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AnySpot: Pervasive Document Access and Sharing

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AnySpot is a Web-service-based platform that seamlessly connects users to personal and shared documents wherever they go, meeting several key requirements of pervasive information access.

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In the early 1990s, Mark Weiser envisioned a world in which “each person is continually interacting with hundreds of nearby wirelessly interconnected computers”[1] that ultimately “weave themselves into the fabric of everyday life until they are indistinguishable from it.”[2] A key to this vision is pervasive information—being able to use any content or service on readily accessible devices over networks that don’t tie us down. Although we’ve come a long way toward this ideal, remotely accessing and sharing documents across protected networks remains challenging.

The World Wide Web, wireless devices, and wireless networks have increased the opportunities for supporting pervasive document access and sharing. However, today’s solutions remain spotty in their coverage for pervasive information needs. To address this, we developed AnySpot, a Web-service-based platform for seamlessly connecting people to their personal and shared documents wherever they go. Here, we describe AnySpot’s design principles and report our experience deploying it in a large, multinational organization.

Pervasive information requirements

To develop a pervasive document access and sharing platform that would approach Weiser’s vision, we had to address the following pervasive information needs:

- *Seamless integration with everyday life.* To minimize impact on users and organizations, we can’t expect them to adopt new storage practices, such as Web repositories; operating systems, such as distributed file systems; or special client technology, such as virtual private network (VPN) client software or thin-client devices.
- *Fast personalized access.* Mobile users are often pressed for time and use portable and embedded devices with limited user interfaces (UIs), such as mobile phones and office copiers. Offering personalization options can dramatically reduce the need for browsing and searching and thus greatly reduce file access time.[3]
- *Seamless sharing.* Document sharing is common, yet sharing files across organizational boundaries remains much harder than it should be. Users should be able to seamlessly share files and folders, without having to deal with the problems associated with email attachments, shared repositories, or extranets.
- *Multiple interfaces.* Users seeking pervasive access and sharing won’t always have a laptop or desktop close at hand. Users need various interfaces, both portable and embedded, including mobile phones and office copiers.
- *Networked services.* It’s one thing to be able to access any document on your cell phone, but it’s another to actually do something useful with it beyond reading it on a tiny screen. Users should be able to easily deliver their documents to arbitrary services for sharing, emailing, faxing, printing, and translating.

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Tools for Mobile Document Access and Sharing

There are numerous tools for accessing and sharing documents across network boundaries. However, no solution fully realizes Mark Weiser's vision for pervasive information.

- Desktop teleporting solutions, such as VNC[1] and GoToMyPC (www.gotomypc.com), let users interact with their desktops from other PCs as if they were their own.
- Virtual private network (VPN) technology—including hardware, software, and Secure Sockets Layer VPNs (see www.juniper.net)—lets remote users securely interact with their firewall-protected resources as if they were inside their corporate firewall.
- "Thin client" solutions leverage client PCs that are akin to "dumb terminals" for securely interacting with a corporate network's applications and data.

Although these solutions support remote access, users typically use email, Web repositories, and extranets to share documents across networks. Email attachments are fine for simple document dissemination, but sharing large files and file collections is complicated due to mail server attachment restrictions. Also, multiple users editing emailed files can lead to versioning problems. As a result, researchers have shown significant interest in using Web repositories for sharing.

Web repositories—such as BSCW[2] and Xerox's DocuShare—let users share and coordinate document collections across networks. Personal online storage solutions, such as Xdrive (www.xdrive.com), let people access and share their files over the Web. However, these solutions don't "weave themselves into the fabric" of users' everyday lives: users must copy files from their desktop PCs and file servers to a centralized repository before they can remotely access or share them.

Extranets overcome some of these limitations, but require special authority, skill, and effort to set up and maintain. Researchers have also developed other systems to address some of these limitations, including distributed file systems such as Coda,[3] and cell-phone-based systems for mobile file sharing, such as Satchel[4] and Serefe.[5]

REFERENCES

1. K. Wood et al., "Global Teleporting with Java: Towards Ubiquitous Personal Computing," *Computer*, vol. 30, no. 2, 1997, pp. 53–59.

2. R. Bentley et al., "Supporting Collaborative Information Sharing with the World-Wide Web: The BSCW Shared Workspace System," *Proc. 4th Int'l World-Wide-Web Conf.*, ACM Press, 1995, pp. 63–74.

3. M. Satyanarayanan, "Scalable, Secure, and Highly Available Distributed File Access," *Computer*, vol. 23, no. 5, 1990, pp. 9–21.

4. M. Lamming et al., "Satchel: Providing Access to Any Document, Any Time, Anywhere," *ACM Trans. Computer-Human Interaction*, vol. 7, no. 3, 2000, pp. 322–352.

5. J. Ahn and J.S. Pierce, "Serefe: Serendipitous File Exchange between Users and Devices," *Proc. 7th Int'l Conf. Human-Computer Interaction with Mobile Devices and Services* (Mobile HCI), ACM Press, 2005, pp. 39–46.

The AnySpot platform

As the sidebar "Tools for Mobile Document Access and Sharing" describes, AnySpot goes beyond current systems by adding fast personalized access, seamless sharing, portable and embedded interfaces, and integrated networked services—all in a single platform. With AnySpot, users can remotely access and share resources stored in any file system, using a variety of client devices over both wired and wireless networks. Users can thus access networked resources from PCs at home and in remote organizations, as well as from Internet terminals and wireless hot spots in airports, hotel business centers, and print shops. Users can also use mobile devices and shared document devices—such as multi-function copiers—to fax, print, and share documents while away from the office.

