Thin Client-Server Computing

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Abstract

The total cost of ownership of a PC in a corporate setting ranges from $3000 to $9000 per year, depending on what survey one consults and the environment where it resides. Thin client-server computing presents an approach to lower the total cost of ownership by replacing the PC's with thin clients, i.e. low-end desktops and fast servers. All application and data processing is done on the server and the client is used to display information and process I/O to the server. This paper presents an overview of the current technology in regards to thin client hardware and software. The main concentration is on Windows Based Terminals, Network Computers and NetPCs. We examine two software products that support this technology: Citrix Winframe and MS Windows Terminal Server. An experiment was done to show how thin client-server technology is implemented using Citrix software and thin clients with the goal of improving the PC laboratory environment at the University. The results from the experiment can be used as guidelines for capacity planning.

1 What is Thin Client-Server Computing?

Thin client technology does user processing on powerful central servers, and the desktop just provides a graphical display and a means of user input. The aim is to strip away the power of the client and give most of the capabilities to the server. However, when we examine thin client-server computing as practiced today, we find varying ways of splitting the processing between the client and server. For example, in the case of a *Network Computer*, Java applets are downloaded on to the desktop and are executed there, whereas in a *Windows Based Terminal*, all user application processing is done on the server. We take the attitude that computation done on the desktop defeats the advantages of thin client technology.

1.1 Why Thin Client-Server Computing?

Thin client-server computing is seen as a way to reduce the total cost of personal computer ownership. *Total Cost of Ownership* (TCO) consists of:

- initial cost of hardware
- initial cost of software
- cost of implementing a network
- system administration and maintenance
- lost productivity because of users doing computer administration

- software and hardware upgrades.

By implementing thin client-server computing the aim is to reduce initial costs as well as the rising costs of administration and maintenance. A study conducted by *Zona Research Inc*. in the Spring of 1996 suggest that an enterprise can expect to reduce costs by approximately 57% by implementing thin client-server computing. [7]

1.2 The Evolution of Thin Clients

Thin client-server technology is nothing new; it has existed for the past 30 years in various forms, e.g. *IBM 3270* terminals attached to a mainframe via serial lines and ASCII terminals attached to Unix time-sharing systems. These character-based devices were popular until *Graphical User Interfaces* (GUI) became common. *X-Terminals*, which support the X-Windows graphical environment, were developed to provide a thin client GUI for Unix users.

Initially PCs used a character oriented user interface, but Microsoft followed Apple's lead and developed a GUI for PCs, i.e. Windows. This, coupled with graphical applications and the surge of the World Wide Web, has changed the way computing is done, making the PC even more popular. Initially, PC's were self-contained and did not rely on central servers. However, the cost of PC ownership, maintenance and administration has become much higher than expected, (A study by Wyse shows that corporate PC ownership over 5 years costs about $15000 [2]) and therefore some corporations are reverting back to centralized computing using thin clients to replace the traditional PC.

1.3 Thin Client Variations

Windows Based Terminals are thin clients, which have the Citrixs *ICA*[1] protocol built into them. These bring full functionality of the Windows NT server to the desktop and the processing is still done on the server. The server side consists of Citrix *Winframe* running on top of a Windows NT operating system. The Winframe software provides multi-user capability to Windows NT operating systems allowing remote logins. An update of the Windows NT operating system called *Windows Terminal Server* [5] will allow host Windows Based Terminals to connect to it directly without having to use the Citrix software.

Network Computers are low cost devices, that are based on Java frameworks supporting a rich graphical user interface. These are mostly used for browsing the Internet, sending email and doing day to day word processing work. Usually, network computer applications are network based but sometimes they offer stand-alone applications as well, e.g. word-processing.

NetPCs are basically scaled down PCs with the approach that the applications can reside either solely on the client or on the server. The operating system resides on the server and

[1] Independent Computing Architecture

is downloaded at boot time. In traditional NetPCs applications are downloaded and executed on the local machine.

