The University of Kansas

Technical Report

Implementation of Ambient Computing Environments Concepts in Microsoft Windows

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ITTC-FY2002-22731-01

August 2001

Abstract

This paper explores the possibility of creating a Windows based, distributed and user-friendly computing environment, similar to that of the Information and Telecommunication Technology Center's Ambient Computing Environments (ACE) project. The Ambient Computing Environments project focuses on creating smarter computational environments that allow the co-opt of resources, user-friendly video conferencing, desktop sharing, and centralized resource allocation. Since ACE is based on a completely custom Linux software architecture that will not port to other operating systems, there has been much interest in creating a similar environment using Microsoft Windows based servers. The approach is to build a test environment using current publicly available software, in which the pros and cons of each software solution can be explored, along with how they interact.

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1.0 Introduction

The Ambient Computational Environments project encompasses many advanced hardware and software technologies to create a smart and robust co-opt computational environment, which improves the integration and usefulness of business computing resources. This technology will enable organizations to implement smart video conferencing rooms and other useful features such as true desktop portability and centralized resource allocation. The following scenario better illustrates some of the ACE concepts:

Herman completes editing his presentation in his office environment. He picks up a small lightweight device, we call a Personal Interactive Device (PID), and heads down the hall toward the conference room. The conference room is equipped with tabletop display screens, video/computer display projectors, sound system, microphone system, controllable video camera, and controllable lighting. When he enters, the conference room senses his entry and turns on the ambient light. Herman sits at a tabletop station and presses his thumb against a reader, is identified and his working context is brought up on the nearby display. Herman directs, through gestures, voice commands, and conventional computer interaction, to put the presentation on the right screen, point "that video camera" at "that seat", "put the remote video feed on the left screen", and so forth. The conference room reacts to Herman's voice commands, gestures, and computer mediated commands. [1]

ACE is designed around the free and open-source Linux operating system. This was selected for its familiarity and its proven software development environment. Since many companies rely heavily on the Microsoft Windows platform to conduct their business, there has been further interest in implementing a similar system for use on Windows based servers. ACE will offer some Windows based client support, but requires Linux servers to provide its functionality. The goal of this research is to implement as many of the ACE features as possible and explore how they might integrate, using only readily available software and hardware for Windows based servers and clients.

Since ACE is based so heavily on custom software that links all of the components and features together, it would be extremely difficult to achieve the same level of integration and functionality that ACE does using standard Microsoft Windows software. However, many powerful software solutions do exist that can accomplish some of the same tasks and offer limited integration. The approach is to build a test environment using current publicly available software, in which the pros and cons of each software solution can be explored, along with their interaction. With this experience a useful ACE alternative for Windows will be derived, but more importantly the functionality that is not part of a Windows environment will be highlighted. ACE's distinguishing features are its ability to provide very powerful security and resource allocation, remote access ability, videoconferencing, and integration with mobile computing devices.

2.0 Resource Allocation

At the heart the ACE design are the databases that store and integrate information about its computing environments. ACE stores several types of data such as user objects, security rules, device directories, and room descriptors. For example, a room descriptor is a special object type that keeps track of room characteristics such as spatial order and room geometry, allowing cameras to know relevant areas of the room. Since all of the ACE daemons will have access to the information in this database, very advanced integration of the ACE services becomes possible.

In order to effectively store all this information, the concept of the ACE Service Directory (ASD) was defined. The ASD uses a Lightweight Directory Access Protocol (LDAP) database to store the entities of the environment, and a more traditional rational database to store the security assertions. LDAP was chosen for its' hierarchical structure for information storage and its ability to more effectively store the attributes of an object. LDAP allows you to build tree-like structures that make the organization and retrieval of data much more logical. It also allows for easy distribution of data across servers, which is a requirement of the ACE design. On the other hand, a relational database was chosen for the security assertions, since some assertions would span multiple sections of the hierarchy.

