Cloud-9 Virtual Lab

By

Colin Howell
Charles Saunders
Daniel Shamblin

Submitted to
the Faculty of the Information Technology Program
in Partial Fulfillment of the Requirements for
the Degree of Bachelor of Science
in Information Technology

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___________________________________________________ __________________
Colin Howell        Date

___________________________________________________ __________________
Charles Saunders       Date

___________________________________________________ __________________
Daniel Shamblin       Date

___________________________________________________ __________________
Mark Stockman, Faculty Advisor     Date
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- Gene Howell, for providing assistance in testing the project’s capabilities from a distance.
Dedication

Colin would like to dedicate this project to his parents Gene and Sharon Howell, for their undying support of achieving this monumental goal.

Daniel would like to dedicate this project to his best friend Janette Davis, for being a source of great friendship and moral support throughout the project.
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Abstract

The Cloud-9 Virtual Lab is designed to provide students with remote access to a computer lab they can use to complete their coursework. Currently, students have to physically be on campus, or otherwise spend time and money on installing the software on their personal computers. This presents a hardship for many commuters and distance learning students, who often have other obligations (such as work, family, or travel conditions) that prevent them from making use of open lab hours. Our project relieves them of that hardship.

Using the University of Cincinnati’s College of Education, Criminal Justice, and Human Services as a test environment, we have created a virtual computer lab that can be accessed remotely. This lab utilizes Microsoft products to reduce the cost of implementation in an educational setting. Students log in with pre-existing credentials, which gives them access to a desktop that is already configured with the same software they would find in a physical computer lab. They also have the ability to save their work to storage space accessible from their personal computers. The implementation of this project will ultimately make the college more attractive to potential students, especially commuters and distance learners.
1. Project Description and Intended Use

1.1 Statement of Need

The University of Cincinnati is in need of a virtual lab environment. We chose the College of Education, Criminal Justice, and Human Services (CECH) at the University as our test environment. It is a nationally ranked (“CECH Education Programs”), achievement oriented, and well respected area of the higher learning environment. As a result of its illustrious reputation, the college’s annual attendance continues to grow and attract more students every year (Nagel). The majority of the students that UC attracts are the traditional high school graduates ranging in the 18 to 20 year demographic. These students tend to live on-campus, either in the dormitories or other on-campus housing arrangements. They have easy access to all of the immediate college resources including 24/7 computer labs and libraries, and do not have to travel large distances (20 – 30 miles) to gain access.

There is another demographic of new students to the college, the adult and family students. These students have been attracted to the college for the same reasons as the more traditional demographic. As a result of family and employment obligations, these students lack the physical proximity to the college that the on-campus students enjoy. Those students with families, children, jobs, and other commitments must always factor in the commute time that is required in order to access a simple computer lab. In addition to the commuting time and other geographical restrictions that they face, there is the added strain of having to purchase the software that is required to be used in order to complete class work in an area other than a computer lab. Nearly all adult families have
not only their own computers, but also a broadband internet connection. The fact that these resources are already in place, the potential of this situation was untouched until the virtual lab solution was put in place. The current state of technology that is available to the University and all students has the potential to make the lives of all of the students much more manageable.

The creation of a Virtual Lab is one such answer. It alleviated the suffering that many students currently experience. Instead of having to make a 30 minute commute and paying for parking, students will now have the ability to log on remotely and access the software programs from any location that has an internet connection. This has benefitted not only the older students, but also the traditional students. In unpleasant weather situations, instead of walking across campus to a computer lab, the students now have the ability to access the computer lab remotely.

