

Share and Share Alike: Exploring the User Interface Affordances of File Sharing

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ABSTRACT

With the rapid growth of personal computer networks and the Internet, sharing files has become a central activity in computer use. The ways in which users control the what, how, and with whom of sharing are dictated by the tools they use for sharing; there are a wide range of sharing practices, and hence a wide range of tools to support these practices. In practice, users' requirements for certain sharing features may dictate their choice of tool, even though the other affordances available through that tool may not be an ideal match to the desired manner of sharing.

In this paper, we explore users' current practices in file sharing and examine the tools used to share files. Based on our findings, we unpack the features and affordances of these tools into a set of dimensions along which sharing tools can be characterized. Then, we present the set of user interface features we have prototyped in an interface called a *sharing palette*, which provides a platform for exploration and experimentation with new modalities of sharing. We briefly present the tool as a whole and then focus on the individual features of the sharing palette that support reported styles of sharing.

ACM Classification: H.5.2 [Information Interfaces and Presentation]: User Interfaces—*Graphical User Interfaces (GUI)*; H.3.m [Information Storage and Retrieval]: Miscellaneous; H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces—*Collaborative Computing*

General terms: Design, Human Factors

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INTRODUCTION

With the rapid growth of personal computer networks and the Internet, sharing files has become a central activity in computer use. It is not uncommon for users to have files

and folders shared with other users on a single computer, often as a default system behavior; files shared with other computers over an intranet or home network; and files shared with other users around the world on web sites and FTP servers. Users also commonly exchange copies of documents as email attachments, transfer files during instant messaging sessions, post digital photos to online photo album services, and swap music files using peer-to-peer file sharing applications.

Despite these numerous venues for and implementations of file sharing, the basic process of sharing files is the same. In order for users share files with others, they need to specify three key pieces of information to the computer: *what* should be shared, *with whom* it should be shared, and *how* that sharing will take place.

The ways in which users control the what, how, and with whom of sharing are dictated by the tools they use for sharing; there are a wide range of sharing practices, and hence a wide range of tools to support these practices. These tools range from peer-to-peer sharing applications like Napster [15], Gnutella [9], and KaZaA [14] to email, the web, various shared folder systems, application-oriented tools like iTunes [1] and Groove [11], and web-based sharing tools like BSCW [3], Wikis [13] and Flickr [8]—just to mention a few.

Users select which tools to use based on how well the affordances and features of those tools map to the sharing situation at hand.¹ For example, content placed on a public web server is generally accessible to any user (modulo password protection) from any site that has Internet access. This means of sharing might be appropriate for a university professor who wants to make her publications available to her research peers, some of whom she knows and others she does not. Sending files as email attachments constrains the sharing to a specific set of users, and provides the

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¹ By using the word *affordances*, we allude to Norman's definition of the term: "the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used" [17]. In this paper, we use the term to characterize the fundamental aspects of a user interface that suggest to the user a tool's ability (or inability) to accomplish a particular kind of sharing.

recipients an explicit cue that new content is available. This style of sharing might be better suited for a worker who needs to distribute a monthly sales report to his supervisor and other members of his department at work.

However, these tools also impose limitations on how file sharing can take place. For example, unless some form of notification is used in conjunction with posting the content to the web, recipients have no way of knowing if or when new information is shared. Sharing files via email requires that the intended recipients are known in advance, and places additional burdens on organizing and maintaining an already overloaded computer-mediated communication channel [2].

The set of tools commonly available and used for file sharing today does not fully cover all of the possible styles and needs of sharing. For example, while content placed in a shared folder on a Network File System volume [16] can be restricted to allow access only by certain users, such restrictions can only be done for hosts in a single administrative domain. Likewise, systems such as Napster allow easy retrieval of content once one knows what one is looking for, but only among other users of the peer-to-peer file sharing software [23].

In practice, certain required features may dictate the choice of tool, even though the other affordances available through that tool may not be an ideal match to the desired manner of sharing. To give one concrete example, users often select either email- or web-based file sharing, because of the universality of these technologies—meaning that they can operate Internet wide and do not require participants to be authenticated (or even known) within the same administrative domain. This property often forces users into these two technologies, even though they provide relatively impoverished affordances for and control over sharing.

