-V 2008 R2 SP1.

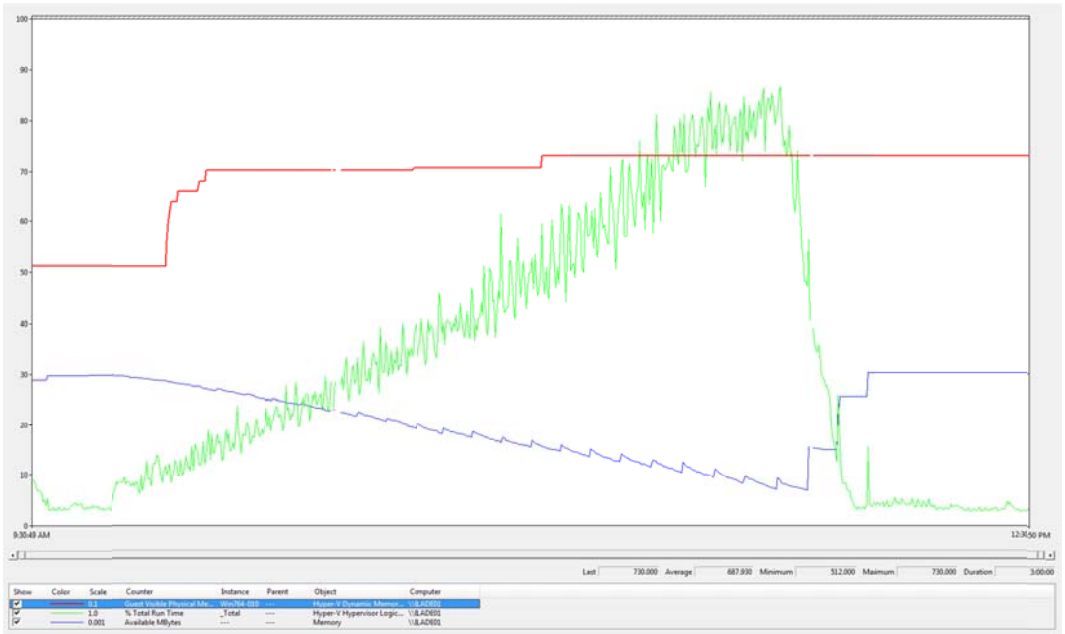


Figure 3: Perfmon log for a test of 120 Windows 7 SP1 64-bit guests.

Figure 3 above shows the Performance Monitor log collected on the Hyper-V host during this test. The red line represents the visible guest memory utilizing dynamic memory on one of the VMs during the

test. The dynamic addition of RAM from 512MB to 730MB happens when this particular VM began its test cycle. The blue line highlights the measurement of overall available memory on the host. You can see the available system memory decline as each VM begins its test cycle and begins to dynamically claim more system resources. Notice also the release off memory per VM back to the host as the test pass finishes. The green line shows the "% Total Run Time" counter which shows aggregate average usage over all of the host's logical processors. This counter tops out at approximately 88% near the end of the test and then quickly declines when all the test cycles have completed. The fact that % Total Run Time never reached 100% during this test suggests that it may be possible to achieve even higher VM densities on this particular host, depending on what users will consider an acceptable response time.[6]

Test Results for Windows 7 SP1 32 bit Guests

Similar tests to those performed for Windows 7 SP1 64-bit VMs determined that VMs running the 32-bit version of Windows 7 SP1 average only 540 MB of system memory under full workload with Dynamic Memory enabled. This immediately suggests that even higher VM density levels can be achieved by using 32-bit Windows 7 guests instead of 64-bit, assuming sufficient resources exist for processor capacity and disk. Nevertheless, for comparison purposes the same target VM density of 120 VMs was used for performing scalability tests with Windows 7 SP1 32-bit guests as was used previously for the tests with the 64-bit version of Windows 7 SP1.

