Using Virtual Machines

to Simulate Complex IT Environments

Technical and business solutions designed for today's complex enterprise networks require in-depth testing and validation before release. Real-life scenarios must be simulated during the test cycle—the larger the application scale, the more complex the test environment. This article suggests a method for addressing many of the needs IT administrators encounter when creating complex test environments that comprise multiple networks, servers, and clients. The proposed approach uses hardware virtualization technology to help reduce the costs, resources, and setup time associated with enterprise software testing.

BY AURELIAN DUMITRU AND J. CRAIG LOWERY, PH.D.

Many software products are designed to function as part of a large, distributed network infrastructure. To help ensure that they will perform as expected, such applications must be tested in complex IT environments that simulate real-life scenarios. This article examines the test environment for a product that interfaces with Microsoft® Active Directory® directory service. In this scenario, Dell engineers scrutinized both the reliability of the product interface—that is, its ability to discover a domain controller—and scalability features such as schema changes and functionality in a multidomain, or *forest,* environment.

The product test bed comprised the following:

- One root primary and one backup domain controller
- One Domain Name System (DNS) server
- Several organizational units, each with a few user groups
- A subdomain (such as a departmental domain) serving several remote user groups

More advanced testing required that multiple domain trees run side by side, and that the product function appropriately when trusts between the domain trees were created. The test plan also called for evaluating the product in mixed-performance environments such as networks comprising local area networks (LANs) and wide area networks (WANs).

The scope of this test plan necessitated a large, complex network that could approximate a production environment. Active Directory infrastructures are usually created with tens or even hundreds of computer systems connected in a multiple-segment, multiple-subnet configuration. These environments are typically found only in medium and large corporations and are generally too expensive to set up for testing purposes because of the large number of physical systems required—including servers, client workstations, network routers, and switches. Aside from the cost of the equipment itself, the time to install many different systems can be prohibitive. Hardware virtualization technology can help test engineers simulate complex IT environments by significantly reducing the cost of physical hardware and the time and resources needed to deploy it.

Understanding server virtualization

At the heart of the virtualization concept is the idea that a single physical server can appear to be multiple physical servers, called virtual machines (VMs), as shown in Figure 1. The physical server hardware layer at the bottom of the figure comprises a standard Intel® architecture–based system such as a Dell™ PowerEdge™ server. The virtualization layer comprises software that creates the VMs by multiplexing the physical resources of the underlying server. For example, the physical processor is time-shared, the memory is partitioned, and network traffic is interleaved across the VMs.

Within the virtualization layer, an interesting extension to networking is possible: Virtual networks enable administrators to create multiple subnetworks of VMs, completely contained within one physical system. The virtualization layer can provide gateway services between virtual networks, or between a virtual network and a network external to the physical server. Dell engineers made extensive use of the virtual networking feature when simulating the complex IT environment described in this article.

The manner in which physical disk storage is shared is particularly important. To understand why, first consider that an operating system (OS) installed directly on a physical server maps the blocks of physical disk space into a file system. If all physical disk blocks were serialized into a single structure, the structure could exist as a single file in a larger, encompassing file system. The virtualization layer creates virtual disks in this manner. Each VM has a large file—a virtual disk—that functions as a block-mapped device.

Virtualization layers can be implemented either as special-purpose operating systems, as with VMware® ESX Server™ software, or as applications running on a general-purpose OS.

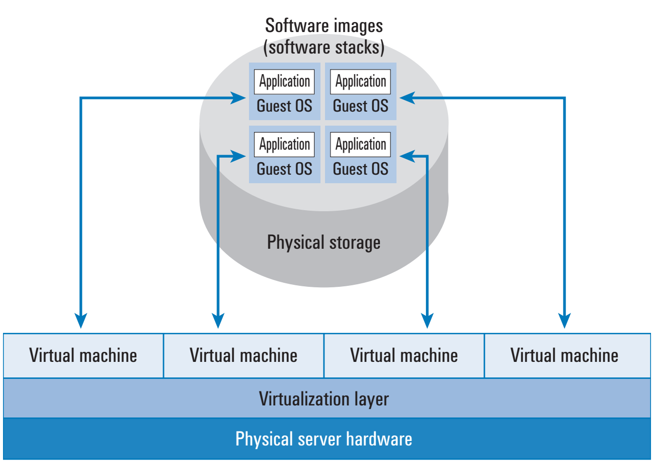

Figure 1. Hardware virtualization architecture

Hardware virtualization technology can help test engineers simulate complex IT environments by significantly reducing the cost of physical hardware and the time and resources needed to deploy it.

