Thin-clients for Clusters: Working Ourselves Out of a Job?

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ABSTRACT
Thin-client technologies provide an alternative to the traditional desktop computing platform for the delivery of computer services to students in public clusters on college campuses. The Academic Computing Systems group at the University of New Hampshire has conducted a series of investigations and tests of Windows Terminal Services and Citrix systems to determine the possible applications and limitations of these technologies with respect to academic computing needs. These tests have illustrated the limitations of thin-client systems as well as the advantages. For the time being, the decision has been made to not look to thin-client solutions as a replacement for the traditional computing cluster environment. Our group is, however, conducting a pilot project with Windows Terminal Services in the summer and fall 2004 to offer students access to course-specific computer programs from their own computers in the dorms or at home. These are applications that have traditionally only been available in the Student Computing Clusters. If this pilot is successful, will we be further reducing the need for public clusters on campus in a world of ubiquitous computer ownership, wireless networking, and easy access to basic productivity applications? Will we be working ourselves out of a job?

Categories and Subject Descriptors
C.5.m [**Computer System Implementation**]: Miscellaneous

General Terms
Management, Design.

Keywords
Thin-client, Windows Terminal Services, Citrix, course software, student computer labs, student computer clusters.

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1. INTRODUCTION
Thin-client technologies provide an alternative to the traditional desktop computing platform for the delivery of computer services. In a thin-client architecture, both storage and processing are centralized on servers while the clients are only used for input and display of a graphical user interface. The actual client can be a dedicated thin-client device or a personal computer that runs the appropriate client application [4,8].

The primary advantage of thin-client architectures is reduced total cost of ownership. Requirements for client hardware are lower than for a desktop computer resulting in less equipment expense both at initial purchase and at replacement because the thin-client can be functional for several years longer than a traditional computer. Management costs are also lower. Since software deployments and data storage are all centralized, installations and backup need to only involve a limited number of centrally managed servers [2,4,5].

In the corporate environment, thin-client systems have been adopted due to the ease with which they can provide simple, cookie-cutter computing environments to office workers at reduced equipment and maintenance costs. In the more varied academic environment, the technology has not been as widely, and where it has been used, it has been mostly limited to administrative services -- essentially the same application as in the business world [3,5].

2. TERMINAL SERVICES EVALUATION
Over the past 18 months, the Academic Computing Systems group at the University of New Hampshire (UNH) has conducted a series of investigations and tests of Windows Terminal Services [9] with and without Citrix MetaFrame [1] to determine the possible applications and limitations of these technologies with respect to academic computing needs. The goal was to develop new ways of delivering access to computer software and services to students for their coursework. We also have examined the impact of thin-clients on budgets and equipment replacement cycles.

The Academic Computing Systems group manages the public Student Computing Cluster facilities at UNH. We currently have approximately 200 Mac OS X, Windows, and Linux systems that we purchase, and we are involved in supporting an additional 250

systems on campus. These computers are generally replaced on a 3-year cycle at a cost of $1100-$1200 per system. Our own hardware replacement costs are approximately $80,000 annually. The replacement costs of the other systems we manage bring this total to $180,000 annually. The Student Computing Cluster environment provides a range of software including Microsoft Office, web browsers, Adobe and Macromedia graphics, desktop publishing, and web development applications, and a set of course-specific software applications ranging from very simple programs to complex mathematical and scientific simulations.

Possible cost savings on equipment replacement are one of the primary motivations behind our testing of thin-client environments. Simplified management is the other. While we do have an Active Directory structure, a robust Fast Ethernet network, utilize servers for most file and application storage, and use disk imaging to deploy Windows setups, we do not have refined tools for automatically deploying individual applications, security patches, and other updates to all our Windows systems at once. This makes addition of new software and corrections of problems in the deployed images difficult, especially when the computers are heavily utilized during the semesters.

Our tests have been based on Microsoft's Windows Terminal Services. Terminal Services allows a client to have a Windows desktop environment and access to applications in a thin-client configuration. All applications reside on the central server, and the user only needs a simple client-side application on a dedicated thin-client device or a computer system with a minimal operating system. Upon connecting to the Terminal Services server, user's login and interact with the remote server in much the same fashion as one would with a regular Windows desktop computer system.

Our first testing was performed in the summer of 2002 on a server loaned by TekResource Service Corporation [6]. This system combined Windows 2000 Server with Citrix's MetaFrame and TekResource's own Think-n-Thin software. Citrix's MetaFrame is an enhancement to standard Microsoft Terminal Services that provides, among other things, access from a wider range of client systems and support for load balancing among a cluster of servers. The Think-n-Thin add-on is a server-side component that provides improved network utilization and performance by optimizing the video display update communications to the client. The server was an HP 800Mhz Pentium III with 512 M RAM.