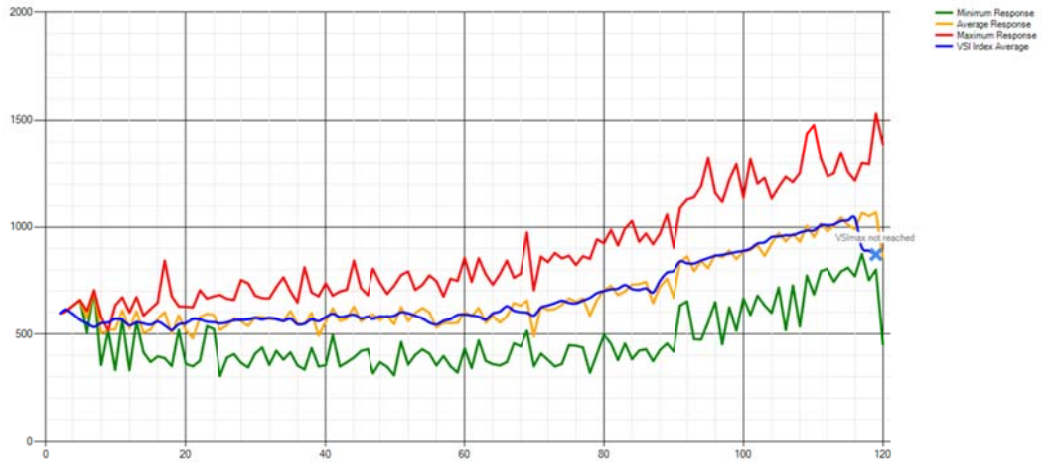


Figure 4: Login VSI results for a test of 120 Windows 7 SP1 32-bit guests.

Figure 4 above shows the Login VSI results for a test of 120 Windows 7 SP1 32-bit guests. As before, the blue line represents the response time or latency users experience when executing their workload. Just like the previous test using 64-bit guests, the response time is again relatively stable and increases

[6] For more information about Hyper-V performance counters, see http://blogs.msdn.com/b/tvoellm/archive/tags/hyper_2d00_v+performance+counters/

slowly as additional users log on. The target VM density of 120 VMs has again been easily achieved, which once again represents a more than 40% improvement in maximum VM density as a direct result of Dynamic Memory in Microsoft Hyper-V 2008 R2 SP1.

Figure 5: Perfmon log for a test of 120 Windows 7 SP1 32-bit guests.

Figure 5 above shows the Performance Monitor log collected on the Hyper-V host during the 32-bit test run. The red line again represents the visible guest memory of one of the VMs during the test; the bump from 512MB to 540MB happened when that VM began its test cycle. The blue line measures overall available memory on the host. It's significant to note that even at 120 guests and full workload the host still maintains around 30GB of available RAM. The green line again shows the "% Total Run Time" counter showing aggregate utilization of all guest over all logical processors on the host, and once again this counter tops out at approximately 88% near the end of the test. Clearly the presence of 30 GB of available RAM and the fact that % Total Run Time never reaches 100% clearly suggests even higher VM densities likely can be achieved on this host, again depending on what is considered acceptable response time for users.

Test Results for Windows XP Guests

As with the Windows 7 SP1 tests above, the environment for testing Windows XP guests was conducted on single Dell M610 Blade with 96GB RAM running Windows Server 2008 R2 SP1 with the Hyper-V role installed. Because older operating systems like Windows XP are not supported by Dynamic Memory, the testing for this scenario involved using 120 Windows XP SP2 32-bit guests each assigned 768MB of static RAM in Hyper-V Manager. All tests were considered a pass with workload level sessions and VSIMax was never achieved.