To extend our platform to a wide variety of file sources, clients, and networked services, we chose a service-oriented architecture based on Web services. Figure 1 shows the AnySpot architecture's main components. The *clients* (top left) include Web interfaces for general-purpose access to user files and special-purpose *external applications* that integrate user files into existing document devices or applications. Users can also add *external services* (bottom left) to their accounts for document processing, routing, and output. The *access point* (center) provides the core system functionality, including user authentication, unified access to users' resources, and a shared file system. Finally, the *file sources* (right) provide a standard interface for accessing user files, folders, and file history across multiple file systems.

We designed the access point and file sources so that system administrators could deploy and manage them independently. A typical organization might deploy one access point behind its firewall and one file source for each Windows or Unix network within its intranet. Alternatively, an application service provider (ASP) might manage access points for multiple client organizations, and the clients would need to install and run only the file sources. For home PCs, users can install file sources that connect to "stub" file source proxies running on the access point server. The proxies then use the incoming connections established by the file sources to dispatch requests to the file sources running behind the users' home firewalls.

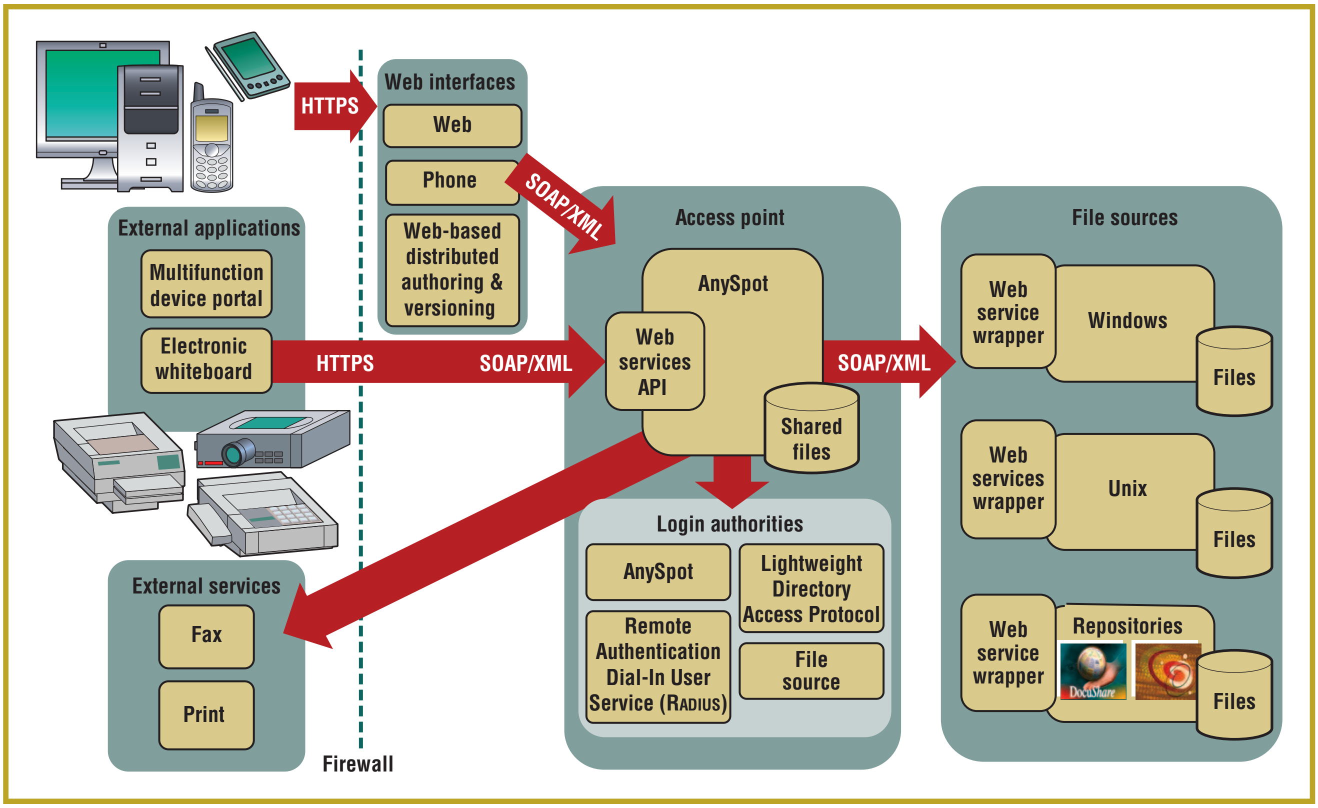


Figure 1. The AnySpot Web-service-based architecture. The clients (top left) include Web interfaces and external applications that integrate users' files into existing document devices or applications. External services (bottom left) process, route, and output documents, while file sources (right) offer a standard interface to files, folders, and file history across multiple file systems.

Realizing the pervasive information vision

AnySpot's design addresses all of the key pervasive information requirements.

Seamless integration with everyday life

AnySpot's file sources support users' existing work practices without requiring them to adopt new storage systems, operating systems, or client interfaces. File sources are Web service wrappers for existing file systems that provide a standard interface for important file access functions, such as *GetFiles* and *GetHistory*. While in the office, users access their files as always. Once they leave the office, however, file sources extend secure access to users' files and history to other devices and networks. We've developed file source wrappers for standalone Windows PCs, entire Windows NT Domains, and Linux workstations. Developers can also create new file sources for other file systems and document repositories and easily plug them into the architecture.