Testing with this system was not conducted in a formal fashion. General experiences with the system were positive. Even with 20+ simultaneous users, performance of Microsoft Office, web browsing, and other basic productivity applications were acceptable. Performance of multimedia playback through QuickTime or Windows Media Player was acceptable at 256 colors, but had noticeable skips and problems at higher bit depths. Similarly intensive graphics applications such as PhotoShop showed decrease performance. In addition, we found that intensive applications, in particular a 1000-iteration program run in Matlab, would freeze the sessions of all connected users while this one program consumed all available CPU cycles. Based on discussion with the TekResource staff, there were options to tune these applications to provide better performance and prevent the one process from utilizing all of the CPU time and stopping other users sessions, but we did not pursue this at that time.

In July 2003, we conducted a second series of tests, in a more structured fashion, using a Dell Optiplex GX260 with a 2 GHz Pentium 4 processor and 1 G RAM running an evaluation copy of Windows 2003 Server with no add-on components. A group of 22 users connected to the server and performed a set of actions in unison. The operations covered basic computer operations (starting the terminal services session, logging in, opening the *My Computer* item on the desktop, and navigating the files and folders on the server), web browsing (launching Microsoft Internet Explorer, loading UNH's main web page, saving this page as a web archive, loading CNN's main web page, and general navigating to and around various websites), word processing (launching Microsoft Word, opening a sample document, inserting a paragraph of text into the document, spell checking the document, and saving the document as a new file), spreadsheets (launching Microsoft Excel, creating and entering a simple expense budget, creating a pie chart using the budget data, and saving the workbook as a new file), and working with other applications. This last set of tests involved SPSS and Matlab which are available to the UNH campus from an existing server so when users launched these programs, the Terminal Services server was accessing the files for these applications over the network. Users also tested Adobe PhotoShop including opening the

Table 1. Terminal Services Testing
(1 = Unacceptable to 5 = Great)

Action	Fail	1	2	3	4	5	*n*	Mean Score
Basic OS Operations								
Start Terminal session		1	2	2	6	10	21	4.05
Login		6	7	4	2	1	20	2.25
Opening My Computer				1	7	14	22	4.59
Navigating folders, etc				5	10	6	21	4.05
Web Browsing – MS Internet Explorer								
Launching IE				5	7	10	22	4.23
Load www.unh.edu				4	8	10	22	4.27
Save web archive				5	4	13	22	4.36
Load www.cnn.com		1	6	4	5	6	22	3.41
General web browsing			2	7	12	1	22	3.55
Word Processing – MS Word								
Launching Word			1	4	12	5	22	3.95
Opening sample file				4	5	13	22	4.41
Inserting a paragraph			1	4	7	10	22	4.18
Spell checking	1	4	5	3	6	3	22	2.82
Saving as new file			1	4	6	11	22	4.23
Spreadsheet – MS Excel								
Launching Excel			1	1	8	12	22	4.41
Creating basic budget				4	10	8	22	4.18
Make a pie chart		1	2	5	5	8	21	3.81
Saving as new file				1	7	13	21	4.57
Other Applications								
Launching SPSS	1	10	6	4	1		22	1.73
Launching Matlab	1	15	4	2			22	1.32
Launching PhotoShop	1	10	3	1			15	1.27
Opening PhotoShop file	8	4	3	1	2		18	1.17

application, opening a sample PhotoShop document, and trying to perform basic photo editing operations. With the exception of SPSS and Matlab, all applications and files were residing on the Terminal Services server. Users were requested to rate the performance of each of these tasks in comparison with their regular computing experience on a scale of 1 to 5 with 1 representing unacceptable performance and 5 meaning that it worked great. Users also indicated tasks that failed. Test results are show in Table 1.

In addition to the usability scores, we monitored the processor and memory utilization of the server during these tests. Processor load varied considerably while all of the physical memory in the server was quickly and consistently allocated forcing the use of virtual memory.

3. TEST CONCLUSIONS

From these tests, we have reached several conclusions regarding the performance and capabilities of Terminal Services, in general and with respect to the utilization of Terminal Services in the Computing Clusters environment.

First, Terminal Services performs adequately for basic productivity applications such as word processing and spreadsheets, for web browsing, and other basic computing tasks. Performance of graphically intensive operations will vary. This is due to the need to deliver a graphical user interface over a network connection instead of directly on the display hardware using accelerated graphics circuitry.