Most popular manufacturers have also come out with their versions of Thin Clients as well. SUN Microsystems has a product called the *Java Workstation* [4], which was developed totally in Java. Network Computer Inc (NCI) has a product out called *Network Computer* [11], which is also Java based.

2 Current State of Affairs

The PC brought computing to user's desktops, and one reason for its success, was that it presented a user-friendly interface. It also brought a much-needed standardization through the operating system and hardware. Initially, the PC was stand-alone, until network operating systems became popular. Network operating systems, like Novell, were the birthplace of network computing on PC's. This was a huge success in the corporate world, since users could now share resources on the local network. For example user authentication and file storage were centralised, but computation was still done on the clients (PCs). However, this did not solve the problem of managing and administering the desktops.

2.1 Disadvantages of PC's

Corporations are feeling a pinch with the rising costs of owing and maintaining a PC. Studies by Gartner Group over the past years have shown that the major portion of TCO of a PC is related to administration and maintenance, approximately 55%. [15] Newer versions come out every two to three months and keeping up with them is expensive and time consuming.

Following are some of the factors that contribute to the high TCO for PC's.

- As the Windows operating system is a single user design, which does not allow remote logins, administration can not be done remotely. There are no proper methods for maintaining these PCs because they require a person to be present in front of the machine to administer it. Unlike the centralised systems, each system has to be backed up individually.
- Aside from the hardware, software maintenance is a major problem. As technology becomes better, software becomes fatter. Every desktop has multiple copies of the same software, which use system resources. Changing user needs requires installation of software to support these needs. Software vendors constantly add unnecessary features to their products to differentiate their products from their competitors offering. This contributes to the bloating of software.
- There is no concept of security on the desktop, as most PCs run a single user unsecured operating system. There is no way to protect the file system, so that the operating system and application software will not be harmed. Data stored on a PC is not secure, and viruses are on ongoing problem.
- At the University of Nevada, Reno, all student PC laboratories have severe administration problems due to unmanaged software installations and viruses. This

leads to licensing problems, the failure of some of the software, the loss of homogeneity among the PCs, and eventually requires reinstallation of the operating system.

2.2 Switching to Thin Client-Server Computing

As mentioned earlier, the cost of PC ownership in a corporate environment is about $15000 for 5 years. In many cases we see unnecessary power on the desktop as most of all computation is done on high-end servers or mainframe computers and the PC acts as an expensive terminal. A good example can be taken from the database world where the data resides on the server and the client sends a query to the database, which is processed by the server and it sends the results back to the client.

The basic aim of thin client-server computing is to revert back to centralized systems because of their reliability and ease of administering. All the processing and data manipulation is done on the server and the client just acts as a gateway to information.
The biggest advantage of thin clients is their ease of use from both an administrators and users point of view. Thin client configuration is simple and it only has to be done once at set-up time. All user settings, file storage and processing capabilities are on the server. The only network traffic that is generated between the thin client and the server is the changes to the display window and keyboard and mouse input from the user.

Figure 1 below depicts how thin client-server computing works.

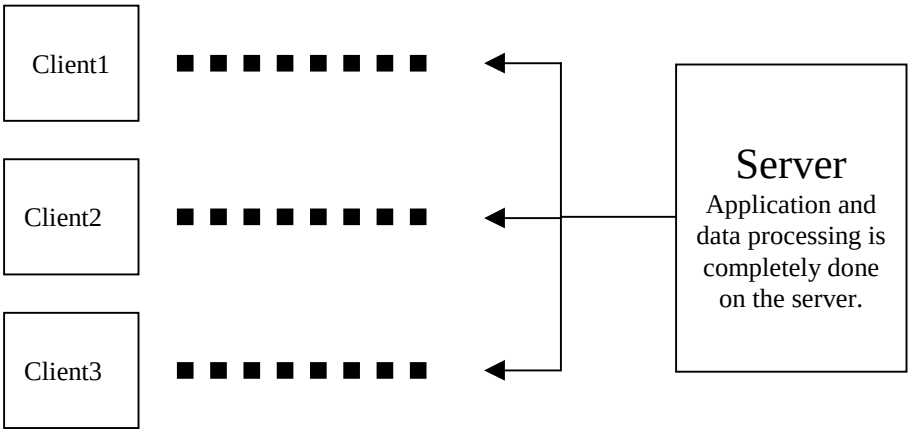

Figure 1

2.3 The Downside of Thin Client-Server Computing

Even with all the above mentioned benefits of thin client-server computing there are a few reasons why the PC has not been displaced from its dominance. As thin client