To securely access resources while away from the office, users must provide their login credentials to the file source so that it can temporarily login as users on their desktop computers or networks. This means that users must leave their desktop computers and file servers running. Each file source validates users' credentials against an appropriate authority. For example, an NT Domain file source will use the Active Directory server on that domain, whereas a Unix file source will use the host's pluggable authentication module service.

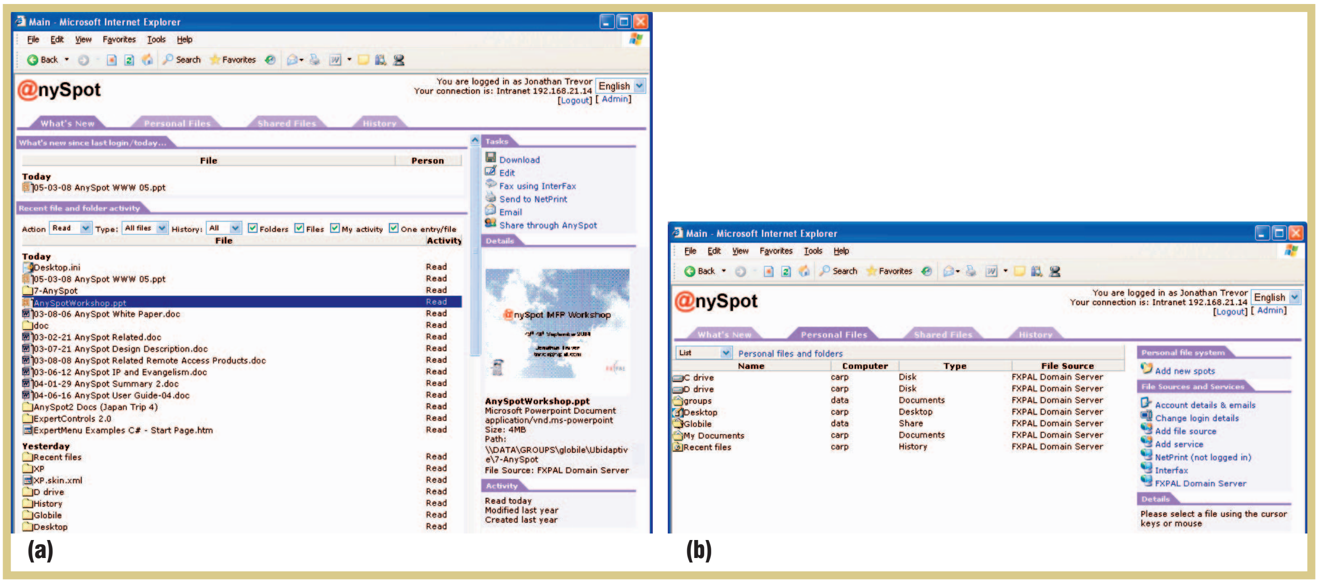
Because the access point acts as a hub connecting remote users with a variety of registered services—from file sources to external faxing and printing services—AnySpot provides single sign-on capability for increased usability.

Fast personalized access

In our previous work, we observed that mobile users were often in a hurry to access files and typically wanted to access the same files that they'd most recently accessed in the office.[3] We therefore developed a personal-history-based interface that presents users' most recently accessed files first. This dramatically reduces the need for browsing and searching, which is particularly important when using limited portable and embedded interfaces. Thus, file sources collect users' file histories so the access point can provide a unified personal-history-based interface for rapid file access.

Each file source uses different mechanisms to gather this information:

- Windows file sources leverage the



(a)

You are logged in as Jonathan Trevor
Your connection is: Intranet 192.168.21.14
[Logout] [Admin]
English

What's new since last login/today...

File	Person
Today	
05-03-08 AnySpot WWW 05.ppt	

Recent file and folder activity

Action: Read Type: All files History: All ☑ Folders ☑ Files ☑ My activity ☑ One entry/file

File	Activity
Today	
Desktop.ini	Read
05-03-08 AnySpot WWW 05.ppt	Read
7-AnySpot	Read
AnySpotWorkshop.ppt	Read
03-08-06 AnySpot White Paper.doc	Read
doc	Read
03-02-21 AnySpot Related.doc	Read
03-07-21 AnySpot Design Description.doc	Read
03-08-08 AnySpot Related Remote Access Products.doc	Read
03-06-12 AnySpot IP and Evangelism.doc	Read
04-01-29 AnySpot Summary 2.doc	Read
04-06-16 AnySpot User Guide-04.doc	Read
AnySpot2 Docs (Japan Trip 4)	Read
ExpertControls 2.0	Read
ExpertMenu Examples C# - Start Page.htm	Read
Yesterday	
Recent files	Read
XP	Read
XP.skin.xml	Read
D drive	Read
History	Read
Globile	Read
Desktop	Read

AnySpotWorkshop.ppt
Microsoft Powerpoint Document
application/vnd.ms-powerpoint
Size: 4MB
Path:
\\DATA\GROUPS\globile\Ubidaptiv
e\7-AnySpot
File Source: FXPAL Domain Server

Read today
Modified last year
Created last year

(b)

You are logged in as Jonathan Trevor
Your connection is: Intranet 192.168.21.14
[Logout] [Admin]
English

List — Personal files and folders

Name	Computer	Type	File Source
C drive	carp	Disk	FXPAL Domain Server
D drive	carp	Disk	FXPAL Domain Server
groups	data	Documents	FXPAL Domain Server
Desktop	carp	Desktop	FXPAL Domain Server
Globile	data	Share	FXPAL Domain Server
My Documents	carp	Documents	FXPAL Domain Server
Recent files	carp	History	FXPAL Domain Server

Please select a file using the cursor keys or mouse

Figure 2. AnySpot's Web UI. (a) The "What's New" tab lets users access recently edited or created files across multiple file systems. (b) The "Personal Files" tab provides unified access to a user's files, folders, and disks across machines and networks.