The goal of our work is to disentangle the features and affordances of file sharing. In this paper, we explore users' current practices and needs around file sharing—how are users currently sharing their files with others; what are the breakdowns that happen in sharing; how do these indicate mismatches between desired sharing practices and the practices enabled by current sharing tools? Second, we attempt to unpack the dimensions of file sharing that are implicitly inherent in current file sharing tools. As noted above, current tools embody a set of features, which may or may not be appropriate to all sharing practices; in particular, users may be forced into suboptimal choices because of certain required or desired features, such as universality. This discussion leads us to the set of user interface features we have prototyped in an interface called a *sharing palette* (see Figure 1), which provides a platform for exploration and experimentation with new modalities of file sharing. We briefly present the tool as a whole and then focus on the individual features of the sharing palette that support reported styles of file sharing.

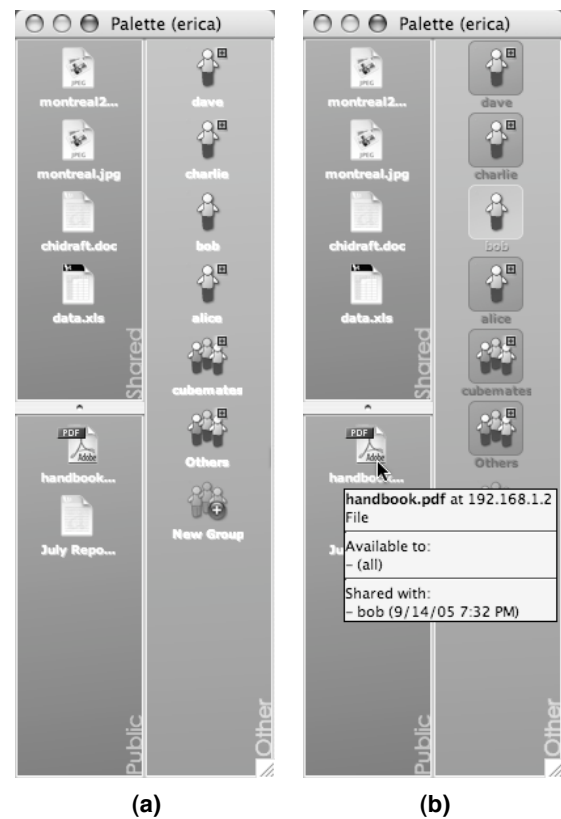


Figure 1: (a) A prototype of the sharing palette user interface. (b) Using the sharing palette to discover with whom the file *handbook.pdf* is currently shared.

SHARING IN PRACTICE

Although file sharing is an extremely common practice, relatively few studies of file sharing practices exist in the research literature. The most significant body of these focus on peer-to-peer file sharing practices [10, 12] and role-based access control of shared resources [19, 21]. Brown et al. [4] and Volda et al. [23] present sharing practices as they specifically relate to music sharing. We are aware of no studies of non-domain-specific file sharing practices, although a recent study by Olson et al. [17] explores preferences for general information sharing.

In order to understand sharing practices, one approach would be to understand the *what*, *with whom*, and *how* of sharing. The study by Olson et al. explores two of these three variables in great detail: what is shared and with whom [17]. In a pilot study, respondents were asked to identify situations in which they (or others) did not wish to share information. Based on the 170 examples collected, Olson et al. ran a follow-up study to explore participants' general willingness to share specific kinds of information with specific classes of people. Their findings indicate that

- users vary substantially in their willingness to share, and as a result, a one-size-fits-all permissions structure for sharing would clearly be inappropriate;
- generally speaking, users treat certain kinds of information similarly when assessing whether or not to share it with others (example classes include

“work email and telephone number,” “pregnancy, health information, and personal preferences,” and “email content, credit card numbers, a transgression”); and

- generally speaking, users treat certain kinds of individuals similarly when assessing whether or not to share information with them (example classes include “spouse,” “manager, trusted co-worker,” and “the public, competitors”).

These categorizations of the *what* and *with whom* of sharing are useful for informing the design of sharing mechanisms. For example, the fact that users tend to treat socially-defined categories of individuals the same with respect to sharing implies that sharing tools might benefit from allowing users to specify meaningful social groups based on the individuals with which they want to share information, and then specify what to share with respect to these categories.