ACE also plans to develop a powerful and simple to use administration interface for this data, allowing administrators to easily manipulate all aspects of the database such as user accounts, hardware profiles, room descriptions, and security assertions. To implement this functionality in Windows, a customizable database would be needed that was capable of storing the same type of information as ACE. Furthermore, some sort of GUI would be needed to access and manipulate the database objects and rules.

2.1 Microsoft Active Directory

The only currently available solution that has any hope of providing ACE-like integration and information storage capabilities for Microsoft Windows is Microsoft Active Directory. Microsoft Active Directory, which is now the standard in all new Microsoft operating systems, creates a very scalable global catalog of network services and resources by making use of a custom LDAP implementation. Active Directory allows for a single point of administration via the Microsoft Management Console (MMC) or its' highly advanced API. Secure and robust replication is also possible to other Windows servers via easy to use administration interfaces.

By default, Active directory stores information about domains, organizational units, users, computers, contacts, groups, shared folders, and shared printers. The real power of Active directory in implementing an ACE-like database, is in its' ability to allow administrators to customize and create new object types. Since modification of the Active Directory structure could be dangerous to a production system, Windows 2000 requires a registry value to be changed and a special snap-in to the Microsoft Management Console to be installed. It would be relatively easy to add the objects that

the generic Active Directory is missing such as cameras, room descriptors, and security rules. The only problem with this is the fact that most existing software designed for tasks such as videoconferencing and device control, will not be able to utilize this data or even know of its existence. Thus, using this approach, it would be possible to store the same types of data that ACE proposes but only have access to the generic objects such as users, computers, and generic hardware such as printers.

There is no solution to this problem without using software that is explicitly designed to take advantage of these new types of objects. Microsoft Active directory, does work extremely well for its' intended task of keeping track of normal objects like users, groups, and printers and will hopefully be extended in the future to encompass more hardware devices. Therefore, Active Directory will not work in implementing an ACE like environment without explicitly writing new software that will make use of the custom objects.

2.2 Windows.NET

Recently, Microsoft has been focusing on a new Internet and business strategy called Windows.NET. This new strategy is based around global information stores that keep information such as your personal email, settings, shopping wallets, and even applications. This will allow you access to your personal data and applications from a PC at home, in the office, or even your mobile phone or PDA. This is very similar to the ACE environment in its ability to provide easily accessible information stores and application portability, but only very simple features are currently available. Most of the advances will come from the successor to the Windows XP operating system called Windows.NET. Even with the release of the Windows.NET operating system in 2002, there will still be no built-in functionality to control hardware such as cameras, projectors, and audio equipment.

The first example of the .NET technology can be found in Microsoft's Passport service. This technology will allow for a single sign-in for authentication to participating websites and a shopping wallet that will store your credit card numbers, address, and other information. Already, there is tremendous public outcry due to the possible monopolization of web based information stores by Microsoft.

With Windows.NET, Microsoft will move more towards the ASP (Application Service Provider) model and start offering centralized application stores. Critics are worried about Microsoft's ability to offer highly important services such as office suites, email, and instant messaging. "The fact that MSN Messenger was down for six days and counting says that Microsoft cannot handle the service business." [2] They are also worried that outsource firms will not want the responsibility of providing so much critical functionality. It is however possible that new markets will be created for application service providers a little at a time. Although this technology is in its infancy, there is no doubt that this is the direction Microsoft is headed. Unfortunately, this new technology is shrouded in secrecy, so little information is available.

3.0 Login Security

ACE will allow users to authenticate themselves by using new technologies such as the I-Button, finger print identification, and a traditional user name/password challenge. The objective of these new technologies is to provide a quicker and more convenient authentication method, along with increased security. I-Buttons are tiny chips that can be imbedded into a ring or any other sort of wearable item, which are interfaced with a special reader. I-Buttons can store additional information such as a picture or RSA keys along with a login and password. Finger print identification involves scanning a user's fingerprint with a small device that usually interfaces with the serial port. All of these technologies are already supported in the Windows environment, and continue to be actively developed. Integration with Microsoft Active Directory is also possible as long as the user and password fields are exchanged at the time of login.