The College of Education, Criminal Justice, and Human Services (CECH) has already gathered a strong and trusted reputation for excellence and the attendance reflects that respectively. With the addition of a remote lab that can be accessed anywhere for students to complete their class work it will become more marketable. Prospective students that currently have family and employment obligations will see this option in a favorable light, given that they will still be able to meet the class requirements in addition to the other obligations that they currently have. It would eliminate the required commute in order to access a computer lab just to use a piece of software that they could not have afforded to purchase independently. The fact that the students will be saving money is another point of attraction to not only new prospective students, but those currently enrolled.
Overall, the creation of this virtual lab will remove the suffering of many current students, both commuting and local. It will eliminate the required travel and expense of visiting campus just to use a required software application, so that life can be more manageable. No longer will students at the University of Cincinnati have to find someone to watch their children, leave work early, or fight traffic just to work on an assignment. This has the potential to make the entire University more attractive to all future students, traditional and non-traditional. Attraction to the University will result in greater enrollment and more success from the current students that are in attendance. With the current level of technology that we have available, the students will now be able to use it to make their lives easier.

1.2 Proposed Solution

Our solution was to create a virtual, remotely-accessible computer lab by utilizing the existing contract that the University of Cincinnati has with Microsoft. By combining the desktop virtualization and remote desktop capabilities of Microsoft Windows Server 2008 R2, the application virtualization capabilities of Microsoft Desktop Optimization Pack (MDOP), and the virtual machine management capabilities of Microsoft System Center Virtual Machine Manager (SCVMM), we provided the college with an inexpensive, efficient way to give students off-campus access to the software they need.

With the solution, students can now access the software needed for their classes that they would otherwise have to pay for or spend time setting up. It will save them money by removing the need for them to buy expensive software, and it will save them time because they will not have to come to campus or spend time setting up the software. They can simply connect to UC’s network, log in with their UC credentials, and access
the software they need. This solution will benefit the University as well. It does so by making the college more marketable and more appealing to traditional and non-traditional students by showing them the potential time and money they could save. The University and CECH in particular do a lot of distance learning and having this virtual lab available to them will help the distance learning students with their course work.

The major constraint in this solution was the hardware that is required to run a smooth remote desktop experience. How many people can be connected at once? How many instances of a program can be ran at any given time? Is the movement and use of the remote desktop smooth? These questions all hinge on the quality of the hardware that we had available. The higher the hardware quality that we would have used, the better our solution would have been. We’ll be able to provide a smoother experience and allow more people to connect at any given time if the hardware that we were given can handle a higher workload for the project. We wanted our solution to be able to allow multiple users connect at the same time as well as multiple instances of the same program running at the same time without too much lag, so that the experience was smooth and usable.

Another constraint that we could encounter is an issue with the software. Under our circumstance we have verified that we can have multiple instances of the same program running simultaneously. Will one license be sufficient for each program to run effectively? Will the purchase of dozens of licenses be required for successful deployment? Are some licenses going to be more expensive than others? Our solution has answered the above questions. A license with multiple uses is required to make it work and some licenses, particularly the ones outside of the Microsoft programs, are more expensive. With the existing contract that the University of Cincinnati has with
Microsoft, it has made obtaining multiple licenses affordable. However, as hinted above, not all of the programs that we will need to have operational are Microsoft products.

One other possible solution to the virtualization problem would be to use View (made by VMware), however the financial constraints that we had on this project prevents the utilization of that tool. View also didn’t work terribly well when applied over a WAN (Wide Area Network), as discovered in a different project during the summer of 2011 (Stockman, “An Investigation”). Citrix has a VDI product (XenDesktop); however the cost constraint and our lack of experience with the product for this project remove it from the solution area.

1.3 User Profiles

There are two different types of users that will use this project: students and administrators. While both categories of user will need to be able to log in and out of the system, each of them will have different tasks they will need to perform using the system. (see figure 1, page 7)

Students, for whom this system is being provided, will be using the system to complete work assigned in their classes. To do so, they will begin by accessing a virtual machine provided as part of the system. Since these students may not be familiar with any form of remote access software, they will need to be provided with adequate, easily understood documentation to instruct them in how to access the virtual machines. However, once they have successfully done so, their tasks will become much more familiar. Since the virtual machines will be running Windows 7, users should be able to successfully access and use the software needed, provided they have received proper instruction in its use. Once their tasks have been completed, they will need a method to
save their work for submittal or future access. Should students not have another accessible method (e.g. emailing their files to themselves, or uploading them to an online storage service such as Dropbox), they will be able to accomplish this with by either using a flash drive with the USB redirection capabilities provided by Microsoft RemoteFX, or by using an automatically created connection to organizational storage space.