Windows recent-documents list by automatically maintaining shortcuts to every file a user has ever accessed on his or her Windows PC.

- Unix file sources can traverse limited file-system sets to construct the history, or they might instead find the information by parsing application-specific files, such as the graphical desktop environment's recent-files list.

Finally, file sources maintain lists of "spots" for each user, which are like Web bookmarks that act as quick entry points into commonly accessed folders, such as "My Documents" on Windows systems.

Seamless sharing

The AnySpot access point maintains a shared file system that supports two types of simple ad hoc sharing:

- *Shared proxies*. These are shortcuts or secure links to personal files and folders (resembling Unix's soft links) that provide seamless access to file source files. When the user modifies a shared file using a proxy, the original file changes, and vice versa.
- *Shared copies*. These are copies of personal files or folders that users can share and modify without affecting the original versions. The access point remembers where the originals are, which allows synchronization in both directions.

Because AnySpot combines features of both in-place remote-access solutions (such as Secure Sockets Layer VPNs) and Web repository solutions, users can access the original version of a shared file through its proxy representation and synchronize a shared copy and the original. These are powerful features missing from today's Web repositories.

AnySpot's shared file system lets user quickly and easily share with others based on their email addresses. AnySpot generates and sends special secure URLs that grant access to shared files. When necessary, it also asks recipients to login or register with the system via an automatic email-based address verification process before granting access. The end result is that users can share entire folders or even disk drives from their local PCs with people outside their network or organization by sending them a short email. Users don't need to copy or move their files anywhere, and, in the case of shared proxies, all participants can see any subsequent changes to the file.

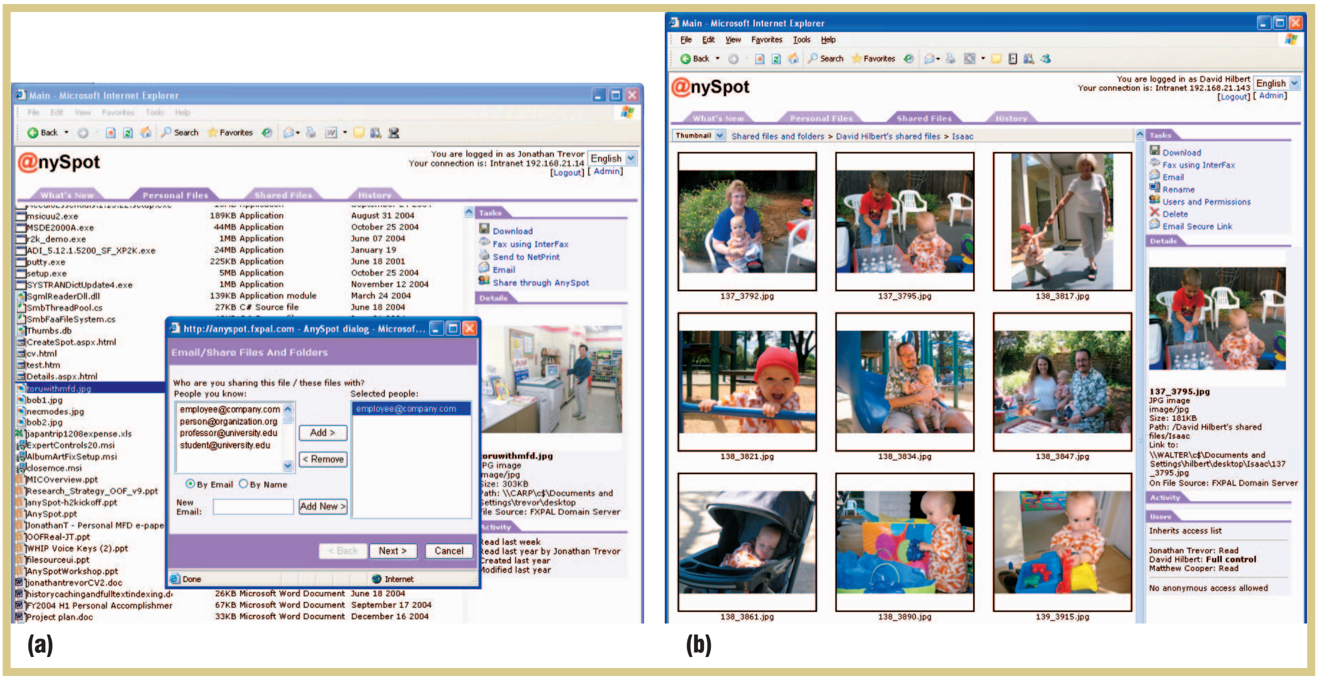
Multiple interfaces

To bring pervasive document features to devices beyond PCs and applications beyond Web browsers, we opted to use Web services. This choice required us to support various authentication mechanisms to provide the best user experience for various devices and usage scenarios.

Our Web services architecture lets us separate the system logic from the UI and build a variety of interfaces on top of the platform. These interfaces range from the most general—accessing and using files from a standard Web browser—to AnySpotPIP, a podium application that lets users present recently accessed presentations by simply swiping a smart card.

Web browser UI. When users log in to AnySpot's Web UI, they first see "What's New," a unified personal-history view of recently accessed and created files (see figure 2a). Users can thereby quickly access the documents they need without having to search or browse networks, machines, and folders.