4.0 Desktop Accessibility

Another important feature of ACE, is the ability for users to have access to their desktop and applications no matter where they are in the ACE environment, be it a colleagues office, a conference room, or in the lobby. ACE users will have the ability to create multiple personalized desktops which can be accessed from anywhere in the ACE environment, given sufficient security credentials. For example, a user can go to a colleagues display and access one of their personal desktops, allowing for effective collaboration in an environment that is not foreign to them. Since all user files will be stored on a common file system, there will be no need to transfer files from one computer to another.

To accomplish this, the ACE design introduces the concept of an "ACE Desktop Server". This software daemon will provide the necessary database and resource allocation for each user's desktop. Due to the distributed nature of ACE, your desktops can exist on any of the ACE enabled servers. To provide access to these desktops, AT&T Cambridge Laboratories' Virtual Network Computing (VNC) package was selected, for its simplicity and multi-platform nature. This software works by taking information from the frame buffer of the server and transporting it over the network to the VNC client software running on the workstation. In theory, ACE users will be able to access their desktops from any platform that supports the VNC client, which includes Macintosh, Windows, and Linux.

Users will be able to select their desktops by using the ACE GUI, which is automatically presented to them when they have authenticated themselves at an ACE enabled workstation. This same GUI will also enable the users to create, modify, and delete their desktops. As you can see, any device that can run the VNC client, be it an old computer, PDA, or laptop, can use the very powerful ACE servers. This makes changing or upgrading a computer a snap since no software or setting will be stored locally. There are many Windows solutions that provide similar functionality, but here we will concentrate on discussing the most relevant and feature rich.

4.1 Microsoft Roaming Profiles

Standard Windows NT and 2000 servers offer a very limited version of desktop portability by providing Roaming Profiles. Roaming profiles are commonly used to allow users to login to a workstation and have their personal settings such as web bookmarks, mail settings, desktop customizations automatically applied. This is a well-proven technology, but does not allow the software you have installed on one machine to be available to you on another machine, nor does it have much support for non-Microsoft applications such as Netscape Navigator.

4.2 Microsoft Windows Terminal Services

In Windows, ACE functionality could be closely mimicked by using Microsoft Terminal Services. This technology was originally designed for application sharing, by allowing users to connect to a centralized server that holds the software. Unfortunately, only Windows 2000 and NT servers can run the Terminal Services Server, leaving out non-server client machines from sharing their desktops. Having every user login to a Windows server for all of their daily use creates a solution that doesn't scale and that would be a logistical nightmare. You would have to give users the ability to install their own software, creating a need to reboot the server constantly. Other issues include strict licensing, cost, and waste of highly capable desktop computational power.

One possible solution to this problem is to allow users to have remote access abilities to their own machine. This would allow users in a conference room access to their personal office machines from small laptops or other portable computational devices. This differs from the ACE vision, but since most users have a very powerful computer on their desks, this allows for a relatively easy solution to the information accessibility problem. Software such as Virtual Network Computing and PC Anywhere would be the best candidates for this scenario.

4.3 AT&T Cambridge Laboratories Virtual Network Computing (VNC)

AT&T Cambridge Lab's Virtual Network Computing software provides very simple and stable remote access capabilities. The fact that it is free and that it works on nearly every platform, are its strong points. Its weakness lies in the fact that it offers no centralized management capabilities, leaving the user full control over the settings and security. This would be way too much of a security concern for any large organization to deal with.

4.4 Symantec pcAnywhere

Symantec pcAnywhere 10.0 Enterprise would provide the best solution to desktop accessibility in the Windows environment. pcAnywhere is the mostly widely used remote access application, and with its latest editions, concerns system administrators have had, such as security and management have been addressed. Its real power lies in its ability to be centrally managed. With simple Microsoft Management Console Snap-

Ins, administrators can control and lock the configuration of all the client machines from a centralized point. It was too easy for users in the past to create major security holes by misconfiguring remote access sessions. Another desirable feature is its ability to integrate with Microsoft Active Directory to provide authentication. This truly offers a centralized way to mange who has access to what resources. It also supports serialization, where a security code can be installed on the client and server software, so anyone outside the company will not be able to connect unless they know the companies private key.