computing revolves around centralized computing it inherits the disadvantages as well, like a single point of failure. It also depends heavily on network bandwidth, which limits it to corporate usage. Another obstacle in thin client growth is the low initial cost of PCs, which make thin clients unappealing to most users. Also, some peripherals such as scanners and receipt printers may be difficult to integrate into a thin client-server environment.

3 Thin Client Hardware

Thin client vendors use standard PC hardware because it is available in abundance and is inexpensive. Most thin clients come with Intel based architecture processors. For example, the windows based terminal used in our experiment was a *Wyse Winterm 2310*, which came with an *AMD* 486 (66) processor. [2] These come with of 4-MB reprogrammable flash memory and 8-MB RAM. [2] The rest of the hardware (e.g. serial ports, parallel ports, keyboard and mouse) is all based on PC standards. Due to the high data rate needed for networking, thin clients usually come with 10baseT NIC (Network Interface Card) interfaces. Thin clients often come with a proprietary operating system that has the basic networking and application protocols built in. Recent models of Wyse Winterm terminals are supplied with a stripped down version of MS Windows called *Windows CE*. [5]

3.1 Windows Based Terminals

Windows based terminals provide an innovative, cost-effective way of accessing 32-bit MS Windows applications running on MS Windows NT. These thin clients combine the ease of management and inherit security of a terminal environment with the application and performance capabilities of desktop PCs. This versatile solution enables system administrators to save time and money, as they don't have to spend time to administer it. Windows based terminals are diskless, but they come equipped with PC standard devices so one does not have spend extra money on purchasing additional hardware

The operating system resides in the flash memory, which is reprogrammable and hence future firmware flash upgrades are possible. Usually the windows based terminals run Citrix Winframe software and use the Citrix ICA protocol for network communication at the application level. With the recent release of the Microsoft *Windows Terminal Server* they now also use the Microsoft *RDP* (remote display) protocol. Windows based terminal vendors usually provide remote administration to administer their thin clients.

3.2 Network Computers

In the early part of thin client evolution, many manufacturers announced that they were going to come out with their own versions of network computers. In early 1996 major network computer manufacturers came out with a set of guidelines called, the *Network*

Computer Reference Profile (NCRP) [6], which is a specification designed to encourage interoperability amongst the various network computers. Using this guideline it was possible for different manufacturers to know what a “network computer” should be and what it should do. Here it is important to mention that network computer is a very broad term and in this paper the thin client aspect of network computers will be discussed. A not-too-useful definition of network computer is “ a device designed to deliver networked information and application for users “. [6]

One of the major differences between a network computer and a windows based terminal is that there is no requirement for MS Windows applications. Network computers come with their local browser and local Java functionality, both being requirements of NCRP. These come equipped with host-based emulators, which reduce unnecessary network traffic. For example Tektronix network computers come with emulators which allow users to access the myriad IBM and DEC legacy applications still in use today. [6]

There is a wide range of functionality in the current set of network computers. Some of them have no support for MS Windows based applications using the ICA protocol, but almost all of them operate on Java based frameworks. They are usually more intelligent and have more functionality then a typical windows based terminal. Unlike the latter, they do have the capability of local application processing.