AnySpot's Web UI is similar to Windows Explorer in Windows XP: Double-



You are logged in as Jonathan Trevor
Your connection is: Intranet 192.168.21.14

msicuu2.exe	189KB Application	August 31 2004
MSDE2000A.exe	44MB Application	October 25 2004
r2k_demo.exe	1MB Application	June 07 2004
ADI_5.12.1.5200_SF_XP2K.exe	24MB Application	January 19
putty.exe	225KB Application	June 18 2001
setup.exe	5MB Application	October 25 2004
SYSTRANDictUpdate4.exe	1MB Application	November 12 2004
SgmlReaderDll.dll	139KB Application module	March 24 2004
SmbThreadPool.cs	27KB C# Source file	June 18 2004
SmbFaaFileSystem.cs		
Thumbs.db		
CreateSpot.aspx.html		
cv.html		
test.htm		
Details.aspx.html		
toruwithmfd.jpg		
bob1.jpg		
necmodes.jpg		
bob2.jpg		
japantrip1208expense.xls		
ExpertControls20.msi		
AlbumArtFixSetup.msi		
closemce.msi		
MICOverview.ppt		
Research_Strategy_OOF_v9.ppt		
anySpot-h2kickoff.ppt		
AnySpot.ppt		
JonathanT - Personal MFD e-pape		
OOFReal-JT.ppt		
WHIP Voice Keys (2).ppt		
filesourceui.ppt		
AnySpotWorkshop.ppt		
jonathantrevorCV2.doc		
historycachingandfulltextindexing.d	26KB Microsoft Word Document	June 18 2004
FY2004 H1 Personal Accomplishmer	67KB Microsoft Word Document	September 17 2004
Project plan.doc	33KB Microsoft Word Document	December 16 2004

Who are you sharing this file / these files with?

People you know:
employee@company.com
person@organization.org
professor@university.edu
student@university.edu

Selected people:
employee@company.com

● By Email ○ By Name

New Email:

oruwithmfd.jpg
PG image
mage/jpg
Size: 303KB
Path: \\CARP\c$\Documents and Settings\trevor\desktop
File Source: FXPAL Domain Server

Read last week
Read last year by Jonathan Trevor
Created last year
Modified last year

You are logged in as David Hilbert
Your connection is: Intranet 192.168.21.143

Shared files and folders > David Hilbert's shared files > Isaac

137_3792.jpg 137_3795.jpg 138_3817.jpg
138_3821.jpg 138_3834.jpg 138_3847.jpg
138_3861.jpg 138_3890.jpg 139_3915.jpg

137_3795.jpg
JPG image
image/jpg
Size: 181KB
Path: /David Hilbert's shared files/Isaac
Link to:
\\WALTER\c$\Documents and Settings\hilbert\desktop\Isaac\137_3795.jpg
On File Source: FXPAL Domain Server

Inherits access list

Jonathan Trevor: Read
David Hilbert: **Full control**
Matthew Cooper: Read

No anonymous access allowed

Figure 3. Other Web UI features. (a) The "Email/Share" wizard lets users share files and folders with anyone. (b) The "Shared Files" tab lets users access and manage shared files.

clicking on folders opens them and displays their contents. Selecting files displays relevant actions or "Tasks"—such as open, download, edit, email, and fax—that users might perform on the file. Just below the task panel is a "Details" panel that shows a preview of the selected file (when thumbnails are available) along with other details, including its name, type, size, modification date, and location. The lowest panel, "Activity," shows the 10 most recent actions—such as emailed, read, faxed, and so on—that the user has performed on the file or folder.

Across the screen's top, tabs form a main navigation bar for accessing users' personal and shared files. As figure 2b shows, when the user selects the "Personal Files" tab, AnySpot shows a list of accessible folders (or "spots"). Users can configure this list; it typically includes links to the user's desktop, documents directory, desktop PC drives, shared folders on file servers, and home directories in Unix networks.

Most tasks provide a wizard-style dialog that leads users through the task steps. For example, the email/share task (see figure 3a) first asks users who they want to send files to, the message's subject and text, and how they want to transmit files to the recipients. Users can choose between attaching a file to the message or making a shared proxy or copy available in the shared file system (optionally protected by a password or requiring the recipient to sign in to identify themselves to the system).

In the "Shared Files" tab, users see a list of files they've shared with others or others have shared with them via AnySpot. In addition to standard file tasks, users can update security requirements for accessing shared files, resynchronize the shared file to match the original (when the original changes), and update the original to match the shared file (when the shared copy changes). Finally, as figure 3b shows, the interface provides an additional panel, "Users," which shows—at a glance—who can do what to each file.

Phone UI. As figure 4 shows, AnySpot also provides a phone UI that lets mobile users email, fax, and print files. The UI provides much of the Web UI's same functionality but is simplified and optimized for the phone's keypad and screen.

In our previous experiences designing mobile UIs,[4] we encountered several situations in which typing a username and password ranged from inconvenient to nearly impossible. We therefore designed the access point to provide an alternative authentication method that associates the user's account with some unique device attribute, such as a cell phone's subscriber ID or a smart card's unique ID. Users can choose whether each device-based login requires their normal password or a simpler PIN.

After logging in, the user can select "My History" to quickly locate recently accessed files or use the "Quick Find" wizard to filter their history based on file type, name, and other attributes. Selecting a file provides a thumbnail preview (when available) and makes network-based services for emailing, faxing, and printing available to users.