We tested pcAnywhere on a 100 MB/Full Duplex LAN and it performed extremely well. The speed and latency were comparable to that of VNC, which has traditionally been the best performing remote access solution. At a quantity of 500, the approximate price for the Enterprise LAN edition would be about thirty dollars each. This solution will work for sharing desktops of individual computers, but does not create a centralized system for application sharing like ACE does.

5.0 Videoconferencing

ACE's videoconferencing capabilities will allow for multi-user video and audio conferencing using its own proprietary transport and encoding protocols. The aim of these special protocols is to create a very efficient means of transporting data for use over the Internet and other low speed connections. Users will have the ability to reserve videoconference rooms and then control their videoconference sessions via the ACE GUI. Other forms of control like voice recognition and PDA support will also be supported.

There are a lot of video conferencing solutions for Windows, but none have the same ability to integrate so many different technologies such as environmental control, voice recognition, and device security. We tested Microsoft NetMeeting, Microsoft Exchange Conferencing Server, CuSeeMe Server. The test setup consisted of three client PC's ranging from a 366Mhz laptop to a 1.5GHz Pentium IV workstation. They all had at least 128MB of memory and made use of Turtle Beach or Creative Labs sound cards. The cameras used were all standard off-the-shelf USB models from Logitech, EZonics, and Intel. All of them were priced reasonably around $50 and produced the same quality image at 352x400. The only real difference between them was the software. We also tested a variety of network speeds including 11 Mb/s 802.11 wireless, 10 Mb/s Switched Ethernet, and 100 Mb/s switched Ethernet all on the same LAN.

5.1 Microsoft NetMeeting

Microsoft NetMeeting is a powerful videoconferencing and collaboration package, with built in file transfer, whiteboard, chat and remote accessibility features. NetMeeting allows two people to collaborate using the H.323 videoconferencing standard, which provides for interoperability with other H.323 compatible clients. It is free to download and comes standard with all of the latest Microsoft operating systems. Due to user

complaints, Microsoft has focused on making it easier to use and set up. One of the nice features is the audio wizard, which allows you to easily set your volume and microphone levels using a graphical tool. Overall, the user interface was very straightforward, but we felt that it would a lot more familiar to users if it was web-based.

Fig1: Typical Microsoft NetMeeting conference with the preview window enabled. (from http://home.rochester.rr.com/netphones/netmeeting.htm)

The Video Quality was good using USB cameras at 352 x 500 resolution on a 100MB Full-Duplex LAN. Users have the option between selecting between better video quality or a higher video frame rate. At the high quality setting, the video was sharp but still lagged when you waved your hand or made any sudden movement. At the high frame rate setting, movement was much better, but picture quality definitely suffered. On the 802.11 wireless LAN, frame rates decreased and it became unusable at a distance where only 2Mb/s was available. Therefore, we would recommend at least a 10MB full-duplex wired LAN for NetMeeting.

The first trial with audio was a complete failure due to extreme feedback problems. Even after running the audio wizard for a second time, the feedback still persisted. It took an adjustment of the microphone and output levels along with a repositioning of the speakers and microphone to finally eliminate the problem. On a larger scale, it would probably be best to distribute some sort of headset with a microphone since it could help resolve possible feedback problems. We tested out the other features it had such as chat, file transfer, remote access, and whiteboard, with good success. Overall, we were pleased with NetMeeting and consider it a very usable and revolutionary business tool.

5.2 Microsoft Exchange Conference Server

The addition of Microsoft Exchange Conference Server allows three or more NetMeeting users to videoconference through a web interface, effectively creating virtual meeting spaces. Microsoft Exchange Conference Server also has the ability to host data conferences, where hundreds of users can all view a common broadcast. Users can schedule videoconferences through the Outlook 2000 client just like they would schedule a normal meeting, with one exception. Since this is an add-on to Microsoft Exchange 2000 Server, they must invite a special user to signify that they want to use a certain videoconferencing resource. This is not as straightforward as one would hope, but does work for the time being. The latest version of the Outlook client, Outlook XP, tries to address this issue by creating a special "Resource" list when inviting meeting members.