Administrators, meanwhile, have tasks much more related to system maintenance. First and foremost, they will need to be able to create and remove the virtual machines that students will use. This may require training on their part if they are unfamiliar with Microsoft's virtualization products. Their other tasks, however, are considerably easier; they will simply need to add and/or remove software from the virtual machines. Training in these tasks, however, is beyond the scope of this project.

There are a number of considerations that will need to be taken into account regarding the technical experience of these users. While students will likely have had prior experience with Microsoft Windows, as well as with the software provided through our solution, they may not have used any form of remote access software before. Because of this, documentation will be created to assist these students in accessing the system. Since they will be unable to save data in the virtual machines, due to limitations of the system, there will also be documentation regarding how and where students can save their work.

As for administrators, they will undoubtedly have experience with installing and uninstalling software, so no documentation beyond that of the manufacturer will need to be provided for those tasks. However, they may not be familiar with Microsoft’s
virtualization products. Given that Microsoft already provides immense documentation
for these products, there will be a reduced need for instruction here. However, should the
procedures of our system differ from those documented by Microsoft, the differences will
be documented to assist administrators.

Figure 1: The project's use case diagram
2. Design Protocols

The major design protocol for our project was the design of our network. All of the interfaces, web pages, and so on were provided by the manufacturers of the underlying software; hence, we were unable to consider their design.

2.1 Network Diagram

Below (figure 2, page 8) is the project’s network diagram. It shows how our project server connects to the rest of UC’s network, the internet at large, and the users’ remote computers. It also depicts how the various server roles and virtual machines hosted by the project server are organized. Most roles reside on the physical host; however, the Remote Desktop Connection Broker resides in its own virtual machine, and each “lab computer” provided as part of the project exists as its own Hyper-V virtual machine.
3. Deliverables

Listed below are the deliverables needed to successfully implement this project.

- Remote login access for a group of test users
- At least SPSS, SQL Server Management Studio, and NetBeans installed and usable, with other programs as time permits
- Policies/scripts that will map a student's UCFileSpace folder to the virtual desktop's I: drive at login
- One backend server configured with Windows Server 2008 R2 Standard and other tools for managing the lab infrastructure
- Management tools for administering the system by adding/removing virtual machines, granting/denying/revoking rights to/from users, and other necessary management tasks.
- At least 3 virtual machines running Windows 7
- A comparison of user experience quality on varying client operating systems
- LDAP authentication to access the virtual desktops
- SSLVPN security to connect to UC's network
- A cost analysis of implementing the project with varying levels of specifications
- Instructional documentation for administrators to use in managing the system
- Instructional documentation for students to use in connecting to and using the system
4. Project Planning

4.1 Project Timeline

The timeline for this project has seen a few different revisions each quarter, as the scope of our project had been either expanded or narrowed. With Autumn quarter giving us the opportunity to research existing solutions, identifying the pro’s and con’s of each, we were able to determine the most efficient and effective path to pursue. Winter quarter allowed us the ability to be exposed to different style and types of available hardware that CECH was capable of providing. As a result of the hardware acquisition, we were able to develop, test, and present a working prototype at the conclusion of the calendar year. Spring quarter presented our group with the opportunity to shift the scope of our project, which resulted in a change from the timeline established in Autumn quarter. The required change provided us the opportunity to make the necessary adjustments that allowed us to make our vision a reality. The included Gantt chart (see figure 3, page 11) details the timeline that we have had to adhere to in order to meet the overall project deadlines.
### 4.2 Project Resources

The main resource for our project is people. Our group will be providing the labor to finish the project. Brian Verkamp and Jason Gerst from CECH will be providing us with the hardware and some of the software for this project to work. The rest of our software is being acquired through MSDNAA. Brian and Jason are also providing us with the work space to develop our project. Professor Mark Stockman, our project advisor, is helping us with any problems we run into during the development of our project, as well as helping us with the documentation for our project.