Processor intensive applications show decreased performance under Terminal Services. This is to be expected since processor cycles are being shared among all of the processes of all of the connected users. Our tests have always been performed on single-processor systems, but for production systems, multiple processors are certainly warranted. It is interesting to note, however, that the single 2.0 Ghz Pentium 4 processor on the second test server was not running at 100% utilization all of the time. On the other hand, we did see consistent 100% utilization of the physical memory. Increased RAM to remove the effects of swapping to virtual memory on disk should show increased performance.

It should be remembered in reviewing these test results that they represent a worst-case scenario of utilization of a thin-client environment. The users all performed the same actions at the same time leading to very bursty loads on the server and multiple simultaneous requests for access to the same resource, whether a file, disk storage, or the network. For example, the decreased performance of spell checking or accessing an off-campus website or loading an application from a remote server are likely to be contributed to this aspect of the testing environment. Under most desktop computing situations, the computer is idle a good deal of time waiting for user input. Given a similar sized set of users all connected to an identical server, it is unlikely that they would all act in concert. Most real world situations would naturally distribute the load more evenly.

One notable exception is a hand-on computer classroom situation where an instructor was leading a group of students through a set of operations. In this case, Terminal Services may show the same performance limitations seen in our testing. One should consider this in making choices about where to deploy a thin-client solution.

4. COSTS

One of the primary reasons we wished to examine thin-client solutions was the potential costs savings. As mentioned, our group currently spends $80,000 annually replacing computers in the Student Computing Clusters given our three-year replacement cycle.

The costs to implement Terminal Services consist of the server hardware and software licenses. The number of server required will vary based on the number of users and type of software being used. Thirty users per server is a good ballpark figure [D. Peterson, TekResource, personal communication]. Based on our testing a modern dual-processor server with a large amount of RAM should be sufficient. Storage costs will vary based on the particular application and whether or not other network storage is available for users already. Still, a server in the $3000-$4000 range should meet the requirements.

Software licenses required depend on the software used. For Windows Terminal Services, Terminal Services Client Access Licenses (TS CAL's) are required, one for each simultaneous user. At educational discount, TS CAL's cost $30 each. Citrix MetaFrame is more expensive with prices quoted to us of $200 per user and is required in addition to the TS CAL's.

Table 2 compares the replacement costs and licenses for a theoretical 30-seat computer cluster based on the above details and assuming that a computer could provide five years of service instead of three. This example also assumes that the Terminal Services server itself would be replaced at $4000 after three years to maintain comparable performance to the regular computers that would be replaced after three years.

Table 2: Terminal Services Cost Comparison

	Traditional Cluster	Terminal Services
Cost of 30 systems	$36,000	$36,000
Replacement cycle	3 years	5 years
Annual replacement	$12,000	$7,200
Server	N/A	$8000
TS CAL	N/A	$900
MetaFrame	N/A	$6.000
Total over 5 years	**$60,000**	**$50,900**

This example does not include any savings that may well be present due to the ability to purchase a lower cost computer system as the client for Terminal Services compared with a regular desktop computer. Computer costs may easily be 20-40% lower given the price of low-end desktop computers today. Additionally, the Citrix MetaFrame component is not required. While MetaFrame does add functionality lacking otherwise, Microsoft has incorporated some of its benefits into Windows 2003 Server, and it is possible to have a Terminal Services environment without it leading to even more savings.

Harder quantify are the management cost savings of Terminal Services compared with traditional desktop computer environments. These will vary widely. For a situation that currently has little automation of installation and maintenance tasks, the time savings for centralizing management and support

may be tremendous. For an organization that already manages the computers centrally, there will be decreased benefits.

5. PILOT PROJECT

5.1 Potential Deployments of Thin-Clients

Based on our tests, we have not decided to move the entire Student Computing Cluster environment for the Windows systems to Terminal Services at this point. The main uses of the Clusters at UNH continue to be word processing, e-mail, and web access, applications which perform well under Terminal Services, but we also have a range of other services and uses including statistical software, image editing, and scientific simulations which do not perform as well. It would be possible to setup a thin-client system providing only those services that perform adequately under Terminal Services while keeping regular computers available for the more demanding functions. The Student Computing Clusters have a tradition of providing identical services on all our systems, as much as possible, as a convenience to our users. Having machines with limited functions would be a significant shift for users and for our support staff. Also, having a new environment to support still maintaining the existing traditional configuration would be an increase in support load, not a decrease.