3.3 NetPCs

NetPCs are scaled down personal computers. They evolved from the diskless workstation concept and are marketed as thin clients. The main concept of a NetPC is to have a PC stripped down to a minimum Intel based processor running a Microsoft operating system. In essence, the operating system resides on the server and is transferred to the client at boot time. All the applications are again sent to the client over the network and are executed on the client. The claim that comes with the NetPCs is that it requires ‘Zero administration’ [5] and Microsoft markets a product called *Zero Administration Kit* (ZAK). [5]

The thin client industry has yet to accept the superiority of the NetPCs because of its basic design issue. In the thin client world, all processing is done on the server and the client only displays the information and does I/O. NetPCs download applications and execute them. Processing balance shifts and hence it is required that the NetPCs have a fast processor. Each application requires a one-time network transfer, but tests have shown that there is less network traffic when a true thin client is used. [10]

The above-described thin clients are the most popular. All of the above still have some issues to deal with, like better administration software and price reduction. Some of the thin clients cost more than a PC and this blunts the claimed cost advantage of thin client technology.

4 Its not all Hardware

The Citrix Corporation developed a technology called *MultiWin,* which added multi-user capability to MS Windows NT 3.51, and using this technology it came out with a product called *Winframe Server*. [9] Citrix also created clients, which accessed NT 3.51 using Winframe server from different host operating systems ranging from Dos to Windows to UNIX platforms. This was a huge success because it brought the capabilities of Windows NT 3.51 to thin clients or even old legacy x86 PCs. Citrix also developed a protocol called ICA (Independent Computing Architecture) which runs above TCP/IP and is used in the Winframe model to establish communication. Citrix has made thin client computing revolve around its software.

4.1 MultiWin and ICA

Citrix created MultiWin as an extension to the Windows NT server providing it a multi-user layer on the server to simulate the local application processing. This application processing would be channelled to the client using its ICA protocol. The ICA display services on the multi-user layer divide the application execution from the display logic. Using the Winframe Server users virtually sit in front of the MS Windows NT console and share resources with other users taking advantage of MS Windows NT's pre-emptive muli-tasking feature. This means that the MS Windows NT kernel, which is made up of MS Windows NT original kernel plus Citrix's MultiWin, schedules resource allocation for each thread in terms of processor time. This ensures that no one particular thread uses all of the CPU indefinitely. This is critical for a multi-user system, as it has to act like it is a single user system, but still gives all users a fair share of resources.

All communication from the client to the server are the keystrokes and mouse movements, which the client sends to the server and accepts in return display changes from the server. All user logons into the MS Windows NT server are also done through the ICA channel. This set-up reduces network traffic as the applications are executed solely on the server and only the display changes are sent on the network. This makes the ICA protocol efficient enough to be used in low network bandwidth situations.

The ICA protocol also delivers true location independence, by running the Windows operating system and the application program at one location on the server and displaying the results on the client. In some aspects ICA is similar to the X-Windows system protocol as it allows the user logons and application execution on the server and only exchanges mouse, keyboard strokes with display changes. The ICA packets consist of a 1-byte command followed by optional data. [9]

4.2 Citrix Winframe

Citrix Winframe brought the capabilities of Windows NT operating system to users desktops. Whether they were running the client software on a thin client or the fastest Pentium based PC, it did not make a difference anymore. The Windows NT operating

system provided a strong foundation for the multi-user capability as the networking was built into the native operating system. What Citrix did with Winframe was to build low level APIs, which simply extended and exploited the design of the operating system.

The security model of users and groups still existed and was used in the Winframe server. As the user logged into the NT operating system via the Winframe server all the security was in place according to the group settings. Symmetric multiprocessing support which came with Windows NT operating system was essential in multi-user access so as to cause multiple processors on one machine to work together for optimal performance. Winframe server also added security features like restricted access and connection restoration. This model also came with application servers whereby only authorised applications could be published to the client. One of the important features that the Winframe Server provided was the client and server drive mapping. This allowed users to transfer data with relative ease. Printing services were also supported and users had access to the installed printers on the server.

4.3 Using Old Hardware

Legacy PC hardware has been one of the most difficult things to dispose of. New versions of the operating systems and applications have forced us to upgrade to newer models. What to do with the old hardware?