VMware GSX Server™ software and Microsoft Virtual Server software are examples of the latter. In either case, administrators can install software applications on a VM in the same way as on a physical server. Each OS installed on a VM, or *guest OS*, can contain one or more applications. Furthermore, a mixture of Microsoft Windows®, Linux®, and Novell® NetWare® operating systems can reside on a single physical server. The file containing a VM's guest OS and applications is called an image, or *software stack,* and sometimes simply a VM (although technically, a VM is the virtualized hardware and not the software stack that it executes).

Hardware virtualization offers many important benefits—such as consolidation, normalization, isolation, replication, and relocation—that affect not only the creation of complex test environments but many other applications as well. For example, hardware virtualization can enable organizations to reduce the total number of physical systems through *consolidation*. The software stack on each VM "sees" the same virtual hardware regardless of the actual underlying physical hardware because of the *normalization* that the virtualization layer provides. VMs do not interfere with each other and interact only through intended network communications because of the *isolation* that the virtualization layer imposes on each VM. A software stack for which multiple instances will be needed can be cloned by copying the virtual disk's file, allowing for quick *replication*. Finally, because virtualized hardware is the same across all physical systems, VMs can benefit from easy *relocation*—the capability to move a VM from physical server to physical server as needed, either by moving the virtual disk file or by placing the virtual disk file on network shared storage.

Creating the virtual test environment

When Dell engineers built the test environment for the scenario described in this article in January 2004, they relied heavily on three key virtualization benefits: consolidation, isolation, and replication. These features can help reduce the setup time and resources required for large-scale testing.

Consolidation. One inhibitor to creating the physical test environment for a large-scale enterprise application was the sheer number of physical systems required. Although theoretically all the systems could be consolidated onto one large physical server using

