Virtual Network Lab Survey

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The following paper looks at the available options in creating a virtualized network lab for use by students and professors alike to create a safe, destructible environment from which to learn networking. For hypervisors, a review of various hypervisors was taken. Hypervisors included in the survey are Microsoft Hyper-V, Citrix Xen, Xen.Org, Marionnet, and VMWare. Following will be a short conclusion offering a proposed solution to the lab.

VMware

VMware is one of the first companies to market with a virtualization engine. VMware has earned a reputation for bringing forward some of the most powerful virtualization software available. Today, armed with a portfolio of technologies that span from the traditional (VMware ESXi) to new frontiers breaking traditional molds (VMware vFabric), the company provides a broad range of products and services to help companies tackle every tier of the virtualization market from legacy support through ThinApps, to High Availability through vCloud and vStorage.

VMware provides a suite of tools and software that a virtual networking lab could take advantage of. Of particular use to at least deploy a lab will be VMware ESXi, which is now known as the vSphere Hypervisor. vSphere Hypervisor is VMware's traditional bare metal hypervisor that allows for the virtualizing of several distributions that would be used in a typical lab setup. This allows for a large range of control, and will enable the use of virtualized networks for segmentation, as well as the proper centralized support through vSphere management.

Some things that will be of benefit to the project will be VMware's ability to oversubscribe memory. One of the many issues plaguing virtualization is wasted resources,

especially memory. Systems may require or run better with large amounts of memory, but not all the time. For instance, in a class room full of systems, VM's will need varying amounts of memory likely around 1GB per VM. But many VM's will sit idle while others will be doing low-intensity work with just a few needing high demands. VMware's memory management feature allows all VM's to have 2GB's of memory available, but oversubscribe the memory based on the idea that not every system will need 2GB of memory all the time. This would allow, for instance, 20VM's to share a 32GB pool of memory whereas otherwise ensuring that each VM had access to 2GB of memory would have limited the VM number to only 16.

Indeed, a cursory glance at VMware, vs. Hyper-V, vs. Citrix Xen, shows that VMware has some key advantages over the others. For one, vSphere ESXi is the only major product that is a bare metal Hypervisor 100%. Hyper-V requires Windows Server 2008. Even in virtualization focused Hyper-V Role, much of Windows Server 2008 has to be installed for this to function. In contrast, Citrix Xen also requires a Linux installation in its management partition. Ultimately, this means that ESXi only requires 144MB to install, while Hyper-V requires at least 3.6GB and Xen requires a Linux install that will require at least more than 1GB of space. In resource use, this puts VMware at a clear advantage. (VMWare)

Advanced memory features that make huge advances for something like a lab setup include RAM over-commitment, transparent page sharing, memory ballooning, memory compression, hypervisor paging, and resource shares. Specifically, transparent page sharing is hugely usable for a lab, where almost every VM will be the same OS. VMware allows for memory pages that match to be shared, saving valuable memory space. This

means that in a classroom running 15 VM's that are all the same (say 15 Windows 7 images), then the memory pages can be shared amongst all the VM's, drastically cutting on memory usage. According to VMware documentation, this could be up to 30% memory savings on a memory constrained host using very similar VMs. Most importantly, this system is OS agnostic. Any combination of OS versions from Windows to Linux can benefit from this technology because it works by hashing memory pages rather than working within the guest OS. (VMWare) Memory compression further saves memory by compressing in-memory data that isn't deemed immediately needed. Finally memory ballooning can be used to force VM's to page some of their memory data so that other VM's requiring more memory can get access to more. It is very obvious that VMware has placed a lot of development time into their memory infrastructure. Since memory is going to be the most constraining thing on a lab setup, this is a crucial advantage compared to alternatives.

In networking, VMware also offers a comprehensive system for virtual networking. Xen Server on the other hand, only supports paravirtualized networking on Linux guest OS's. Additionally, VMware supports IPv6 across the host and guest operating systems. This is an increasingly important advantage especially when creating network labs since IPv6 will become increasingly important to study in the classroom. Citrix Xen does not support IPv6 currently, in any capacity.