Citrix's thin client software attended to this in a timely manner and proposed a solution. Using Citrix client software for operating systems like DOS or even Windows 3.11, old PC's could be used as thin clients. This made good use of hardware, which was outdated and was a headache for the users. Using Citrix's Winframe software it was possible use legacy PC hardware.

Figure 2 shows how the Citrix thin client-server model looks like.

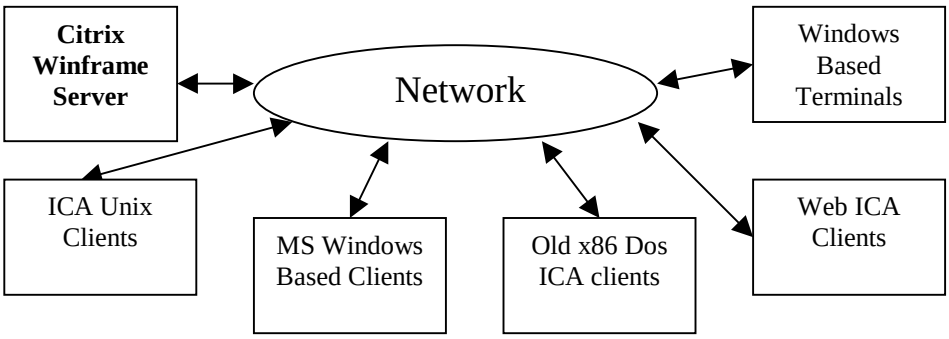

Figure 2

4.4 Windows Terminal Server and Citrix MetaFrame

Citrix Winframe's success was the reason that Microsoft decided to license MultiWin technology from Citrix to make its own multi-user operating called MS *Windows Terminal Server*, which was an extension to Windows NT. A new protocol called the RDP (Remote Display Protocol) was developed which was based on the International

Telecommunications Union's (ITU) T.120 protocol. This is an international multi-channel conferencing protocol standard, which is used for high-bandwidth environments and supports encrypted sessions. MS Windows Terminals Server is entirely protocol-independent, so it can function using RDP or a third party add-on protocol such as Citrix's ICA.

MS Windows Terminal Server comes with clients for MS Windows 95, MS Windows NT operating systems, which use the RDP protocol. To use MS Windows Terminal Server with other host operating system clients, Citrix's *MetaFrame* has to be used. Citrix's MetaFrame is the upgrade from Winframe and provides access to the Terminal Server from virtually any client device. It still uses the ICA protocol which has become an industry standard. One of the new features that MetaFrame comes with is the Load Balancing option through which administrators are able to group multiple Citrix servers to automatically route users to the less loaded server. This results in optimization of server utilization and application performance. Another important feature that, RDP does not incorporate is audio, but is supported by ICA in MetaFrame.

5 Case Study

The Microsoft Windows Terminal Server / Citrix MetaFrame combination is the latest thing in the thin client world. Until recently both these products were in Beta 2 versions and have just been released. The corporate world is still using Citrix Winframe software on NT 3.51. Most have yet to upgrade to Windows NT 4.0 just because Citrix did not have a Winframe Server for it. Few studies have been published on MS WTS/Metaframe due to their recent release. Microsoft has conducted studies regarding server resource requirements and has come up with a basic configuration: [13]

- Minimum processor Pentium 166Mhz
- Base 32MB memory (RAM) for the operating system
- 8MB memory (RAM) per user.

As discussed in various studies, resource requirements depend on the type of load on the server, and what kind of applications will be executing on it. For an average load the following resource configuration has been suggested. [13]

- 15 - 45 users per Pentium processor (suggested processor is Pentium Pro)
- 4 - 12 MB memory (RAM) per user
- 2 – 6 kbps network bandwidth.

The network bandwidth is crucial as in many cases users might be executing large, dynamic graphic applications instead of simple word processing.

5.1 An Experiment

In our case we used the following configuration.

- Pentium 133 MHz Processor
- 64 MB Ram (200MB swap space)
- 1.2GB hard disk
- 10/100-Mb network card connected to a 100-Mb Network.