However, since current tools for sharing use widely differing mechanisms to specify what to share and with whom, it is also important to explore how users are currently sharing their files. Thus, we conducted our own study to extend the findings of Olson et al., specifically attempting to understand how sharing occurs, the expectations users have for how information shared with others will be used, and the breakdowns that users have experienced in their own file sharing experiences.

Our study consisted of an in-depth survey instrument and follow-up interviews. The survey asked participants to complete an open-ended table identifying the individuals with whom they share files at work, the kinds of information they share, the mechanisms they use to share the files, and how much control over the information they typically grant to the sharing recipient. We also asked our respondents to rate a series of statements about file and service sharing using a 5-point Likert scale (e.g. “I am generally aware of all of the files that I am sharing, and with whom I am sharing them”) and to identify situations in which their file sharing practices had broken down or had not worked out as expected. We conducted brief follow-up interviews with several of our participants to clarify their responses and go into more depth about their sharing practices.

Our findings reflect the sharing practices of ten employees at a medium-sized research organization. We decided to study expert computer users, as we wanted to capture as much breadth in sharing practices as possible. We also wanted to understand the breakdowns that occurred not necessarily due to inexperience or usability issues, but due to fundamental mismatches between the affordances of current sharing tools and user needs. 6 of our participants were female and 4 were male.

Our participants’ responses regarding with whom they share files generally reflected the findings of Olson et al. Although asked to specify individuals with whom they share files—so as to encourage accurate, descriptive responses—in about a third of the responses, groups or

classes of individuals were used to describe a set of sharing practices. In many of these cases, the classes mapped directly onto categories identified in the Olson et al. study. Additionally, our survey respondents reported sharing files at work regularly with an average of 7 individuals or groups.

The types of files shared (in terms of content, as opposed to association with a particular application) by our respondents were extremely diverse. Even when coded to eliminate naming differences among respondents based on the context in which they were shared, 34 different types of files or electronic information were mentioned, ranging from business documents and paper drafts to music, ideas, schedules, and even TV shows.

In contrast to the number and diversity of file types shared, the sharing mechanisms our respondents reported using were far less varied. Email was by far the most commonly reported means of sharing files (43% of all responses), followed by use of shared network folders (16%) and posting content to a web site (11%).

In 13% of the reported sharing instances, our respondents told us that for a single individual/group and particular type of file, multiple sharing mechanisms were routinely used. Although it is possible that, for some respondents, files are shared in different ways depending on the situation, the combinations of mechanisms most commonly listed—email and shared network folder, email and website—combined with informal follow-up interviews suggest that respondents often used one sharing mechanism and a second, out-of-band notification mechanism simultaneously. In many cases, this strategy was used to make a recipient aware that a new file (or new version of a file) was available while ensuring that the file was persistently available for others to retrieve.

Finally, our respondents reported few expectations regarding access control over files once shared. All indicated that they expected sharing a file to carry with it a minimum of read privileges—an indication that visibility and access are essentially synonymous in a practical sense. Furthermore, almost all of our respondents indicated that they anticipated that the files they shared would carry either read or full control privileges, except for cases in which the mechanism for sharing automatically endowed a particular set of privileges (e.g., iTunes allows sharing recipients to use but not duplicate shared music). We were somewhat surprised, given the expert nature of our participants and the general awareness of potential problems related to digital rights management, that nobody we surveyed indicated concern about preventing unauthorized redistribution of shared files.

Sharing issues and breakdowns

We also asked our survey respondents to report on instances in which breakdowns in sharing had occurred or when sharing had not worked out the way that they had expected. Three main classes of breakdowns in sharing were reported:

- forgetting what files had been shared and with whom,

- difficulties in selecting a sharing mechanism with desired features that was also available to all sharing participants, and
- problems in knowing when new content was made available (or updated) when acting as a sharing recipient.

While most of our respondents reported that they agreed with the statement, “I am generally aware of all of the files that I am sharing, and with whom I am sharing them” (average of 3.7 on a 5 point Likert scale with 5 representing strong agreement), most of the sharing problems reported were related to respondents’ discovering that they had forgotten which files they had shared, with whom they had shared them, or that they had difficulty managing the file permissions—either having set them incorrectly or having forgotten to change them at all.