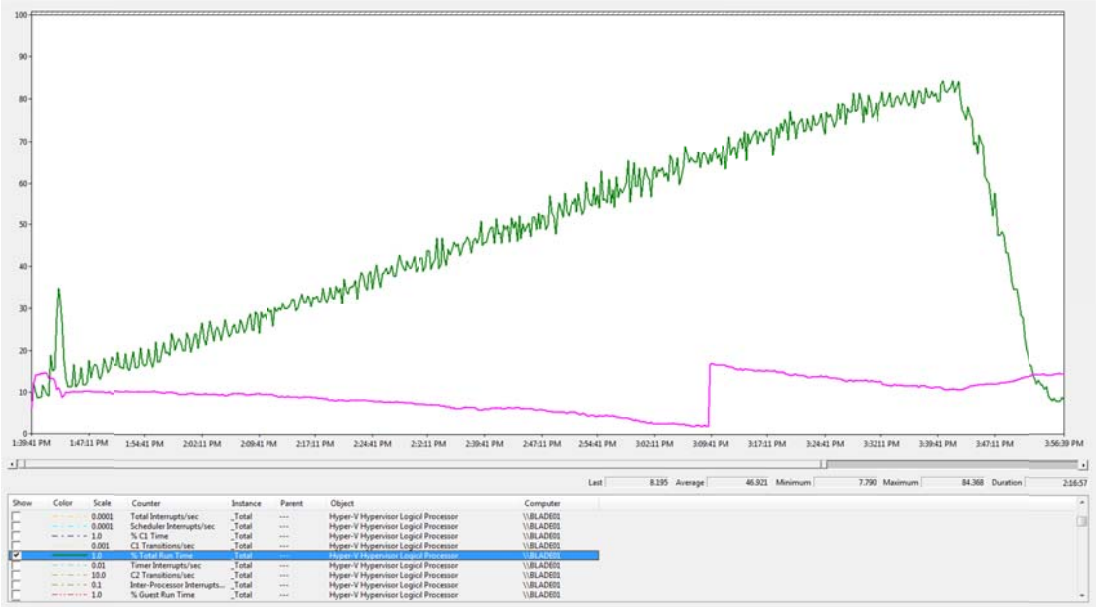


Figure 6: Processor utilization (green) and available system memory (pink) with 120 Windows XP SP2 32-bit guests.

Figure 6 above shows processor utilization (green) and available system memory (pink). These results show that the host is at maximum density and close to memory saturation. The test results for Windows XP guests indicate that it is possible to have 120 concurrent VDI workload level sessions against 120 Windows XP Virtual Machines residing on a single blade Microsoft Hyper-V 2008 R2 server using the hardware configuration described earlier. Good overall performance can be achieved using the out-of-box configuration of Microsoft Hyper-V 2008 R2 SP1, but VM density levels are static and rely on overall system memory because Windows XP is not supported with Dynamic Memory. Nevertheless, VM density levels for Windows XP guests are still good provided your hosts have modern CPU architectures and you allocate at least 768MB per client. However, because Windows XP guests are not able to take advantage of Dynamic Memory, the release of Service Pack 1 for Windows Server 2008 R2 provides a compelling reason for businesses considering implementation of a VDI solution to seriously consider using Windows 7 as their guest operating system for VDI.[7]

Test Results for Citrix/Microsoft VDI

The high-complexity VM density test environment was designed to provide VDI scale numbers matching those of a typical enterprise-class network. To create this test environment, Citrix XenDesktop 4

[7] Businesses who choose Hyper-V for VDI and still need Windows XP guests should consider an integrated Citrix/Microsoft VDI solution to take advantage of investments by Citrix in the area of VM density scalability. Microsoft's own investments in this area with Microsoft Hyper-V 2008 R2 SP1 targets only VDI guests running Windows 7 or later.

software was added to the environment and scaled up with more blades and EqualLogic SAN equipment so the virtual machines could be provisioned and streamed from the hosts to the clients. The intent was improving the original Dell reference architecture based on Microsoft Hyper-V 2008 R2 RTM that ran 1000 users on 12 blades down to 8 blades, taking into account the already tested configuration of 120 VMs per host. XenDesktop was used to provision all virtual machine instances from a single VM having Windows 7 SP1 as its guest OS using Citrix Provisioning Server. This approach dramatically decreased the VM replication and rollout time as well as the amount of storage needed for VMs. Testing was conducted from twenty-two Login VSI Launch workstations to achieve full system usage over time. Figure 7 shows the setup used for this environment:

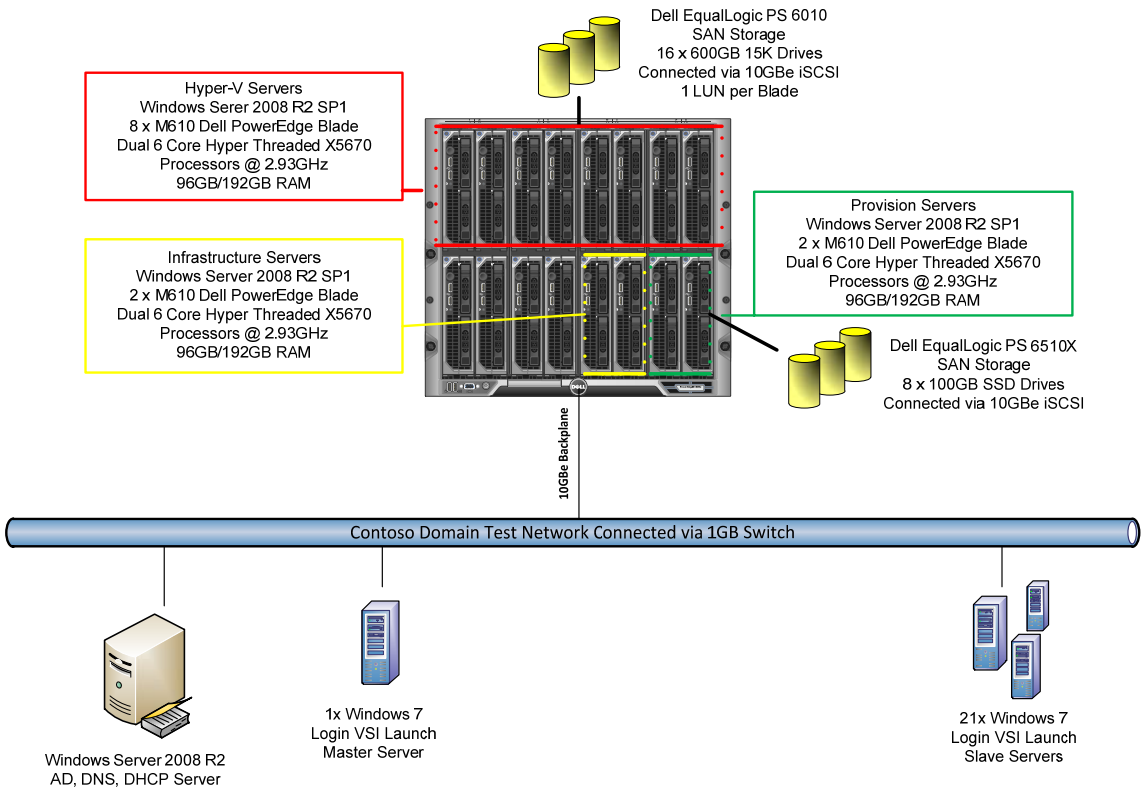


Figure 7: Details of the VDI environment using Citrix XenDesktop and Microsoft Hyper-V 2008 R2 SP1.

Figure 8 below shows the Login VSI results for a test of the combined Citrix XenDesktop and Microsoft Hyper-V 2008 R2 SP1 high-complexity VDI infrastructure. These tests successfully achieved the goal with 960 VMs running on 8 Dell M610 blades with 120 VMs provisioned per blade. The test is a pass and clearly shows the superior ability of enterprise-level infrastructure running on minimal hardware to provide an acceptable VDI user experience:

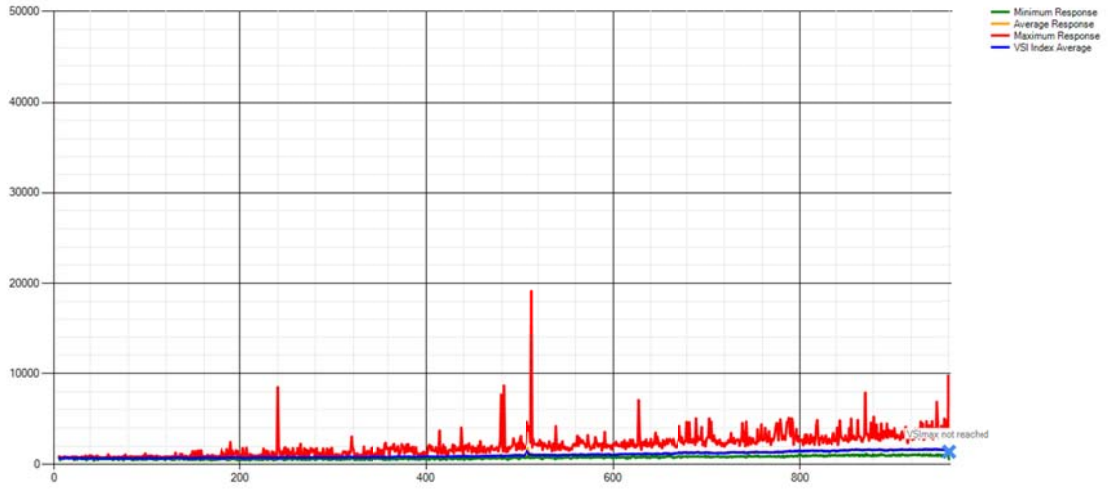


Figure 8: Login VSI results for a test of 960 Windows 7 SP1 32-bit guests running on a Citrix/Microsoft VDI infrastructure.

Additional Observations from VDI Testing

While achieving higher VM densities in various VDI environments was the primary focus of these tests, several other observations became apparent as the various tests were being performed. These observations are presented here as additional considerations when choosing a hypervisor for a VDI solution for your organization.

Hypervisor Out-of-Box Experience

The VDI tests performed using Microsoft Hyper-V 2008 R2 SP1 required no tuning at all in order to achieve their targeted VM densities, which were more than 40% greater than the VM densities achievable on pre-SP1 Microsoft Hyper-V 2008 R2 hosts. In other words, the Microsoft Hyper-V 2008 R2 SP1 hypervisor with Dynamic Memory enabled is well-tuned out-of-the-box to provide significant gains in achievable VM density while keeping response times under 2 seconds to ensure an acceptable user experience.

Microsoft Hyper-V 2008 R2 SP1 also exhibits native or near native performance in all areas of processor, memory and disk IO compared to a physically installed server. As disk IO performance is a critical factor in achieving density, it is important when conducting internal hypervisor performance analysis to pay careful attention to disk IO performance, especially disk queue length and disk IO latency. Microsoft Hyper-V 2008 R2 SP1 is very strong in this area which could support a significantly lower SAN investment or increased VDI density.

Hypervisor Time to Restore State from Failure

Our tests also suggested another consideration that might be important when selecting a hypervisor for VDI, namely, the time needed to restart and log on to all VMs on the host in an unplanned disaster recovery failover of the host. This time factor can be important because it affects the business continuity capabilities of a VDI solution by defining the window of service outage that can occur when a virtualization host unexpectedly shuts down, for example because of power failure, and live migration cannot be employed. By performing a one-off test involving shutting down the Microsoft Hyper-V 2008 R2 SP1 host in VDI environment, it was observed that it took about 15 minutes to restart the host, restart all the VMs on the host, and successfully log on to these VMs so that users could resume their work. While 15 minutes may sound like a long time to restart, other hypervisors may not allow a complete restart this fast, especially when scaled to high densities and high levels of memory over commitment. Dynamic Memory by contrast, delivers immediate memory management value and does not require additional computation to calculate memory gains as competitive solutions require. Clearly this is a significant issue that requires careful consideration in hypervisor choice as it can significantly impact business productivity in failover situations.

Business Value Impact of Choosing Hyper-V for VDI

Cost-reduction is frequently cited as a reason for adopting VDI, with customers indicating that through VDI they can deliver a rich-desktop experience to a user through a low-cost endpoint device. That approach to determining the value of a VDI implementation ignores a wide variety of important factors.

The traditional Total Cost of Ownership methodology typically assesses the “direct cost” impact of a technology investment – primarily the costs of hardware, software and IT labor. When considering the TCO of VDI, it is necessary to consider not only the hardware, software and labor costs of supporting the endpoints, but also the hardware, software and labor costs in the datacenter.