The 100-Mb was a local network where a bottleneck of 10-Mb existed at the router. The hard disk was divided into two equally sized partitions: applications and system.

The MS **WTS** installation was similar to that of Windows NT 4.0. Our server was a stand-alone server and was not part of any domain. It is imperative that the terminal server should never be a primary or backup domain controller, as it has to manage substantial load of remote logins. In other words, all the user logons and authentication should be handled by another server, which is managing the domain. Once the MS Windows Terminal Server was up and running we tried to test it with clients using the RDP protocol. The first test client was a Pentium workstation with Windows 95.

The **MetaFrame** installation was again pretty straightforward and the default options were chosen. Using an ICA client loaded on the same Pentium workstation, MetaFrame was tested. ICA automatically remapped the client and server drives to the default settings, which were chosen, at set-up. Experimental users were created and were configured differently to observe the different behavior during logons and logouts. Terminal Server comes with connection restoration, which means that if the connection is lost, the same desktop will be again, presented on the next logon. This is a very useful tool while using a dial-up connection to the MetaFrame server. A modem was also installed and a connection was created for ICA modem dial-up. For both RDP and ICA, connections have to be created for use and security can be set-up on them to restrict access. This helps prevent the installation of unlicensed software.

The Terminal Server file system was NTFS (NT file system). Proper security had to be set-up on the file system so that users might not be able to write on the system and applications drives. Using S*amba* [16] installed on the departmental Unix servers, users have access to their home directories where disk quotas are available. File system quotas are not available under MS Windows NT. One of the biggest shortcomings in MS Windows NT is an insecure file system. After numerous efforts of trying to lock down the file system, we came to the conclusion that it needed more research as to what files are needed by NT to have write privileges for users. This was left unresolved, as it was very time consuming. One of the on going battles was to take out the user profiles from the operating system directory and put them in the user's own directories. We were also unsuccessful in doing that. However we should mention that these problems did not come with the MS Windows Terminal Server, as they are intrinsic to MS Windows NT.

We obtained a Windows Based Terminal (2310) from Wyse, which came with the ICA protocol installed. Using that we connected to the Terminal Server via MetaFrame. The firmware operating system in the Windows Based Terminal can be upgraded to use

RDP. Next a copy of Solaris 2.6 ICA client was downloaded from Citrix's website and was installed on one of the Sun servers so that it would be available to all Solaris workstations. One of the problems that were encountered while operating ICA client from Solaris was that it only ran an 8-bit frame buffer. An attempt to also use the Java ICA client on Solaris was not successful as the Java Development Kit (JDK) installed on the Sun servers was an older version. Just to test the Java ICA client, the latest version of the JDK on MS Windows NT was downloaded and used to set-up the client. It worked, so we came to the conclusion that JDK on the Sun Server was not the correct version. RDP and ICA 32-bit Windows clients were tested over a PPP connection at a baud rate of approximately 24000 bps. Our Network looked like Figure 3

5.2 Results

The above set-up worked without a problem for two or three clients. It was recognised that if more load was to be put on the server, extra server resources would be needed. Here are some of the interesting results that were noted :

5.2.1 Memory usage

Connection	*Memory at Connection*
Normal User	12Mb

Table 1

In addition there was 2 MB of usage by the system for its own processes to accommodate a user session. The above user connection figure also includes network connection restorations as well.

Product	*Memory at Start-up*
Microsoft Word	4 – 6 Mb[?]
Microsoft Excel	6 – 6.8 Mb[?]
Microsoft Internet Explorer	7 – 7.2 Mb[?]
Microsoft Visual C++ *	5 – 7 Mb
Telnet	1.4 – 1.8 Mb
Windows Explorer	3.2 – 3.5 Mb
Netscape Communicator	7.9 – 8.4 Mb[?]
Turbo C++ *	6 – 6.9 Mb

[*] Means that it is running a compiler, an editor and executing a program

[?] Means that these process are either loading up web pages or documents at start-up time.