AnySpotPIP podium application. The AnySpotPIP application runs on a shared

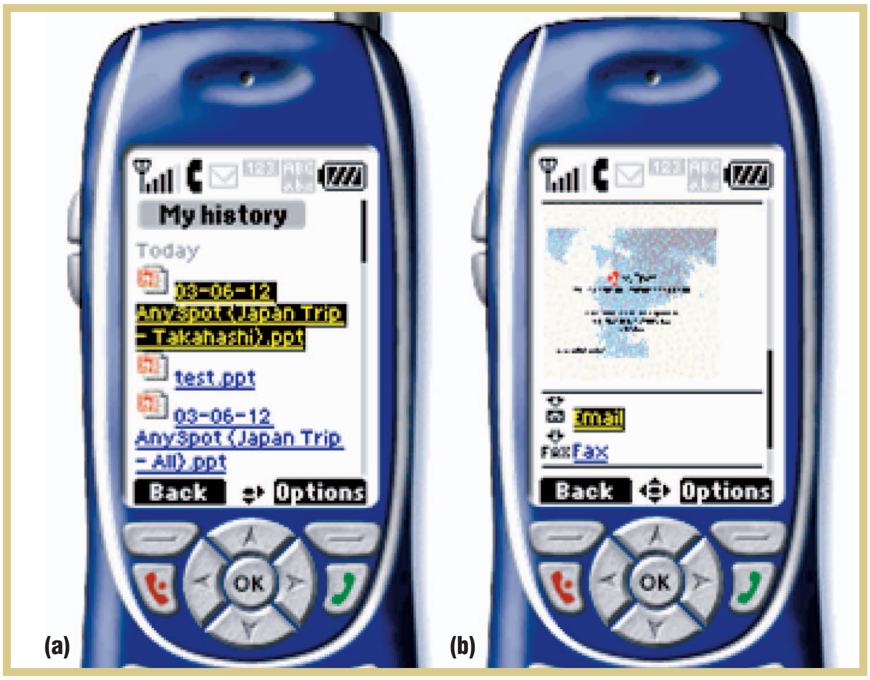

My history
Today
03-06-12 AnySpot (Japan Trip - Takahashi).ppt
test.ppt
03-06-12 AnySpot (Japan Trip - All).ppt
Back
Options
OK
(a)
Email
Fax
Back
Options
OK
(b)

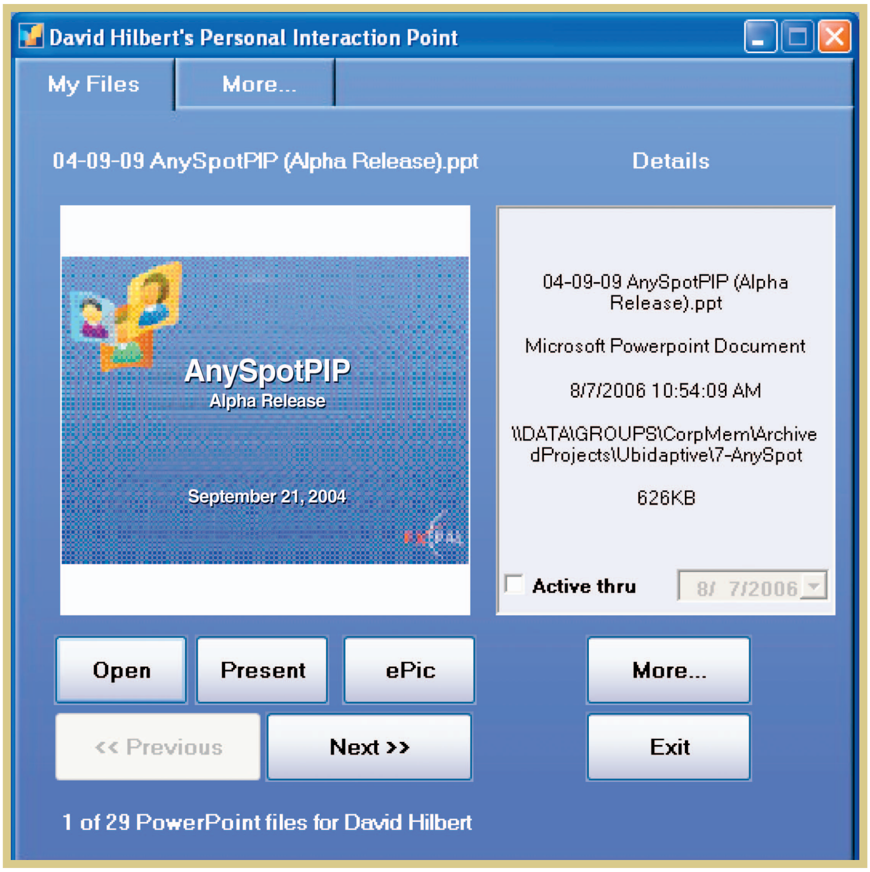
Figure 4. The phone UI. The UI's unified history capabilities let users (a) locate files quickly and (b) do something useful with them.

device—like a podium PC or Smart Board—and lets users swipe a smart card to instantly open and present their desktop documents (see figure 5). AnySpotPIP is a redesign of a previous system usable only within a Windows Domain.[3] Because AnySpotPIP uses AnySpot as its underlying file system, we can install it anywhere—in a distributed organization, for instance—and users can instantly present their files wherever they go. The user's card encodes the URL for the user's AnySpot server, and AnySpotPIP makes use of AnySpot's ability to login users using credentials other than their email addresses and passwords. Users simply walk up to the podium, identify themselves using their card, and press the "Present" button to show their most recently edited presentations.