### 4.3 Project Budget

Below are two projected budgets for the project. The first of these is the development budget; this is what it will cost to develop the project. There is also an
implementation budget, which shows the costs of implementing the project after its completion, should CECH choose to do so. (see Table 1, page 12)

Note that none of the software programs that would be used by student users (e.g. SPSS, Adobe Creative Suite) are listed here. This is because they have already been licensed by CECH.

Table 1: The development and implementation budgets for the project.

<table>
<thead>
<tr>
<th>Software</th>
<th>Development Budget</th>
<th>Implementation Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two instances of Windows Server 2008 R2 Standard</td>
<td>$0 (MSDNAA)</td>
<td>$156.32</td>
</tr>
<tr>
<td>25 licenses for Windows 7 Enterprise</td>
<td>$0 (volume licensing)</td>
<td>$0 (volume licensing)</td>
</tr>
<tr>
<td>5,199 Windows VDA licenses</td>
<td>$0.00 (MSDNAA)</td>
<td>$5,666.91</td>
</tr>
<tr>
<td>Microsoft System Center Virtual Machine Manager 2008 R2 – Server ML</td>
<td>$0.00 (MSDNAA)</td>
<td>$160.88</td>
</tr>
<tr>
<td>25 Microsoft System Center Virtual Machine Manager 2008 R2 – Client MLs</td>
<td>$0.00 (MSDNAA)</td>
<td>$119.75</td>
</tr>
<tr>
<td>1 year subscription to Microsoft Desktop Optimization Pack for 25 systems</td>
<td>$0.00 (MSDNAA)</td>
<td>$81.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hardware</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>One server workstation</td>
<td>$0 (already owned)</td>
<td>$0 (already owned)</td>
</tr>
<tr>
<td>Testing workstations</td>
<td>$0 (already owned)</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$0.00</strong></td>
<td><strong>$6,341.18</strong></td>
</tr>
</tbody>
</table>

There will be no cost to develop the project. All hardware that would be used is already owned by CECH, and all software that would be used is obtainable either directly from CECH, or through the Information Technology program’s MSDN Academic
Alliance agreement. However, should the college choose to implement the project after its completion, they will be responsible for the associated software licensing costs.

In addition, we have developed a budget for what the hardware would cost to implement at different levels (see table 2, page 13). The prices for it were obtained from Dell, and are subject to change. They only include the bare minimum requirements to run a lab of 10, 20, or 30 VMs on the server, and not any extras (operating system, graphics card, etc.), nor do they take potential discounts into consideration.

Table 2: A potential hardware budget for implementing the project

<table>
<thead>
<tr>
<th>RAM (GB)</th>
<th>Hard Disk Space (GB)</th>
<th>10 VMs (cost in $)</th>
<th>20 VMs (cost in $)</th>
<th>30 VMs (cost in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1GB</td>
<td>30 GB</td>
<td>$1,842</td>
<td>$2,913</td>
<td>$4,163</td>
</tr>
<tr>
<td>2GB</td>
<td>30GB</td>
<td>$2,334</td>
<td>$4,323</td>
<td>$5,573</td>
</tr>
</tbody>
</table>
5. Proof of Design

So far, the project has been developed to the point where multiple users can access a small pool of virtual machines at the same time. As long as a user is on the organizations network (whether by being on campus, or by connecting to it through a VPN), they are able to access the Remote Desktop Web Access server that provides users with a gateway from which to access the virtual lab. Upon connecting to the server, they log in with their credentials on the project domain (see figure 4, page 14), and are presented with a screen that allows them to select which pool of desktops to connect to (see figure 5, page 15). Since the project only uses one pool of desktops, this screen is somewhat unnecessary; however, it is an integral component of the Remote Desktop Web Access server, and will also provide for the creation of future desktop pools (e.g. if administrators want to create one pool for each school/department within a college).

Figure 4: The login screen for the Remote Desktop Web Access server.
Once a user is connected to a virtual machine in the desktop pool, they are able to run any software installed in the virtual machine. At this time, the list of software usable in our test environment includes NetBeans, SQL Server Management Studio, and SPSS; this will be expanded given enough time after or during the completion of other project tasks. Needless to say, administrators in other environments will be free to use different sets of software in their virtual machines.