The availability of a sharing technology for all recipients also played a substantial role in how our participants selected a mechanism to use to share files. They often reported that whenever uncertain about the tools available to their intended sharing recipients or when having problems communicating through a firewall, they tended to fall back to the most universal mechanism in order to share their files. In most cases, the mechanism of choice was to send the information in an email or as an attachment (or, worse, printing out a document and hand delivering it).

Finally, we noted several complaints about the visibility that current sharing mechanisms provide. One participant noted that this lack of visibility affected her sharing practices in two ways: first, she was frustrated that she needed to constantly send email messages to her writing collaborators to inform them when she had updated content on a group-owned collaborative website. Additionally, she resisted posting certain content to a web site since she had no way of knowing who was accessing the information or when the accesses were taking place. These comments, also echoed by other participants, seem to acknowledge a need for better visibility of individuals’ actions surrounding sharing—both for those sharing the files and those accessing them [7].

TRANSLATING SHARING PRACTICES INTO DESIGN

Although users reported a wide range of experiences with sharing, there are a number of salient points that motivate our work on developing new user interface techniques for file sharing. First, various tools exhibit certain properties that users find useful in the process of sharing. Depending on what they are sharing, and with whom, users may feel the need to restrict access to certain administrative boundaries, they may desire the ability to notify others about the presence of shared content, and they may wish to have a log of who has accessed shared content. Currently, no single tool supports all of these desired sharing practices; depending on the situation, users must choose to use one of a variety of separate sharing tools.

Second, despite their desires for a particular functionality, users are often forced into making compromises. Not all tools can be used in all circumstances, with all people, and

with all types of content. Very often, users compromise by sacrificing certain desired affordances or features in order to achieve other required ones. For example, users may be forced to use email because of its universality, even though another mechanism (supporting password protection, public access, or some other desirable property) might be otherwise better suited to the situation at hand. Developing tools that capture the broadest possible set of affordances can reduce the amount of compromise required to affect sharing.

Finally, it is these compromises that lead to what we have termed *breakdowns* in sharing, where problems arise because of mismatches between the properties of the tools in use and the type of sharing the user wishes to accomplish. Clearly, minimizing these kinds of breakdowns is a primary design goal.

In order to determine the most useful set of user interface affordances to explore, we looked to existing sharing tools and the attributes of those tools most influential in the selection of a sharing mechanism. We undertook an analysis of the sharing tools reported as most commonly used by our participants to identify the affordances of each and to enumerate a set of user-visible dimensions along which these tools varied² (see Table 1 for an excerpt of this analysis).

The attribute of utmost importance was clearly the scope of sharing enabled by the sharing tool. The most commonly available sharing tools were those most often used for sharing files. Additionally, we heard several stories about users “falling back” on email when other, in some cases, more appropriate sharing mechanisms were not available to both users or capable of communicating across a particular computer network.

Since addressing is directly related to with whom information should be shared, it can also likely be described as one of these primary characteristics. Furthermore, implicit knowledge about the sharing technologies available to different users was shown to strongly influence the choice of sharing modality used.

Our respondents reported the most breakdowns with respect to the visibility and availability of notifications provided by a particular sharing tool. While these affordances seem to be at a much finer level of granularity than scope and addressing, because of their impact on the overall sharing interaction design, we also consider them to be critical attributes.

After this are a large number of features that may or may not be desirable in certain circumstances, based on with whom something is being shared, and what is being shared. These include:

² By “user visible” dimensions, we do not mean attributes such as code size or internal characteristics; rather, we mean artifacts of the systems that affected the decisions of users about whether or not to use a given tool for a particular purpose.