Outlook add-in. Our Outlook add-in lets Outlook users send large attachments and folders seamlessly via AnySpot without leaving the Outlook application. Users attach files and folders to their email messages by dragging and dropping them on the message. After the user presses send, the add-in removes attachments from the message, uploads them to AnySpot (or creates shared proxies that point to the originals), and a very small HTML attachment containing the secure URLs is sent in their place. Thus, AnySpot users can use a mail client to share large documents with recipients whose email servers won't accept large email attachments.

Networked services for extending device capabilities

A powerful approach to increasing pervasive document access and sharing capabilities is to harness network-based services to extend a target device's capabilities.[4] In AnySpot, we can integrate external services into the access point to supplement the built-in tasks that users


David Hilbert's Personal Interaction Point

04-09-09 AnySpotPIP (Alpha Release).ppt

Details

04-09-09 AnySpotPIP (Alpha Release).ppt

Microsoft Powerpoint Document

8/7/2006 10:54:09 AM

\\DATA\GROUPS\CorpMem\ArchivedProjects\Ubidaptive\7-AnySpot

626KB

□ Active thru 8/ 7/2006

1 of 29 PowerPoint files for David Hilbert

Figure 5. The AnySpotPIP podium application. Users simply identify themselves using a smart card to instantly open and present desktop documents.

can perform on their personal and shared files and folders.

Two examples of external services that we've integrated include InterFax (www.interfax.net) and NetPrint (www.printing.ne.jp). InterFax is an online fax service that accepts a variety of file formats and faxes them to any fax machine. With this third-party service, users can instantly fax their files, even from their cell phones.

NetPrint is a Fuji Xerox print service that lets users upload their files and print them on Fuji Xerox multifunction devices (MFDs) in thousands of 7-Eleven stores across Japan. Service users upload a document to the service's Web site and receive a unique eight-digit code that they can later use to print the document on any 7-Eleven MFD. AnySpot considerably enhances the service's value by enabling cell phone users to instantly route any of their documents to NetPrint on-demand, letting them print any file rather than just those they'd previously uploaded.

AnySpot offers continuous resource access, without requiring that files be in a special location for remote access. It reduces the need to plan for contingencies when traveling or working offsite.

Deployment and user experience

We've deployed and used two AnySpot versions (with the Web UI, phone UI, and other interfaces) at our laboratory of approximately 25 researchers for nearly two years. We first demonstrated the system's capabilities at several staff meetings, then encouraged our colleagues to sign up and use AnySpot prior to traveling. At this time, more than three-quarters of our colleagues have accounts.

Over the past year, we asked our colleagues to send us anecdotes about how they use AnySpot. Our goal was to learn which scenarios were most useful to our users and how AnySpot fits in with other technologies. Our users vary from the technically savvy to more casual computer users. We've observed five different usage patterns with the current system.

Unanticipated data access

There are many situations in which users need personal or corporate information access while traveling. Typically, users plan ahead, copying the presentations or data onto a laptop or portable storage device. However, in several cases, users found that their preplanning was either insufficient or rendered useless by external factors beyond their control. The following quote illustrates a common example (and the workaround):

> *[W]e were giving a presentation and demo at [a company]. We brought a machine with the presentation on it, but somehow that machine did not want to connect to the projector. They offered us the use of one of their Macs ... After 15 minutes or so of trying all kind of things, [a colleague] suddenly said 'Let's try AnySpot.' So, we started up a browser on the MAC, and there the original copy of the file was on my desktop, which we could easily get. Très cool.*

This problem illustrates one of the most frequent uses of AnySpot—to fetch and give a presentation on a foreign machine when the laptop fails. One particularly extreme case occurred when a user was preparing a conference presentation. Because laptops "never fail," he wasn't carrying the material in any other form (such as a CD-ROM). When the hard disk crashed the evening before two presentations, he used AnySpot's Web UI in the hotel's Internet room to burn a CD-ROM containing the presentation and several videos from his office desktop machine, which was a continent away.

In another case, users attending a meeting were unexpectedly asked for supplementary materials that weren't on their laptop, so they simply opened AnySpot's Web UI and retrieved the relevant information.

Changing work practice: A safety net

Once users became more confident in AnySpot's capabilities and stability, we noticed a change in work practice:

> *Now, when I am on the road, I feel considerably more secure about materials I might not have thought to have brought along—I know I can always go online and retrieve easily any files I might need.*

Another user noted that AnySpot helps him get going quickly:

> *I was preparing for a trip, but needed to leave work in a hurry.... However, I knew I could use AnySpot at home to get my files, so I didn't worry about it. I got home, got the files, and everything was copasetic.*

AnySpot offers continuous resource access, without requiring that files be in a special location for remote access. It thus reduces the need to plan for contingencies when traveling or working offsite.

A secure email alternative

Many people use email as a main method for distributing documents. However, organizations sometimes place limits on incoming attachment size (for example, 2 Mbytes) and are increasingly limiting the types of attachments they'll accept (for example, only ZIP or text) to protect against viruses. Getting files to recipients—even those within your organization but on different networks—

often requires uploading files to some Web site and setting up access permissions before sending the URL.

Many of our users use AnySpot's email task to send large presentations or materials securely to others both within and outside our organization.

> *We have used AnySpot several times to email really large files of posters for poster sessions to group members who were at conferences.*

AnySpot also offers a safe and easy alternative for sharing highly sensitive documents with external users. Users in our organization have leveraged this capability for sharing materials with our patent attorneys. Users simply select the documents or folders and share them in the shared file system, protecting them by limiting access to the lawyers only, by adding a common prearranged password, or both.