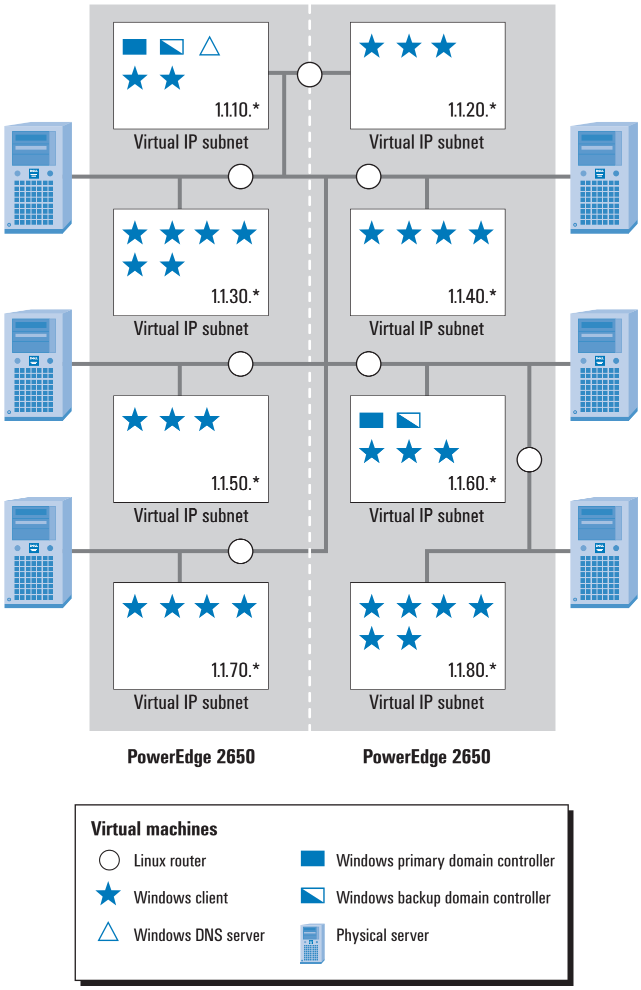

Figure 2. Virtualized network test environment for Active Directory client

virtualization technology, some limitations exist. In all cases, the number of VMs that can be hosted depends on the physical capacity of the underlying server and the aggregate workload characterization of the VMs. For this particular test case, engineers determined that between 10 and 20 VMs could easily coexist on a single PowerEdge 2650 server. And this scenario presented an additional constraint: The product being tested is a physical hardware component and must be installed in a nonvirtualized environment. Therefore, the systems on which the product under test was installed had to be physical systems. However, the rest of the test bed, comprising domain controllers, client workstations, and network routers, did not have the same physical dependency and could be consolidated onto two physical systems.

Isolation. Because virtualization enables multiple, potentially different operating systems to run simultaneously on the same physical server without side effects, the many types of systems found in a heterogeneous network environment can be created virtually. The domain controllers for this test environment as well as client workstations were hosted by virtualized Microsoft Windows 2000 Server systems, and the network routers were virtualized Linux routers. An important aspect of this test environment is that the fact that these systems are virtualized is transparent to other servers, both virtual and physical. For all practical purposes—such as communicating with other virtual and physical systems—VMs have the appearance and functionality of physical systems.

Replication. For this scenario, test engineers needed to construct many instances of domain controllers, client workstations, and network routers. However, they needed to create only one "reference" software stack for each of these categories. Once built, each reference stack was cloned simply by copying and then personalizing the file with a configuration specifying details such as virtual machine ID and network name. Dell engineers used this method to create as many instances of each component as needed.

Figure 2 shows the implementation details for the virtual environment used to test the Active Directory client product. Physical servers on which the product was installed are indicated along the right and left sides of the diagram. The large box in the center shows all of the VMs, in this case distributed across two Dell PowerEdge 2650 servers—each with dual Intel Xeon™ processors, 8 GB of memory, six physical network interfaces, and 138 GB of hard disk space—running VMware ESX Server 2.0.1 software.

The virtual IP subnets contained various VMs that are depicted in Figure 2 as stars, triangles, and rectangles. Six of the eight subnets (1.1.30.* through 1.1.80.*) were connected to both virtual and physical systems. The routers, represented by circles between the virtual subnets, were implemented as VMs running the Linux OS configured as a software router. Although not as fast as the hardware equivalent, a software router—regardless of the implementation, virtual or physical—offers an important benefit: control over the latency of network communication. This software router configurability played an important role in simulating the communication latencies found in LAN and WAN environments.

Evaluating the virtualized Active Directory test environment

The test plan required that engineers simulate an Active Directory domain (including subdomains) with up to 25 users. Figure 3 presents the relevant information for evaluating the impact of virtualization in creating the Active Directory test environment. Comparing an all-physical setup with the hybrid physical-virtual setup used in this test environment shows that virtualization can help reduce deployment efforts and associated costs, and simplify changing test configurations.[1]

[1] For more information, see "Introducing VMware ESX Server, VirtualCenter, and VMotion on Dell PowerEdge Servers" by Dave Jaffe, Ph.D.; Todd Muirhead; and Felipe Payet in *Dell Power Solutions*, March 2004.