	E-mail	Web Site	Password-protected Web Site	iTunes	Shared Folders	Web-based Document Repository	Concurrent Versioning System (CVS)
Scope	Universal	Universal	Universal	Subnet	Administrative Domain	Administrative Domain	Universal or Administrative Domain
Addressing	Selective	Public	Selective	Either	Either	Either	Either
Visibility	Archive of sent messages	Files and permissions on server	Files and permissions on server	Integrated into music library	Files and permissions on folder	Varies	Depends on front-end tool used
Notifications	Push	None	None	None	None	Optional	Optional
Location of files during share	Recipient or 3rd-party server	Provider or 3rd-party server	Provider or 3rd-party server	Provider	Varies	3rd-party server	3rd-party server
Specification of access control	Implicit	N/A	Out-of-band	Out-of-band	Out-of-band	Out-of-band	Out-of-band
Access rights	Copy	Copy	Copy	Stream	Copy/Modify	Copy/Modify	Copy/Modify
Logging	Implicit	No	Potential	No	No	Yes	Yes
Redistribution	Any	Any	Any	Restricted	Any	Any	Any
Versioning	Not explicitly supported	No	No	No	No	Yes	Yes
Generally push- or pull-oriented	Push	Pull	Pull	Pull	Pull	Implementation-dependent	Combination; often more similar to pull

Table 1: Characteristics of sharing practices and manifestations of those characteristics for some of the most popular sharing mechanisms reported in our study. The first four rows—scope, visibility, addressing, and notifications—represent primary considerations for choosing a sharing modality. The data in each column reflect the characteristics generally held by applications implementing each of the represented sharing mechanisms.

Location of files during share. Where are files stored between the time that the provider shares them and the recipient accesses them?

Specification of access control. How does a provider specify who can access the shared content? By “out-of-band,” we note sharing mechanisms for which users need to exchange some access token (e.g., a password) to intended recipients using a secondary medium (e.g., over email).

Access rights over shared content. Can a recipient copy the shared content? Can they change it?

Logged access. Is it possible for the provider to determine who has accessed shared content and when that access has taken place?

Redistribution controls. Are there facilities to prevent unauthorized redistribution of shared content?

Versioning of content. If shared content can be changed, is it versioned, so that previous versions can be accessed?

From our perspective, there are gaps in the features offered by certain tools. For example, received notifications that new content is available is only available when sharing takes place over a communications channel or the sharing mechanism is configured to send emails as part of the sharing process. As noted earlier, users are often forced

into sacrificing desirable properties in certain tools because those tools do not provide other required properties. Therefore, if a user wants to make sure that their intended recipient knows that a new file is available, he or she generally has to fall back to email as the sharing mechanism.

These findings suggested the possible utility in creating a new type of sharing platform that addresses the gaps in the table above, in an effort to reduce the forced compromises currently inherent in sharing.

Push- and Pull-oriented sharing: A design space for sharing interaction design

A common characterization of information exchange is whether the information is actively “pushed” from the provider to the recipient, or whether it is simply made available and then retrieved, or “pulled,” at the recipient’s convenience. [4]

Since file sharing is one concrete instance of information exchange, the canonical notions of “push-oriented” and “pull-oriented” sharing certainly make sense. In fact, this distinction is quite closely connected to the particular interactions that are required to affect sharing, both on the part of the provider and on the part of the recipient. Furthermore, if one places the most common sharing

mechanisms along a continuum with e-mail serving as an typical exemplar of a push-oriented sharing technology and posting content to a web server as that of a pull-oriented sharing technology, it becomes clear that many of the other attributes of these tools begin to cluster along the continuum as well.

The distinction of *push* vs. *pull* seems to fundamentally define the type of sharing taking place, at a higher level than—but deeply interconnected with—the other categories. The orientation of a sharing mechanism with respect to *push* vs. *pull* appears to be critical in defining the interaction nature of that mechanism; with any of the other categories, altering the mechanism’s characteristics within that category would still preserve the effective character of that sharing mechanism. For this reason, we consider *push* vs. *pull* as important as the previously identified critical attributes of universality, addressing, visibility, and notification in defining a sharing mechanism.

While the choice of a particular technology obviously affects the actual interaction details of sharing, we believe that certain general characteristics are implicit in both of these modalities:

Push-oriented sharing:

- Requires effort and attention on the part of the sender;
- May require effort and attention on the part of the receiver to process the pushed information (the actual balance of attention with respect to the sender and receiver depends on the nature of the push technology in use); and
- Requires some *a priori* knowledge on the part of the sender to name recipients (email addresses, for example). Often, these may be provided out of band (via a telephone call, for instance).

Pull-oriented sharing:

- May require setup effort and attention on the part of the sender;
- Requires effort and attention on the part of the receiver to acquire the content; and
- Requires some *a priori* knowledge on the part of the receiver that (1) new content is available, and (2) where and how to access that new content.