In external storage, VMware supports Host USB pass-through even with USB 3.0 devices. This means that sharing files across many VM's from a host is fully supported even with very fast USB 3.0 storage. No other current hypervisor can do this. In looking at internal storage, Thin Provisioning is a great solution for a budget-constrained IT

department setting up servers. It is often frustrating to set up multiple Windows guests due to high Hard Drive space requirements. With Thin Provisioning, a hard drive can be over provisioned to ensure that the guests will not throw warnings, but the storage space is there for some VM's if needed. This is supported by Hyper-V, and limited deployment in Citrix Xen, but it is advised against in production use by both. (VMWare)

Since memory, and hard drive space, and networking abilities will be the 3 large constraints in developing a successful network lab, it is apparent that VMware provides solid benefits in its use over products such as Citrix Xen and Hyper-V. While the brand transition to vSphere Hypervisor has left open room for research (there have been few demonstrations of this revised product in use in class labs, but rather the older ESXi 3 and 4 releases), there are several use cases of VMWare being used in academic settings for virtualized classrooms, with VMWare and Wyse offering steep discounts on hardware and software to begin developing solid system deployments and use cases. (Rashid, 2011)

- Whatcomm Community College uses VMWare to virtualize their datacenter and finally their classrooms by leveraging VMWare View, ThinApp (for legacy applications) and vSphere 4.1. (VMWare, 2011)
- Gainsville State College uses VMWare to virtualize their GIS labs by leveraging VMWare Workstation, Fusion, View, and vSphere 4.1 (VMWare, 2011)
- Journal details the implementation of a VMWare Virtual Lab for institutional use. (Burd, Gaillard, Rooney, & Seazzu, 2011)

Windows Server 2008 R2/2012 Hyper-V

Windows Server 2008 R2 and Windows Server 2012 both offer Hyper-V as an add-on Role at no additional cost. Hyper-V offers customers a single set of tools to control and manage their physical hardware as well as the virtual resources and infrastructures ("Windows Server 2008 R2 Hyper-V Datasheet").

Windows Server 2008 R2 Hyper-V offers great features like Dynamic Memory, which balances how memory is allocated between virtual machines based on changing workloads; Live Migration for moving running Virtual Machines without affecting users; Cluster Shared Volumes storage to simplify shared storage; Support for running different guest OSs like LINUX, Windows, and others as 32 bit or 64 bit systems ("Hyper-V Features").

Windows Server 2008 R2 Hyper-V also offers great built in features for Managing and creating Virtual Networks. Hyper-V supports External Virtual Networks where the Virtual Machines can access the physical network and communicate with external servers (outside of the virtual machine cluster), they can also talk to other virtual machines on the same network; Internal Virtual Networks to allow Virtual Machines to communicate with each other and the host; and Private Virtual Networks fort virtual machines to communicate with each other and be isolated from the outside network on the host. These great features are built into Windows Server 2008 R2 Hyper-V and are easily managed from the same Server Manager ("Configuring Virtual Networks").

Windows Server 2008 R2 Hyper-V is not as widely used as some of the other virtualization technologies. Therefore there are not as many case studies on the matter.

However, below is some general information on how to utilize the Hyper-V system in a virtual lab, and a brief use statement from Penn State DuBois. This section also includes detailed instructions, from Microsoft, on how to create Network labs and general labs using Windows Server 2008 R2 Hyper-V.

Penn State DuBois

One of the current projects of Penn State DuBois is an Online Networking Environment, they are implementing this in order to offer students the ability to perform network laboratories through an online environment. They plan to use this system to allow students to do everything from simple tasks like joining domains to more advanced tasks like configuring domains and Exchange servers. They plan to use the Windows Server 2008 Hyper-V system to implement and give students access to this safe environment for network labs. However, they do not provide any information on how they plan to do this other than that they are doing it. (Current Projects at in the Penn State DuBois IST Lab).