It is impossible to quantify specific cost impacts without considering the details of a specific configuration. Hardware configurations, software licensing models and management best practices directly affect cost-structures, often in non-linear ways. It is possible, however, to make some general observations about the TCO impacts of choosing Hyper-V for VDI:

- VM density has a significant influence on datacenter cost structures. VM density determines how much server capacity must be purchased, managed and supported for a given number of VDI clients. Whether used in a low- or high-complexity deployment, the testing has shown that Microsoft Hyper-V 2008 R2 SP1 delivered VM densities significantly higher than achievable on pre-SP1 Microsoft Hyper-V 2008 R2 hosts. For a deployment of any given size, these density improvements will allow customers to realize hardware and software cost savings compared to pre-SP1 hosts.
- While hardware and software costs tend to be associated with one-time deployment activities, IT labor costs occur throughout the lifespan of the solution. Solutions which require significant

up-front engineering and configuration can have two different effects on costs; either an investment in engineering effort is required up front, or an ongoing cost occurs due to elevated operations and support labor for a poorly implemented solution. The testing strongly indicates that Microsoft Hyper-V 2008 R2 SP1 delivers a well-tuned out-of-the box configuration with a minimum of up-front investment, as well as a steady-state platform with little requirement for ongoing performance tuning. This is the best of both worlds; a solution which can be deployed and managed with low incremental labor costs.

- The third major category of cost impact in a typical TCO analysis is the cost of support and remediation in the event of failure. This cost category considers not only the labor cost of IT staff involved in restoring service, but the impact of downtime on affected users and business processes. The testing found that if a failure did occur, VDI services hosted on Microsoft Hyper-V 2008 R2 SP1 could be restored quickly, resulting in reductions in both IT labor effort and end-user impact. The combination of resilience and rapid restoration of services represents a differentiating TCO benefit over the entire lifecycle of the implementation.

No matter how detailed, a TCO analysis cannot fully describe the impact of a technology investment. TCO only addresses budgeted line-item impacts, the model does not include non-monetary aspects of "business value". Based on research performed by Microsoft's "War on Cost" team, there are significant areas of business impact which, while not appearing on the IT budget, can make or break the question of whether or not the technology investment delivered "value" to the business. Considerations include:

- **Operational Agility** TCO analysis drives an IT-centric view of technology, but the most impactful technology investments are those which allow the business to respond rapidly to changing conditions, requirements and priorities. Because VDI services hosted on Microsoft Hyper-V 2008 R2 SP1 deliver solid performance out of the box, readily tunable configurations and dynamic use of system resources, IT gains an unprecedented ability to deliver agile, on-demand services to meet business needs. Those services can be delivered reliably, scalability and efficiently, with minimal incremental IT effort. That represents an enormous opportunity for IT to be a strategic enabler for the business.
- **Quality of Service** As noted above, resilience and service restoration have a direct-cost impact in a TCO analysis. Those same attributes drive non-monetary benefits as well. Testing indicated that VDI guests hosted on Microsoft Hyper-V 2008 R2 SP1 delivered exceptional performance at the endpoint, contributing to end-user satisfaction and improved productivity. In an environment where business processes are critical, Microsoft Hyper-V 2008 R2 SP1 enables a world class experience. In addition, because Hyper-V seamlessly integrates with the System Center suite of management tools, that service-quality can be monitored and managed through a single interface.
- **Risk Management** Disaster recovery – or, more specifically, the ability to rapidly restore end-user services in the event of a catastrophic event – is a key scenario for any VDI implementation. Using Hyper-V SP1 in conjunction with System Center Virtual Machine Manager, IT can rapidly provision virtual machines on diverse hardware platforms, managing physical and virtual

infrastructure resources seamlessly through a single integrated management platform. The new processor compatibility mode, for example, means that services can be restored and live migrations performed across different processor versions in the same family, alleviating the need to have "hot spare" hardware in exactly matching configurations.

Conclusion

The business value of a VDI implementation cannot be expressed with a simple deployment cost calculation. The full picture includes ongoing capital and operational costs as well as impacts on other pillars of value, such as operational agility, service quality and risk mitigation. The best hypervisor for VDI is therefore one that allows IT to implement VDI solutions that are easy to engineer, don't need custom tuning, easy to manage and support, and cost-effective to deliver.