Table 2

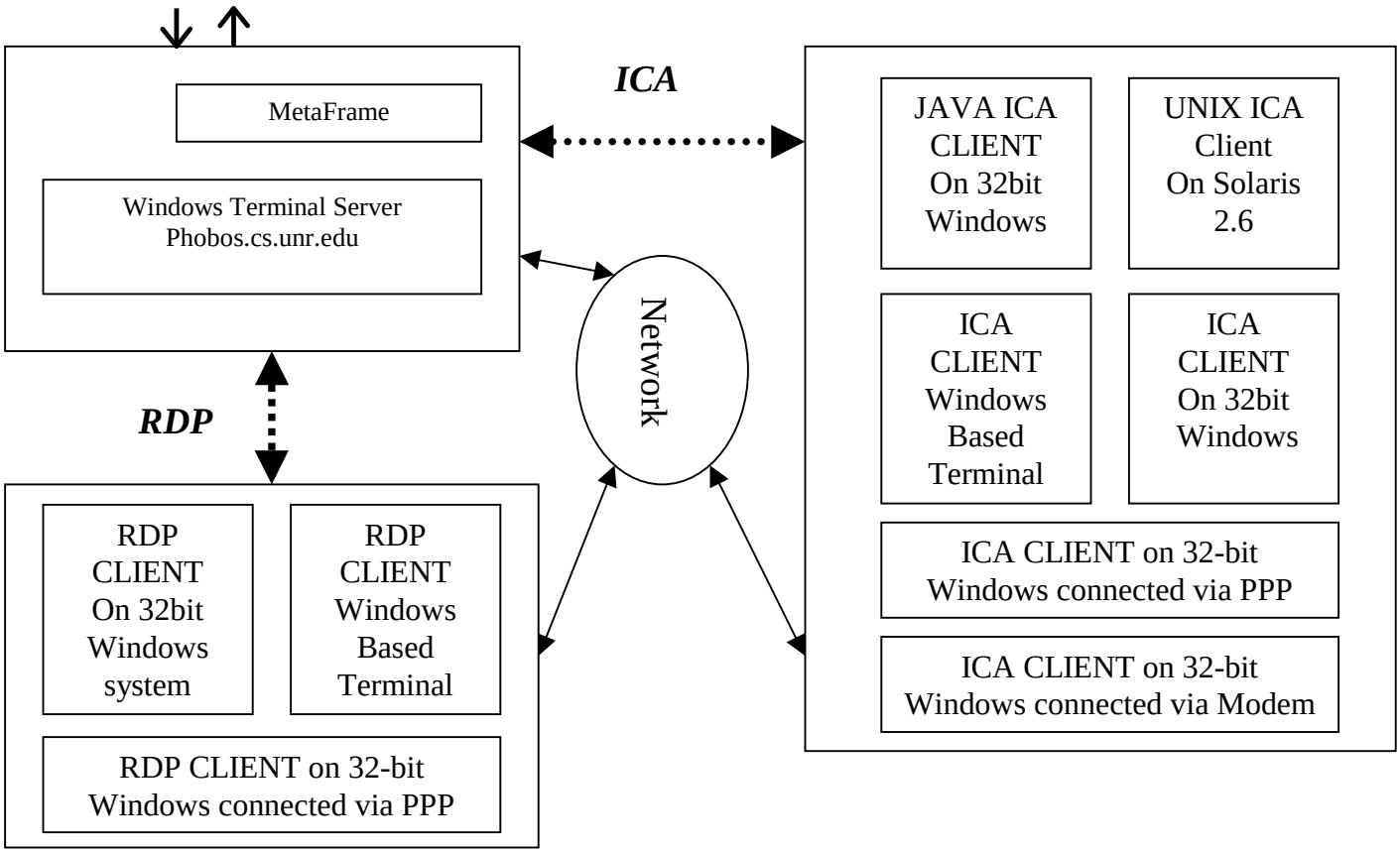

Figure 3

It is very important to note here that these results only show memory usage at start-up time and these applications do relinquish memory once they have started and normal work is being done. The above figures are the maximum limit because that is what we need to set-up an environment. But we have to cater for people starting up applications simultaneously and provide ample buffer that the system does not run out of memory. Measurements do however show that CPU usage is relatively low. So lets figure out how much memory is needed for a load of 25 users. From Microsoft's studies we know that a dual processor Pentium Pro-200 can sustain a load of 30 Heavy users. The memory requirements are broken out as follows, using the worst case scenario.