A lightweight complement to IPSec VPN

Our company provides employees with either hardware or software Internet Protocol security VPN so they can connect to the intranet from their home PCs or laptops. A few employees in our organization have used AnySpot to complement our VPN system and to overcome some of its unintended limitations.

> *I use it to work on articles when I'm at home instead of using VPN and mounting remote drives to work on the files that are stored on office machines. I download a copy of the file to my laptop using AnySpot, and upload it after editing. I can just use my normal home network instead of relying on VPN, which times out or can also disconnect if my laptop sleeps (while I watch TV).*

> *At home, I use a Mac, and for the longest time, VPN was broken for Macs, so you couldn't really get to the company's intranet. I started using AnySpot to retrieve files from my office computer to work on them at home. I believe VPN now works again, but I never felt the need to install it. AnySpot does everything I need.*

By offering immediate access to recently edited or created files, AnySpot complements traditional VPN solutions.

Creating small extranets

For software releases and sharing pictures, users frequently take advantage of AnySpot's ability to make entire hierarchies or even single large files securely available outside the organization without having to copy or move files.

Previously, when we wanted to share software with our parent company, we shipped it via FedEx on CD-ROM or created special password-protected areas on our external Web site. Each of these solutions had drawbacks. FedEx took much longer, while changing our main Web site required creating a sub-Web, protecting it appropriately, and then transferring the correct documents to it. AnySpot eased this process. Users can now simply create a secure link to a folder on one of our main file servers and protect it by either using a password or restricting access to particular email addresses. Further, by examining each file's activity trail, we know who accessed the software release and when.

Many of our users maintain picture folders on their PCs. Now, rather than uploading the folders to a Web site and creating an index page, they often used AnySpot to simply email a link to the folder. Although the end result isn't as aesthetically pleasing as a customized Web page, the Web UI's thumbnail view offers a much quicker and easier alternative for sharing photos (see figure 3b).

Real-world adoption challenges

We encountered several unexpected issues when trying to deploy AnySpot in our large, multinational parent organization.

Security concerns

Successfully deploying AnySpot requires that network administrators let Internet clients connect to an intranet server using SSL. As a result, they must configure the corporate firewall to allow incoming HTTPS connections. While several increasingly popular SSL VPN solutions—from Cisco, Nortel, Juniper Networks, and others—have this same requirement, some companies remain reluctant. In fact, some countries have government guidelines advising against allowing any external traffic to enter internal networks through firewalls.

One solution is to use a layered network approach, in which a reverse proxy screens all incoming requests. This was our initial approach. We've also developed a reverse tunnel approach, connecting an internal server to an external gateway, which then uses the outbound connection to send inbound requests. This is similar to the GotoMyPC (www.gotomypc.com) and SwanSTOR (www.areabe.com) approaches and requires no incoming firewall openings.

Successfully deploying AnySpot requires that network administrators let Internet clients connect to an intranet server using SSL.

Network administrators were also concerned that user accounts might be compromised, allowing unauthorized access to protected resources. To address this, added support for RSA's two-factor authentication to prevent replay attacks (through key-logging, for example).

Although current corporate security policies have raised challenges in deploying AnySpot, we believe there's a trend toward SSL-based VPN solution adoption, and that AnySpot's many security features (two-factor authentication, no buffer overrun possibilities, no unchecked user parameter SQL queries, and so on) make it a secure enterprise solution.

Environmental concerns

In some countries, compliance with ISO 14000 environmental management standards is an important goal. To conserve energy, many companies turn off lights, air conditioning, and workstations when they're not in use, such as at lunchtime and overnight. Unfortunately, our design and usage scenarios implicitly assume that users' desktop PCs and file servers will always be on. However, we've begun exploring alternative models that wouldn't require continuous PC availability, such as an online backup and synchronization-based solution, possibly focused on users' most recently accessed files.

Our experience illustrates at least two cases in which combining features from different system types produces something more valuable than the individual systems offer. First, by combining in-place remote access capabilities with simple sharing features that are typically found in Web repositories, AnySpot lets users share resources in-place, with no copying or versioning issues. Second, by connecting our pervasive file-access capabilities with a service in Japan that lets users print pre-uploaded documents, users can print any document, any time, at any MFD-equipped 7-Eleven in that country.

Web services provide a compelling framework for pervasive computing for several reasons:

- They let developers combine independent systems in unanticipated ways.
- The clean separation they enable between logic and interfaces lets developers quickly build novel clients to support portable and embedded applications.
- They facilitate easy service connections, which lets devices with limited capabilities (like mobile phones) leverage more powerful networked services for increased capabilities (like faxing and printing).

As more services and devices become dispersed throughout the environment and network, Web services will enable more flexible coupling of functionality and devices, resulting in more service use and more device capabilities.

REFERENCES

1. M. Weiser, "Some Computer Science Issues in Ubiquitous Computing," *Comm. ACM*, vol. 36, no. 7, 1993, pp. 75–84.
2. M. Weiser, "The Computer of the 21st Century," *Scientific American*, vol. 265, no. 3, 1991, pp. 66–75.
3. D.M. Hilbert and J. Trevor, "Personalizing Shared Ubiquitous Devices," *Interactions*, vol. 11, no. 3, 2004, pp. 34–43.
4. B.N. Schilit et al., "Web Interaction Using Very Small Internet Devices," *Computer*, vol. 35, no. 10, 2002, pp. 37–45.

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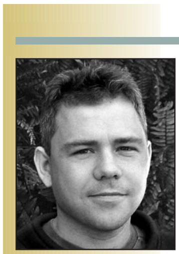

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