The performance and density improvements delivered in Microsoft Hyper-V 2008 R2 SP1 unquestionably drive significant cost reductions in comparison to other VDI solutions, but when all the aspects of business value are considered the differences are compelling. As one customer recently reported, "With Hyper-V and Dynamic Memory, we've been able to consolidate our data center footprint by more than 50 percent, increase server capacity by about 35 percent, and reduce power costs by 33 percent" (Alan Bourassa, Chief Information Officer, EmpireCLS Worldwide Chauffeured Services).[8]

With the joint Citrix/Microsoft approach to VDI, businesses can leverage the enhanced VM density capabilities of Microsoft Hyper-V 2008 R2 SP1 to provide their users with the rich experience of Windows 7 using Remote FX while enabling IT to securely manage both their physical and virtual infrastructures using System Center. Through robust integration with Windows Server 2008 R2 and System Center management capabilities, and together with partner technology from Citrix, Microsoft Hyper-V 2008 R2 SP1 clearly delivers unique end-to-end business value for VDI that is second to none.

Additional Resources

For an overview of Microsoft's end-to-end VDI offering, see http://www.microsoft.com/windows/enterprise/solutions/virtualization/operating-system/.

[8] See http://www.microsoft.com/casestudies/Microsoft-Active-Directory-Domain-Services/EmpireCLS-Worldwide-Chauffeured-Services/Chauffeur-Service-Attains-Seven-Nines-Uptime-Less-IT-Work-by-Using-Virtualization/4000009115.

VDI case studies can be found at http://www.microsoft.com/casestudies/Case_Study_Search_Results.aspx?Type=1&Keywords=VDI&LangID=46.

VDI Standard and Premium Suite licensing details can be found at http://www.microsoft.com/windowsserver2008/en/us/rds-vdi.aspx.

Details concerning Windows Server 2008 R2 Hyper-V features and capabilities are available at http://www.microsoft.com/windowsserver2008/en/us/hyperv-main.aspx.

For information concerning Microsoft's System Center family of products, see http://www.microsoft.com/systemcenter/en/us/default.aspx.

Tips on how to tune System Center Virtual Machine Manager for VDI deployments can be found at http://blogs.technet.com/b/vishwa/.

For a technical overview of the new Dynamic Memory feature in Service Pack 1 for Windows Server 2008 R2, see the Dynamic Memory Technical Overview whitepaper which can be downloaded from http://download.microsoft.com/download/D/1/5/D15951B6-B33C-4A57-BCFB-76A9A6E54212/Implementing_and_Configuring_Dynamic_Memory_WP_SP1_final.pdf.

Information about the new RemoteFX feature included in Service Pack 1 for Windows Server 2008 R2 can be found at http://www.microsoft.com/windowsserver2008/en/us/rds-remotefx.aspx.

For information concerning Citrix desktop virtualization products and technologies, refer to the Citrix website at http://www.citrix.com.

Appendix A: Login Consultants Medium Session Workload

The following details describe the scripted workload performed against each VDI virtual desktop using the Login Consultants Medium Session Workload Tool (Login VSI v 2.1.2).

- Emulates a medium knowledge working using Office, IE and PDF.
- Once a session has been started the medium workload will repeat every 12 minutes.
- During each loop the response time is measured every 2 minutes.
- The medium workload opens up to 5 apps simultaneously.
- The type rate is 160ms for each character.
- Approximately 2 minutes of idle time is included to simulate real-world users.
- Each loop will open and use:
    - Outlook 2007, browse 10 messages.

- Internet Explorer, one instance is left open (BBC.co.uk), one instance is browsed to Wired.com, Lonelyplanet.com and heavy flash app gettheglass.com (not used with MediumNoFlash workload).
- Word 2007, one instance to measure response time, one instance to review and edit document.
- Bullzip PDF Printer & Acrobat Reader, the word document is printed and reviewed to PDF.
- Excel 2007, a very large randomized sheet is opened.
- PowerPoint 2007, a presentation is reviewed and edited.
- 7-zip: using the command line version the output of the session is zipped.