Operating System at start-up time with a few user daemons		64 MB
System load for user connection	2.0 MB	
Per user load on user connection	12.0 MB	
Per user load on application start-up	47.6 MB	
Total user load	61.6 MB	
25 User load on Server		1540 MB
Total Memory required		1604 **MB**

The above analysis is not completely correct since these program memory requirements are for start-up time and they do release some memory once they have started. Not everyone starts up all the applications at one time and not every one uses all these applications. Lets look at a modest approach.

A user in a typical Computer Science I lab would use a Browser, Windows Explorer, Telnet, One compiler, Word and maybe Excel.

This comes out to approximately 32 MB of applications per user.

(32 + 12 + 2) * 25 + 64 = **1214 MB**

This amount of memory would still scare some people but this was done using a worst case scenario. Remember this number reflects that 25 users will simultaneously be logging into the system and spawning off these applications. There is not even a remote chance that this will happen as the network and the CPU's will scheduled, in a way that this does not happen.

5.3 Capacity Planning

The above demographics are based on an environment where people are constantly using all the applications at the same time and the applications are consuming the maximum amount of memory. A good estimate could be allocating flat 32 MB per user on a system which comes up to **800** MB for 25 users. 1GB of memory on a system would be ample for a user load of 25 users. A very important point to note here is that we have not taken into consideration the swap space.

Now that we have determined the hardware configurations, here are few suggestions.

- Strict user management through Windows NT group management. Only group members should be allowed to access the Terminal Server.
- Make another server, the Primary Domain Controller (PDC) so that all user logons and policies are managed and implemented on the PDC and not on the MS WTS server.
- If user load exceeds estimations bring in another Terminal server into the domain and distribute load. Proper user management would be really helpful in this case.
- User load distribution can only be done through Citrix's load balancing option. But still proper group management should be in place.
- The operating system should have its own partition. As MS Windows NT does not have disk space quotas, it is difficult to control adding of user or application files. If the operating system resides on a different partition, then by simply setting file system permissions operating system integrity can be secured.
- File system permissions should be carefully monitored.

6 Conclusions

In today's ever-changing computing industry it is very difficult to predict what is going to happen in the future. It will be interesting to see where the thin client industry will go from here. Another arena where the thin client technology is heading into is the world of PDA's (Personal Digital Assistants), wireless terminals and mobile phones, which come with the capability of web browsing and email. Personal computers still hold much of the market share in today's computing industry. A few obstacles, which still stand in the way of thin client-server computing, are mentioned below.

- Networks bandwidth. In a LAN environment thin clients work very well. Using thin clients over modems or PPP connections is still not feasible. Faster network capabilities will have a favorable impact on thin client-server computing. Options are available, like ISDN, Cable modem and Digital Subscriber lines (DSL), but these are expensive or are not fully deployed.
- Stronghold of the PC industry on home users and small business. One of the reasons for the PCs success was that it found a place in peoples homes, and whatever you are using at home, you would like to use at work as well.
- There is not much difference in cost between a PC and a thin client. Thin client vendors are struggling to lower their pricing because the PC keeps on becoming cheaper. Higher end PCs are still expensive but older models are available at competitive prices.

Thin clients do have a genuine place in the corporate world where TCO plays an important role and where PC computing has exceeded TCO expectations. Thin client-server technology inherits the problems of centralized computing like for example single point of failure. Thin clients are network dependent and without a fast networks they will never reach the height where the PC is today. In fact Sun Microsystems's slogan '*The Network is the computer*' says it all. [4]

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