Comparison criteria	All-physical setup	Virtual-physical setup
Initial setup time and associated costs	With all equipment at hand, the physical setup can take anywhere between 24 and 40 hours.	VMs can be easily cloned, which enabled engineers to grow the test configuration from one to 25 clients in about two hours. Each VM is essentially a file that can be manipulated through standard file-copy commands. Each time a VM is cloned through this method, an extra step is required to personalize the new VM. Besides saving time on wiring, copying and personalizing each VM takes only about five minutes as opposed to running a standard installation (at least 20 minutes for Windows 2000 Server, for example). Overall, it should take fewer than 16 hours to deploy hardware to be tested; install ESX Server software; create master copies of the main components: domain controller, DNS server, Dynamic Host Configuration Protocol (DHCP) server, client, and router; clone the VMs as necessary; and check the functionality of the entire system.
Ease of switching test configurations	Switching between test configurations may require rewiring some or all of the systems. Depending on the specific configuration needs, it could take from two hours to a day or more to rewire, change IP addresses, and so on. For example, changing the authentication mode from in-domain to cross-domain may require moving the component under test to a different subnet.	Virtual networks enable network configuration changes to be accomplished in a matter of minutes by bringing up the ESX Server Web console, identifying the VMs that require network configuration changes, and effecting the changes. Depending on the specific configuration needs, new virtual network adapters may need to be created and assigned to specific VMs.
Equipment	Implementing a physical setup comparable to the virtual-physical test environment described in this article would require procuring at least 10 servers, 25 workstations, 8 routers, LAN cables, and so on.	Two PowerEdge 2650 servers can host all the servers, workstations, and routers for the virtual-physical test environment described in this article.
Support effort	The larger the physical test infrastructure, the more time and effort it requires for support and maintenance.	Less hardware requires less support and maintenance. Moreover, if a VM goes down, it can be cloned immediately, reducing overall downtime significantly.

Figure 3. Evaluating virtualization benefits in achieving the base requirement

Figure 4 highlights the benefits of rapid replication in meeting the second test requirement: to create multiple domains. The findings of this test case indicate that cloning allows the virtual infrastructure to be quickly extended, creating additional domains simply by cloning existing domain infrastructure.

As demonstrated by the scenario described in this article, hardware virtualization offers many advantages for building complex test environments. By lowering initial and subsequent setup times, reducing the need for hardware, and decreasing the support effort for large test beds, virtualization can help minimize testing costs and favorably affect schedules—potentially helping to improve time to market for technical and business software products.

Beyond the creation of test environments, hardware virtualization offers many other potential enterprise benefits. For example, reducing the number of physical servers through consolidation can reduce capital and operating expenses as well as ongoing maintenance costs. In addition, managing VM workloads dynamically across the data center can help increase uptime and enable IT organizations to respond quickly and flexibly to business-critical computing demands across the enterprise.[2]

Comparison criteria	All-physical setup	Physical-virtual setup
Initial setup time and associated costs	The same amount of effort must be spent to create each new domain. Nothing can be reused.	Cloning VMs enabled engineers to create each new domain component in a matter of minutes without incurring the time and expense of physical reconfiguration.
Equipment	The more domains that need to be deployed, the more servers are needed.	Two PowerEdge 2650 servers per domain satisfied the requirement more cost-effectively than a rack of server equipment.

Figure 4. Evaluating virtualization benefits in achieving the scalability requirement

J. Craig Lowery, Ph.D. (craig_lowery@dell.com) is a senior engineering development manager in the Dell Product Group—Enterprise Solutions Engineering. His team is currently responsible for developing products that realize the Dell vision of the scalable enterprise. Craig has an M.S. and a Ph.D. in Computer Science from Vanderbilt University and a B.S. in Computing Science and Mathematics from Mississippi College.

Aurelian Dumitru (aurelian_dumitru@dell.com) is a senior software engineer with the Custom Solutions Engineering team at Dell, where he works to deploy and customize systems management solutions for medium to large enterprises. Before joining the Custom Solutions Engineering team, he was lead engineer for the Remote Management Delivery team. Aurelian has 12 years of experience in hardware, software, and system design and integration and has two patents approved. He has an M.S.E.E. degree from the Technical University of Iasi, Romania.

FOR MORE INFORMATION

Dell and VMware ESX Server:
http://www.dell.com/vmware

[2] For more information, see "Virtualization as an Enterprise Computing Infrastructure" by J. Craig Lowery, Ph.D., in *Dell Power Solutions*, June 2004.