Administrators are able to set up virtual machines for the pool. This involves creating the virtual machine using Hyper-V Manager on the project server, installing Windows 7 Enterprise on the virtual machine, installing the software for use in the virtual machine, joining the virtual machine to the project’s Active Directory domain, and running a PowerShell script provided by Microsoft to configure the virtual machine for use in a virtual desktop infrastructure (see figure 6, page 16). Once the machine is
created, the administrator connects to the virtual machine that runs the Remote Desktop Connection Broker and adds the new virtual machine to the pool of available virtual desktops (see figure 7, page 17). This marks the machine as available for students to use when they log into the virtual desktop pool.

Figure 6: Configuring a virtual machine for use in a virtual desktop pool
The lab performs authentication using an Active Directory domain. This can be either a domain created specifically for the lab (as in the case of CECH), or a previously existing domain. However, even if administrators already have a non-Active Directory solution in place (such as Novell eDirectory), they can still use centralized identity management by linking the lab’s Active Directory domain to whatever setup they currently have in place.

There are also methods for allowing users to save their work for later use, even on a non-lab computer. One of these, implemented in the test environment, is to provide
users with access to network storage space. In the case of CECH, a script was created to mount a student’s UCFileSpace folder as a network drive when run. Administrators can also choose to allow students to give the virtual machine access to the drives on their physical computer; however, this is not recommended for security reasons. Lastly, using Microsoft’s RemoteFX technology, USB devices can be redirected to the lab VM. This allows users to plug in a flash drive (or similar device) and save their work to it. However, we were unable to implement this in our test environment, owing to the increased system requirements of RemoteFX

To sum up the system’s functionality from a student’s perspective, consider the case of a hypothetical student, Rory Williams. He is going back to school to earn his bachelor’s degree in Information Technology, but is taking mostly online classes so he work full-time at his nursing job, and so he can spend more time with his wife Amy. His biggest challenge this quarter is Computer Programming I, partially because he has been having difficulty installing and configuring NetBeans on his own computer. Since he is a CECH student, the administrators have already configured an account for him, so he decides to try it out. After connecting to UC’s network via VPN, he opens a web browser and visits the login page for the lab (see figure 4, page 14), and selects the CECH Cloud-9 Lab option to access a virtual machine (see figure 5, page 15). The lab server then redirects him to an available virtual machine, and he is presented with a desktop containing icons to access the lab programs (see figure 8, page 19). He uses one of these icons to open NetBeans, and decides to make sure everything is working properly, opting to run a simple “Hello World!” program to accomplish this (see figure 9, page 20). It runs successfully, and he can begin working on his assignment.
Figure 8: The desktop presented to the user after they log into a virtual machine
From an administrator’s perspective, consider the hypothetical administrator Kaylee Frye. She has just started a new job with CECH, and her first assignment is to start creating a new pool of virtual desktops to support the college’s students. Fortunately for her, the server roles are already in place. All that she’ll have to do is create and configure a virtual machine on the Remote Desktop Virtualization Host, assign it to a new pool on the Remote Desktop Connection Broker, then check the pool using the Remote Desktop Web Access server to verify that it is working properly.

She begins this task by creating a virtual machine that will be used in the pool. To do this, she logs onto the server hosting the Remote Desktop Virtualization Host role and is presented with a Server Manager window at login. In this window, she expands the list
of server roles and opens Hyper-V (see figure 10, page 21), the role responsible for managing virtual machines. From here, she chooses to create a new virtual machine, working her way through the wizard and providing the settings she was given for the virtual machines to be created. Afterwards, she begins the process of installing the operating system and software needed for the virtual machine, and running the PowerShell script needed to prepare it to be used as part of a virtual desktop pool (see figure 6, page 16).