To schedule a videoconference, the user creates a new meeting request specifying the start and end time, along with other participants they would like to invite. The schedule checking ability of Outlook, allows the meeting creator to see the others schedules so they can avoid any possible conflicts. Once everything is set up, an email is sent around to all the conference attendees, and they are automatically given the chance to set an alarm to warn them 15 minutes before the conference starts. Also, the special user who represents the videoconferencing resource, sends an email to everyone containing a URL that users click on when they are ready to start the meeting. When the attendee clicks on the URL, a window is displayed with a list of connected users, their optional video windows, and the NetMeeting style controls.

Fig. 2: A typical Microsoft Exchange Conference Server videoconference; Notice the NetMeeting controls at the top of the screen. (from http://exchange.devx.com/upload/free/features/exchange/2000/08aug00/bs0008/bs0008.asp)

The actual video conferencing sessions have the same exact feel as NetMeeting with the same features such as whiteboard, chat, file transfer, and desktop sharing. We were able

to get a three person conference going with no problem. The picture quality and performance were comparable to that of a two person NetMeeting conference.

The video bridging and scheduling abilities of Microsoft Exchange Conference Server really make videoconferencing an attractive resource. A business site license for Conference Server is around $3000-$4000 and does not include licensing for the required Exchange Mail Server.

5.3 CuSeeMe

CuSeeMe Networks, which has just been acquired by First Virtual Networks, offers two videoconferencing solutions, CuSeeMe Conference Server and Click2Meet. CuSeeMe Conference Server, is their multi-user H.323 compliant package that is in common use all over the Internet today. One of the obvious advantages is the fact that it will run on SunOS, Linux, and Windows. Its powerful and easy to use interface was impressive, providing a very natural set of controls that typical users would be comfortable with.

Fig. 3: CuSeeMe Conference Server's simple to use interface.
(from http://www.fvc.com/products/videoware.htm)

On our local LAN, CuSeeMe performed as well as Microsoft Exchange Conference Server, providing clear audio and video. Even though the look and feel of CuSeeMe is desirable, it is hard to justify spending $40,000 for a 25 concurrent user license.

Click2Meet is a videoconferencing resource manager that creates a central web portal where people can schedule and perform real-time videoconferencing. Using the Click to Meet interface, users can find each other and schedule conferences in a simple manner.