We do see other areas of possible use for a Terminal Services environment. One of these is to provide Internet access kiosk with limited functions. We have experimented with other options to replace the simple functions provided by now obsolete VT terminals for quick and easy access to e-mail. Terminal Services may have uses in this area. Another potential use we have considered is to extend the range of potential uses for a Macintosh-only computer lab. We have maintained a Macintosh training classroom for several years, but the demand for it has decreased, and we have tried other solutions such as Virtual PC to provide Windows-only applications on this hardware. Terminal Services is promising in this area, as Microsoft has released a Remote Desktop Connection client for Mac OS X systems to allow Mac OS X clients to access a Windows Terminal Services server.

A different space where thin-client technology has been effective is in remote access. Since any application can be made available over a network connection with Terminal Services, users can access resources otherwise unavailable from their locations. With this in mind, we are planning a pilot project for the 2004-2005 academic year.

5.2 Project Goals

In excess of 95% of UNH students have their own computers, but they must come to the Student Computing Clusters to access course-specific software programs that are not available anywhere else. Using Terminal Services, we will make these software applications available to students in their dorms or off-campus residences. Funding for the project has been secured through the technology fee paid by all students.

As a pilot, only selected applications will be made available for students in some courses. An important part of this project will be to assess this service from the student perspective. Do they find it desirable and useful? A successful pilot will consist of both a system that technically functions as expected and users who use the system and find it works well for their needs.

If the pilot is a success, the plan is to make the service permanent and to extend it to as many applications as possible. We also see this pilot as a first-step to other potential uses of Terminal Services on campus since it will establish the necessary infrastructure.

5.3 Software Selection

For the pilot, it is important to select only those software applications that will function well under Terminal Services and are appropriate to deploy in this fashion. We are beginning by reviewing the current list of course-specific software in the Student Computing Clusters. These fall into four main categories.

The first are programs available either via a free download over the Internet, on a CD that came with a textbook, or via a network license purchased for the university. Although these are installed in the Clusters for user convenience, users can also install them on their own computers currently. There is little to gain my making these available via Terminal Services.

A second category consists of programs that require particular hardware. For example, the Music Department has licensed the Finale and Sibelius music notation applications. For full functioning, these programs require direct access to MIDI sound cards. Terminal Services does not allow access to MIDI hardware on the client computers so these programs will not function properly in a thin-client situation.

A third category of software is plug-ins or add-ons to other applications. We have several web browser plug-ins as well as add-ins for Microsoft Excel and other programs. Since we are not providing these host applications, there is no need to try to provide this group of software.

The last category are proprietary programs which have been licensed for use by departments for instructional purposes, are not available to students in other fashion, and are not dependant on other hardware or software that will not be present in the Terminal Services environment. These are the programs we will be using in the pilot. Not all of these programs currently in the Student Computing Clusters will necessarily be installed because we want to limit the size of the pilot and because we will require that faculty in these courses work with us to educate the students on the use of the service and on evaluating their students' experiences.

5.4 Deployment

The pilot project will use two identical servers. Both servers will have dual 2.66 GHz Xeon processors, 4 G RAM, and two 73 G SCSI hard drives. The hard drives will be configured using RAID Level 1. RAID 1 is being chosen, despite the higher cost in terms of unusable disk space, instead of RAID 5 because of the increased write performance of RAID 1 [7].

Two servers are being used for redundancy to help assure service availability in case of hardware failure. It also will allow load balancing either via a simple round-robin DNS solution or via a third system running an application to provide monitoring of the load on the two servers and distribute connections appropriately.

5.5 Evaluation

The pilot is scheduled to being with the start of classes in the fall. Student experience using the system will be evaluated twice in the semester via a survey administered by our department in conjunction with the faculty for the course. The first of these surveys will be administered after the first month of the course. Data from this evaluation will be available in time for presentation at the SIGUCCS conference on October 10-13, 2004. The data will also be made available, along with this paper, at http://at.unh.edu/siguccs2004/.

Another aspect of the pilot that will be watched closely is the impact it has on use of the Student Computing Clusters. We track usage of the clusters, based on the number of logins, and have records extending back over 8 years. These numbers have reflected the increase use of computers in general, a shift in use from the clusters to students own computers when Internet access was made available in dorms, and a rebound in use of the Clusters over the past few years due, in part, to an increasingly large set of course-specific software. It will be interesting and important to see if we are reducing use of the Clusters by making this exclusive draw available elsewhere.

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