![Figure 10: The Hyper-V role on the Remote Desktop Virtualization Host server](image)

Once the virtual machine has been created, she connects to the computer running the Remote Desktop Connection Broker role, responsible for redirecting users to the appropriate virtual machines, and opens its Server Manager window. She expands the Remote Desktop Services and Remote Desktop Connection Manager options, and selects the option for RD Virtualization Host Servers. This presents her with a list of servers with
the Remote Desktop Virtualization Host role installed and ready for use (see figure 11, page 22). In the right pane of the window, she chooses to create a new virtual desktop pool, gives it a name, and selects the virtual machine she just created. From here, she can log into the Remote Desktop Web Access panel to see if her new pool is showing up and working properly (see figure 5, page 15).

Figure 11: The Remote Desktop Connection Broker role on its server
6. Testing

To ensure that this solution will be proven adequate, we have implemented a few different testing scenarios. We wanted to confirm our belief that with an accessible broadband internet connection, the connection speed to the Virtual Lab would provide the students with an environment comparable to the physical labs currently located on campus. To prove this, we accessed our prototype from campus, and from distances up to 640 miles away (in Brooklyn, New York). As our results show, the amount of connection latency is acceptable. Another portion of our testing involved students connecting to the Virtual Lab to examine the usability of our prototype. This involved connecting to the lab from both on campus and from a remote location. Our testing parameters and results provide the validity of our prototype as a viable solution as seen in table 3, on page 23.

Table 3: The results of our testing

<table>
<thead>
<tr>
<th>Distance from UC Campus (miles)</th>
<th>Operating System</th>
<th>Remote Download Speed (Mbps)</th>
<th>Remote Upload Speed (Mbps)</th>
<th>Lag (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Windows 7</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>Windows XP</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>Windows 7</td>
<td>4.34</td>
<td>0.64</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>20</td>
<td>Windows XP</td>
<td>4.34</td>
<td>0.64</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>40</td>
<td>Windows 7</td>
<td>4.39</td>
<td>1.78</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>40</td>
<td>Windows XP</td>
<td>4.39</td>
<td>1.78</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>120</td>
<td>Windows 7</td>
<td>10.96</td>
<td>1.63</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>640</td>
<td>Windows 7</td>
<td>29.88</td>
<td>4.92</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

Because of the fact that this project could be deployed on an enterprise level if implemented for an entire college, we also wanted to test the load bearing strength of the server that we had been provided. To do this, we simply had 3 users log in, each one using one of the 3 virtual machines that we had already established, and work on the programs that we had installed. One could have been doing extensive SQL queries, while
another was building a program in NetBeans, and the third was processing statistics work in SPSS. We performed this test in 2 different environments, one on campus, and another in our furthest reaching test ground, New York. The results were outstanding. All 3 machines performed perfectly without any significant lag, proving that this solution is more than capable for enterprise deployment.
7. Conclusions and Recommendations

Over the course of this project, we have concluded that it is feasible to use Microsoft technologies in creating a virtual, remote computer lab for student use. The varying limitations that students may have (including, but certainly not limited to, travel time, family/work obligations, and financial limits) mean that for many students, it can be difficult for them to either visit campus to complete their assignments, or to obtain and install the needed software for their own use. Should their school implement a virtual lab like we have developed here, not only would these student-level hardships be mitigated (if not outright eliminated), but the school would make itself more marketable to potential students, through being able to offer such a solution to student problems. It is even conceivable that they could use the same technologies to manage a lab designed for on-campus use, which would save money on the hardware for such labs.

However, we will acknowledge that our project does have one major weakness: the amount and quality of hardware available to us. Having only had one system to act as a server, we were unable to build the project to a level one would actually see it implemented at (i.e. at least 20-30 simultaneously running virtual machines, similar to what one would see in an on-campus lab). While we believe that the project can be properly scaled to the point where our current results would reflect what one might see with a more robust infrastructure, we would also like to call for more research into this area, to determine not only the feasibility of managing a larger-scale virtual lab, but also what other VDI-related technologies can be used in improving the overall quality of education.
References


Fellows, Russ, and John Webster."Storage Considerations for VDI Implementations." InfoStor - Data Storage News, Resources and Products for ISCSI,


-27-


Stockman, Mark, Andrew Eaves, James Mills, Daniel Shamblin, and Gregory Szczublewski. *An Investigation into VDI (Virtual Desktop Infrastructure) for Consumers*. Unpublished research.