This approach is quite useful for entities that need to maintain low physical hardware costs and disk usage. This approach is using differencing disks, which allows each guest Operating System to only use additional hard drive space where is differentiates from the parent disk. For example if you create a Windows Server 2008 R2 virtual machine and use it as the base you can create additional Windows Server 2008 R2 virtual machines using differencing disk and they will only take up additional room from how their settings and applications differ from the base virtual machine. This is a great way to save space when working with limiting hardware. This is also beneficial since any Windows Updates to the base virtual machine will apply to all, since they all pull the basics from that base

virtual machine, which eases applying updates, however, to note, it is important that you do not open or use the Base after you start differencing new Virtual Hard Disks off of it, or all of your virtual machines can be made unusable. To further your quest to minimize resources you can change how the non-used servers work by implementing Server Core Installation, which has no graphical interface and therefore consumes less disk space and uses less memory. However, this should only be for servers that are performing tasks that do not require intervention or use of by the students, since it requires using the command line interface.

Setting up the Server

First off we need to install the Hyper-V role on the host instance of Windows Server 2008 R2, to accomplish this we need to add a Role, and for Hyper-V we will choose it and the physical network connection we wish our virtual machines to use. Once we have the role installed we need to launch the Hyper-V Manager. We now need to set up a Virtual Network. To do this we will open the Virtual Network Manager. We can now create our Virtual Internet network s that will allow our virtual machines to communicate between each other.

Now that we have our network setup we need to create a Base Virtual Machine, we will use this to spin off our other virtual machines and make changing them easier for future updates and software changes. To do this from Hyper-V Manager we need to go to New and then Virtual Machines, since this is our Base, we can just name it Base, we will then give it the needed Memory, access to a network, and create it a Virtual hard Disk. We can then install the Operating System, which will be just like installing an operating system on a real computer. We now have our Base virtual machine. We will now remove it from the

management list in Hyper-V Manager; this will remove it, but leave the Virtual Hard Disk, since we do not want to open this again once we start differencing our new guest operating systems.

We can now create our Virtual Machines that we will manage; use for our lab. These virtual machines will be based on the Base we created, which will save space; they will only take up space for settings and applications installed on them. We can reopen Hyper-V Manager and go to New and then Hard Disk… We will choose Differencing as our Disk Type, we will then specify the name of this Virtual hard Disk and where to save it on the Host Operating System. In the Configure Disk section we will point to the location of our Base Virtual Hard Disk. We can then copy and paste the new Differencing Virtual hard Disk as many times as we need to; for each virtual machine.

For each Virtual Machine we need; as many copies of the Differencing Virtual Hard Disk; we will create a Virtual Machine that will be listed in the Hyper-V Manager. Once we have them all created we are ready to set them up. Now depending on what your final goal is will decide how you set them up. For example, lets say you want to add a Domain Controller, you would then set it up with two network adapters, one internal and one external, and lets say you wanted some SQL servers, you could give them three internal and one external network adapters. Depending on the role you are going to give to the computer will decide how you set up the network.

Once the network and virtual machines are setup, we just need to configure the individual machines to perform their function. For example, we need to change each machines computer name and if needed add the roles that computer needs; for example,

adding the Active Directory Domain Services, or DNS Server role. Depending on what this virtual machine is going to do, you will add the role it needs. If you are not installing Server roles, then these computers might just be Desktop machines and will just need to be copied from the Base and then its name changed, and added to a Domain, if you created a Domain Server in your Virtual Network (Create a Windows 2008 R2 Hyper-V Lab Network).

Security is always a concern, and luckily Windows Server already offers a great deal of easy to use security programs. Windows Firewall offers a nice firewall, and you can easily add your own and disable Windows Firewall from the Windows Control Panel, you can also use Industry leading malware protection software like Microsoft Forefront Security to manage your virtual machines and servers, both of these tools run perfectly with a near integrated feel inside of the Windows Server Operating System, this results in integrated updated with the Operating System, and faster performance using the Windows core components for security and intrusion protection.

As you see from the walkthrough above, creating a virtual lab is quite simple with Windows Server 2008 R2/2012 Hyper-V, some schools like Penn State DuBois has already begun to implement this type of system and many more will probably follow. Hyper-V is a relatively new technology and has not been out as long as other virtual infrastructures. It offers great benefits and being core component of x64 Windows Server it is essentially free since you already have the Windows Server OS. Hyper-V is expected to get a nice improvement in the Windows Server 2012 which is scheduled for early September 2012, and should only get better and easier to manage. With Hyper-V being an integral part of

Windows Server it has more control over the Operating System and has a smaller footprint than other virtual machine management software.