Often, however, these traits—which are inherent in the division of labor between push and pull—are obscured by the actual technology used to affect sharing. Different implementations of push or pull may shift the balance of labor or require “workarounds” on the part of users to accomplish their sharing needs.

In summary, our design goals for creating a sharing user interface are as follows:

- The push/pull distinction is of primary importance, as it helps to define the most central aspects of the sharing interaction.
- The representation of users and groups is important, particularly in terms of addressing with whom files should be shared. Some of the most common examples we saw in our study were of users wanting to

selectively address things to the public, to individuals, or to semantically meaningful groups of individuals.

- Notifications are useful when using pull mechanisms, and relieve users of the extra burden of having to use out-of-band mechanisms to notify recipients of new content.
- Maintaining visibility—leading to improved awareness of sharing state—is essential, and is critical in preventing breakdowns in knowing what content is shared and with whom.

Although universality of the sharing mechanism is extremely important, it is also a variable more closely affiliated with the underlying sharing transport mechanisms than with the user interface.

Based on our findings, we developed a set of interaction features that mitigate some of the current weaknesses in push and pull sharing technologies; these features do away with some of the problematic aspects of push and pull as embodied in current technologies, and allow users to select a sharing modality based more purely on the affordances of that modality.

THE SHARING PALETTE PROTOTYPE

The sharing palette is a two pane, palette-style user interface for managing shared files. The sharing palette prototype enables users to quickly and easily specify the visibility of and permissions for files without having to maintain access control lists. It also allows users to maintain awareness of the files they have shared with others.

Using the Sharing Palette: A Scenario

Mike, a busy marketing director for a startup company, has just returned to his office following the weekly departmental meeting. After checking his inbox to make sure he hasn’t missed any important emails, he reviews a text document he created containing the minutes from the meeting.

The team had discussed an upcoming advertising campaign and decided to form a working group with members of the sales department to set the goals for the campaign. Mike brings his sharing palette to the foreground and locates the icons representing Tom and Jill, two of his best promotions managers, in the blue “other” pane on the right side of the palette. He drags Tom’s icon to the “New Group” icon and types a name for the new sharing group, “working group,” in the dialog box. The new group icon appears in the “other” pane. He drags Jill’s icon onto the group, adding her as a member of the group, and then scrolls down the “other” pane to find their counterparts on the sales team, adding each to the group by dragging it and dropping it on the working group’s icon.

Once Mike finishes creating the ad hoc group, he searches his computer to find a file of relevant ad campaign notes that his boss, the Vice-president of Sales, recently sent to him. He drags the file from his desktop onto the working group icon in the palette. A moment later, its icon appears in the yellow “shared” pane on the left side of the palette, indicating that it is shared with some, but not all of the

users on the network. He hovers his mouse over the file's icon in the "shared" pane, and the icons for the working group, Jill, Tom, the sales team members, and his new group are highlighted green in the "other" pane; Mike is satisfied that nobody else will be able to access the file.

Mike switches focus back to his meeting minutes and verifies that no other tasks need his immediate attention. He closes the document and then drags its icon from the desktop onto the sharing palette icon for the Vice-president of Sales, who will want to know about the working group developments. As the icon for the minutes document appears in the yellow "shared" pane, Jill's icon in the "other" pane and the campaign notes icon in the "shared" pane are simultaneously highlighted red for a moment indicating that Jill is accessing the file; Jill must be scanning the campaign notes document now.

Mike moves on to other tasks. He opens his project management application and is about to make some notes about a scheduling change when a change on his computer's monitor catches his eye; Jill's icon is now glowing steadily white, indicating that she has shared a new file with him. Mike clicks on Jill's icon and an auxiliary pane appears, containing all of the files she is currently sharing with him. Among the half dozen icons, one is glowing white. He drags the highlighted file icon onto his desktop and opens the file. It appears that Jill's team had brainstormed a number of ideas for a previous ad campaign that hadn't been used, but might be perfect for the upcoming campaign! Intrigued, Mike settles in to peruse the document...

Palette Interaction Features and Implementation

The sharing palette presents local files in the left pane, and other users on the network and the files that they are currently sharing on the right (Figure 1). The left pane is divided into two sections, "shared" and "public." Icons in the public section represent files available for anyone else on the network to use. Icons in the shared section represent files that are being shared with one or more individuals. Files that are not currently shared are not displayed in the sharing palette.