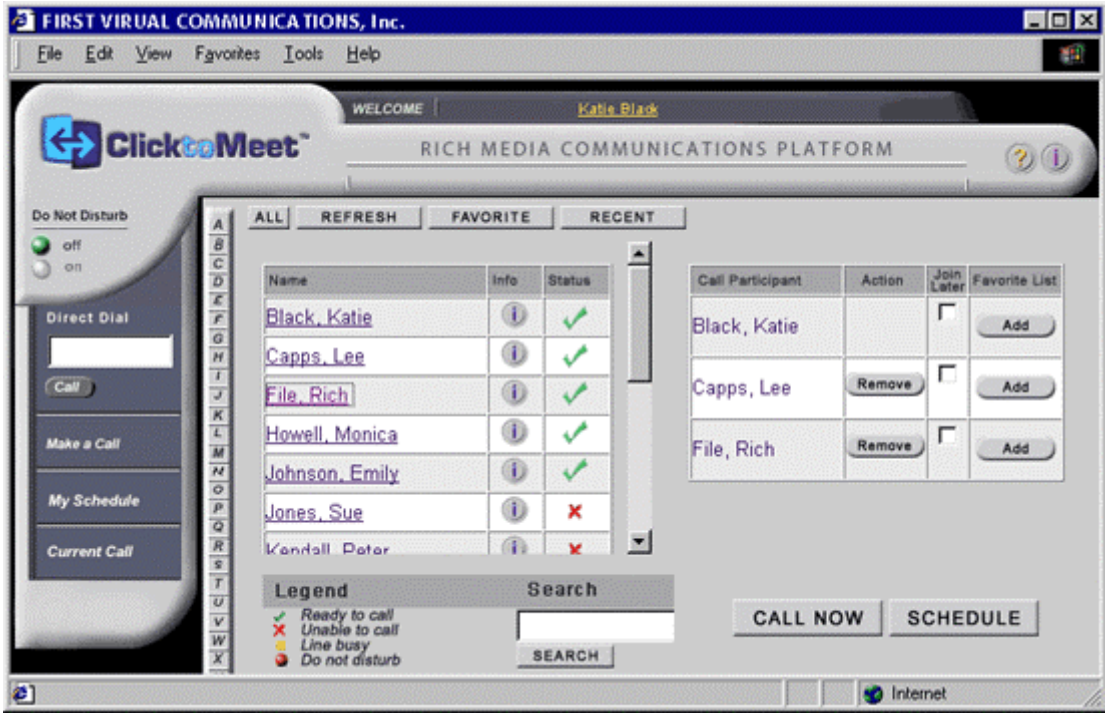

Fig: 4 – The ClicktoMeet Interface
(from http://www.fvc.com/products/clicktomeet_ui.htm)

Click2Meet is really an add-on for the CuSeeMe Conference software, providing a great way to manage video conferencing resources. The software also acts as a gatekeeper since it can control legacy ISDN, IP, and ATM videoconferencing hardware. Unfortunately, we were not able to test this software since no demo version is available. They are asking $70,000 for licensing that allows sixteen simultaneous users to videoconference at once with no limit on the maximum number of total users.

Overall, the videoconference solutions for Windows will give you basic videoconferencing functionality with scheduling capabilities, but will not offer any true ACE-like integration. They will not be able to control the cameras, projectors, lighting or audio hardware, or offer any sort of security for these devices. Also, these solutions are tailored for the individual desktop user and are not designed for multi-user conference room meetings where multiple people will need to interact simultaneously.

6.0 ACE Hardware

ACE will take specific advantage of the advanced programming interfaces (APIs) of hardware devices, so they may be controlled by the various ACE software daemons. For instance, the voice command daemon might interact with the camera daemon to reposition the camera after receiving a voice command from a user. Another example would be the scenario of a person walking into a videoconference room, identifying themselves, and having the projector automatically turn on and calibrate itself to the

room. This is all possible since the ACE environment will have full control over most of the hardware.

The current generation of Windows videoconferencing packages do not have the functionality of controlling hardware. Some hardware devices do come with a GUI to control them, but there is no way to imbed it into other programs. Hardware control will most likely have to be supported at the operating system level, and standards will have to be further developed before this problem can be solved.

ACE also tries to mimic hardware functionality in software. The object is to decrease the amount of hardware in the form of external rack equipment such as pre-amps, mixers and signal processors. Instead of using an elaborate outboard microphone mixer, echo canceller, and signal processor, ACE calls for a simple 10-channel A/D converter and custom software to do the rest. The ACE audio daemon will just simply sample each of the 10 input channels, adjust the levels based on pre-programmed room characteristics, and perform the necessary echo cancellation and signal processing. This eliminates a fair amount of external hardware and gives the ACE environment complete control over all aspects of the sound. My recommendation for the Windows environment would be to use an outboard microphone mixing solution that is specifically intended for voice conferencing. The Shure AMS8100, which retails for around $1800, provides eight input channels and automatic microphone activation.

7.0 Voice Recognition

ACE relies on voice recognition for the control of cameras and environmental controls to create a more user-friendly environment. For example, users will be able to give commands such as "dim lights" and "volume down", providing a very convenient means of controlling the videoconferencing hardware without having to use a GUI. ACE will use IBM's Via Voice software on the Linux platform to perform this task. Since these features rely heavily on the use of custom software that makes use of the speech recognition software's API, this will be very difficult to attain this functionality in Windows without writing custom software. However, since some voice recognition packages allow you to control the execution of programs, very limited functionality might be possible.