Hyper-V and its Virtual Machines can easily be managed from the simple interface, while virtual hard drives can be added without restarting. Internal Virtual Networks can be used to move files to the virtual machines, and create a Virtual Active Directory Domain ("Useful Hyper-V Scenarios")

Windows Server 2008 R2 and Windows Server 2012 are some of the most popular Server applications in the world. Boasting several built in roles and applications to make managing a network easier than ever. Windows Server 2008 R2 and 2012 also include the very popular Hyper-V Role, which should be perfect for our virtual lab. It offers a simple management tool and with Remote Desktop we should be able to give people access, public IP, and with either Windows Firewall or one of the other options can easily secure our server ("Configure Remote Desktop to Hyper-V". We can use Active Directory to manage users and what they can and cannot do. Remote Desktop can run on Windows and Macintosh and allow our end users to access their virtual computer.

Windows Server 2008 R2 and 2012 include Hyper-V, which is price effective over VMware where you are just getting Software and need a Host Operating System. Microsoft offers numerous educational alliances and offers Free versions of its Standard Server edition through Dreamspark. The built in features and ease of use of Hyper-V should make it the best choice, and the integration into Windows makes it great for hosting Windows Guest Operating Systems, and Hyper-V can easily control most other aspects of Windows

since it is, itself, a Windows component. Using a system that has full control over the Host OS and the most common Guest OS is a great benefit when picking a Virtual Infrastructure.

Citrix Xen

Citrix Xen (known from here on out simply as Citrix so as to not confuse it with Xen.Org) has a long history of providing virtualization competition to VMware. Citrix's best quality is the way it integrates several dozen products into a powerful infrastructure wide system, from OS/systems virtualization, down to the app level, and on into the storage arena. While pricey, this system can be completely integrated with Citrix providing engineers and support for the entire system. With this, Citrix is certainly a heavy hitter in the virtualization world. Citrix has heavy ties with Microsoft, with more than 20 years of partnership and cross licensing. Many of Citrix's hypervisor features can be controlled from within Microsoft Windows via Windows Powershell and SSS (Server Side Scripting). Microsoft APP-V products, Hyper-V products, and Terminal Services products all integrate with a Citrix system should the enterprise managers wish them to co-exist.

Citrix is a heavy contender bare-metal hypervisor in terms of this project because of its flexibility. As a more open hypervisor it has a history of not requiring top of the line hardware, running on much more basic everyday workstations which allows for more affordable labs. VMware, on the other hand, is notorious for its limited driver support (thus causing VMware to follow a strict hardware compatibility list which normally includes very expensive server grade hardware). Citrix also readily integrates in VDI systems with thin or thick clients with no to little licensing requirements (thanks to its simple terminal services

gateway integration). This allows Citrix to deliver many enterprise features to a lab like environment, enabling colleges to more easily test out simulations with their students.

Some of these features do not come for free however. Citrix is generally regarded as buggier than VMware solutions. Citrix suffers from more SAN management and large enterprises with clusters (such as 5 or more units) can suffer from what is known as heartbeat failure. Instances of heart beat failure occurring cause certain servers to be dropped from the farm, causing enterprise disruption until the server is re-added, only to possibly have another drop some time later. Citrix systems also do not check for multiple points of management (something that could be fixed by a primary/slave key arrangement). In instances such as this, a user on the access GUI, a user at the server itself using the CLI, and a program communicating via Powershell from within the virtual environment can all issue conflicting commands to the cluster with the same level of authority, causing a hard lock of the system. It's these kinds of reasons that gives Citrix the number 2 position behind VMware.