7.1 IBM ViaVoice

IBM offers multiple versions of the ViaVoice software for Windows. All of the versions allow you to perform dictation but only the Pro and Advanced versions allow the ability to execute programs or browse the web via voice. Unfortunately this offers limited functionality due to the fact that the program has to be completely controllable via command line arguments or that it has to support ViaVoice explicitly.

7.2 Dragon Naturally Speaking

Dragon System's Naturally Speaking has been around for a long time and has focused there research on accurate voice recognition. They won the PC Magazine's Editor's Choice Award as the best speed recognition package. From my experience, Dragon Naturally Speaking has shown much better recognition rates.

8.0 Handhelds and Portable Computing

Handheld computing has come a long way in previous years and is showing no sign of slowing. Powerful handhelds such as the Compaq IPAQ have extremely fast processors and high quality color screens. In its early stages, ACE plans to use the Compaq IPAQ to implement the ACE GUI for camera and environmental controls. This gives them a very advanced platform to provide highly customizable control of all facets of ACE. There has also been talk about forwarding phone calls to it using Voice over IP when you are away from your desk. Right now, the ACE team is evaluating the usability and performance of the Linux operating system on the IPAQ. ACE is still in its infancy regarding portable computing and is waiting for new applications to arise.

Windows Compact Edition (Windows CE), is Microsoft's operating system offering to the compact world. There is an ever-increasing software library available for it, and it has a special version of the Internet Explorer web browser. With the Microsoft Mobile Information Server installed on an Exchange server, a Windows CE handheld can access an Exchange server without being synced in a cradle or using a normal PC. Technologies like NetMeeting, pcAnywhere, and Virtual Network Computing are not available currently, but it is likely they will be released in the future.

9.0 Conclusion

Without writing custom software for the Windows environment, most of ACE's innovative functionality will be lost. It will not be possible for the videoconferencing software to control the projector, cameras, or lighting, nor will any of the software have access to a database of security assertions. Also, cameras will have to be positioned manually without having access to the room descriptor database and it will not be possible to control the videoconferencing environment via voice commands.

Even though true ACE-like integration is not possible using off the shelf software, all is not lost, since some of the same raw services can still be offered. Symantec pcAnywhere could provide a very cost-effective and useful remote access solution. A company could benefit from putting dumb terminals in conference rooms, allowing employees to have access to their personal computers on their desk. Now that there are ways to centrally manage these services, a comfortable level of security can be obtained. This however, does not provide a truly centralized desktop portability solution, in which your desktop and applications are kept on centralized servers. For videoconferencing, Microsoft

Exchange Conference Server will provide a good desktop-based solution since it could be an inexpensive add-on to a company's existing Exchange mail environment. Even though it will lack the control and security features that ACE offers, it still provides a relatively easy way to videoconference. This however, will not provide a good conference room solution without having a machine for each user and connecting each user individually.

Unlike ACE, outboard hardware will have to be used to mix and process the microphone signals. This leads to more videoconferencing hardware and increased complexity. Voice recognition will not be possible for controlling the videoconferencing software since the software is designed for simple tasks such as web browsing and dictation. There will also be no GUI to control user access or the device directories.

Once the software base for PDA's evolves, programs like pcAnywhere and Virtual Network Computing will become available and give users access more powerful computational resources and information from portables. Software like Microsoft Mobile Information Server provides a great way to link PDA's to a Microsoft Exchange mail server, allowing the direct exchange of contacts, calendar, and email.

Without writing custom software for the Windows environment, many of ACE's true advantages will be lost. However, with the information in this document, a systems designer could hopefully design a more useful computational and collaboration environment for Windows based servers. As software continues to evolve, it is possible that hardware device security will make its way into Microsoft Active Directory and new standards will be developed for hardware control. Unfortunately, Microsoft only gives us a glimpse of what technologies they have planned for the future such as Windows.NET. Even with rapid software advances, we feel that a concept such as ACE with its advanced integration capabilities and large feature set will take a long time to emerge in Windows based off the shelf software.

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