Xen.org

Xen.Org is an open source bare-metal hypervisor specializing in para-virtualized support (virtualization that does not require x86 processor virtualization such as Intel VT-x or AMD-V). Because para-virtualized support requires modified kernels (which is against Microsoft's patents/copyrights), Windows is not officially supported on systems not using VT-x or AMD-V supporting processors. Specialty kernels of the popular Linux OS's, however, are readily available; therefore Solaris, Linux, and NetBSD are the typical clients for Xen.Org. Xen.Org is now known as XenServer Free Edition (after the acquisition by

Citrix). It should be noted that Free Edition is maintained as completely open source, however this also leaves much of the Citrix features absent as they are based on closed source code.

Marionnet

Marionnet is a simulation system designed to make it easy to instill a virtual network laboratory to simulate different actions be it in a classroom or enterprise setting. It acts as a program (non-bare metal) that works with an already installed kernel. It supports both x86 and x86-64 kernels. While not extremely clear as to its support, the README and script hint that it is only built to support Debian and derived OS's (such as Ubuntu) with its installer script. Other OS's will require a complilation from scratch, and varyingly successful installs were reported and written about on the Internet, including for Gentoo, CentOS, and Fedora Core. It does change many parameters of the OS and thus it is firmly believed that unless the system contains important configurations, the OS install will be fairly useless for anything else other than Marionnet once it is installed, and uninstalling it is not a clean process. Marionnet is supported within a virtualized environment, such as on an ESXi host. As with any stacked virtualization design, memory allocation must be watched on two levels, both the "Virtual" OS (the OS hosting Marionnet) and the "Physical" OS (ESXi or other bare-metal hypervisor). If these figures are not monitored according to load, performance bottlenecks can easily occur.

The most important part of Marionnet is its ability to simulate various network affects in a virtual environment (thus preventing the need for various hardware to be physically acquired). Because Marionnet can be virtualized and isolated, it is quite simple

to set up a room of test labs via computer terminals to teach students various networking and load principles. It can simulate the following hardware: computers, Ethernet hubs, Ethernet switches, IP routers, straight Ethernet cables, crossover Ethernet cables, Ethernet clouds, and Ethernet sockets. The last two are especially important in a lab environment. The Ethernet Cloud is a generic object that simulates the internet. When packets are sent from your end to another location, it's impossible to know what hardware ect your transmission will run through. These anomalies can create delay or issues. These anomalies can be set up in a custom cloud object to make part of your virtual network, thus allowing a user to simulate various breakdowns of topology. The External Socket acts a embodiment of the Ethernet bridging in the OS. By creating a socket and connecting your virtual network to it, you are essentially connecting your network into a female Ethernet jack in your room, IE you're plugging your network into your existing physical network. From here virtual devices can use your network services (such as DHCP/DNS servers), download from the internet, or other such things.

There are a few drawbacks to Marionnet. One of the major ones is the fact that the virtualized computers are not based on a tried and true virtualization method. The filesystem is still very much in its infancy, and therefore, disk waste and inefficiency are still quite high with the current release. On top of this, in a virtualized environment, this leads to even more critical IOPS being consumed for what should be lackluster loads, thus increasing the hardware necessary to run a lab of Marionnet systems.

In conclusion, VMware has a long list of features, of which key ones are listed below for the purpose of a network lab:

- Academic Alliance Support
- Licensing model favoring low-power installations such as in academia
- Memory over-provisioning
- Transparent Page Sharing
- Storage Thin Provisioning
- USB 3.0 support
- Superior virtual networking
- Booting support from even iSCSI
- Popularity for community-based support
- 3rd party support and certification

When compared to Microsoft Hyper-V and Citrix Xen server, VMware vSphere Hypervisor comes with very clear and advantageous benefits when being used for the purposes of creating virtual labs. It is the ideal choice for building out a virtual lab system.

In addition to VMWare's abilities, Marionnet can be leveraged as the guest within the VMWare Host in order to build a virtualized network lab. VMware's own virtual networking system can provide management and data transfer between the Host and the guest systems. In this regard, Option 2 will be chosen. This is our preferred option because it will allow the exploration of VMWare and Marionnet's cohabitation. Since there are many examples of Marionnet's deployment but relatively few documents on implementation in a pre-virtualized environment, it will be important to test portions of this system before designing labs that can be centered around the architectures. Pre-existing labs will likely not count for the nested virtual networks that would be implemented in a system.

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