The right pane, labeled "other," represents files that have been shared with the local user by others on the network. These icons are, in this prototype, sorted by the user who is making the resource available, however, sorting the list by the computer on which the file resides or the physical location of the hosting computer would be equally feasible. The right pane also includes ad hoc groups, an "Others" group that serves to reduce clutter in the interface, and an icon for creating new groups (Figure 2).

Users can drag files or folders from their desktop onto the sharing palette to share them with others—and vice versa (Figure 3). Files or folders dropped in the public section of the left pane are shared with all other users; files or folders dropped onto other users' icons or group icons are made available only to that user or group, respectively. (These files then also appear in the shared section of the left pane, to promote persistent visibility of all shared objects.) Files

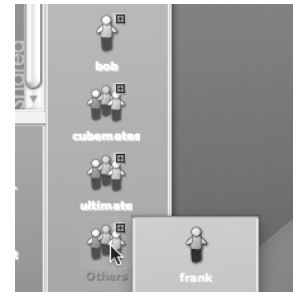


Figure 2. Several representations of potential recipients and providers in the "other" pane of the sharing palette. From the top to the bottom: single user, two ad hoc groups, and a special group aggregating all other individuals not immediately relevant to the palette user.

shared by others and dragged out of their pop-up windows are copied to the destination of the drag on the sharing palette user's computer.

File icons can also be dragged within the sharing palette. For example, resources in the shared section of the left pane can also be shared with everyone by dragging them into the public section. To remove a shared file, its icon can be simply dragged out of the palette altogether, and all sharing permissions are immediately revoked.

Initially, no local files are shared with any other user or group. This default configuration constitutes a secure starting point for sharing files, as nothing is shared with other users until explicit action is taken to enable the sharing behavior [25].

Users can also compose their own groups of individuals in order to streamline the sharing of files with several people at once. A user icon can be dragged onto the "Create Group" icon at the bottom of the other pane to create a new group (Figure 4). User icons can then be dragged onto groups to add them to the group membership list, and they can also be dragged out of the group contents popup to remove them from the group.

A special group named "Others" is always displayed towards the bottom of the right-hand "other" pane. This group is used to aggregate and hide other users that are not immediately relevant to the palette user. Since user icons appear in this pane automatically whenever other instances

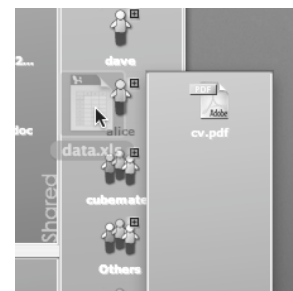


Figure 3. An example of the interaction required to share a file with a particular user. In this case, the file *data.xls* is being shared with the user *alice*.



Figure 4. An example of the interaction required to compose an ad hoc group. In this case, the dragged user icon is being added to the group named “Others.”

of the sharing palette are detected on the network, this serves as an elementary means for providing scalability in the user interface. Furthermore, hiding user icons in the Others group allows the palette user to aggregate all sharing notifications deemed by the user to be of low priority.

Finally, the sharing palette helps users to maintain awareness about what they have shared and with whom. When the mouse cursor is held over an icon in the left pane (Figure 5), detailed information about the object it represents is displayed in a tooltip and all users and groups with whom the object has been shared are highlighted in the right pane. Different highlighting colors are used to distinguish between users with whom the object has been made available—green—and those that have actually retrieved the file—red. Additionally, the tooltip provides detailed information about the time that each user most recently received a copy of the shared file.

The sharing palette prototype is implemented in Java and uses Swing, Java2D and a custom animation toolkit to render the user interface and its interactive effects.

The sharing infrastructure used to create the sharing palette prototype uses the Apple Bonjour³ protocol for discovery. As a result, visibility of shared resources is limited within a subnet. Although this limitation prevents the sharing palette prototype from being used to share files beyond the boundaries of a typical office workgroup, thereby limiting the palette’s universality, it still enables exploration of sharing practices with many of the individuals and groups reported as common sharing recipients in our study. The limited discovery horizon also helps to maintain the usability of the user interface, since our visualization techniques were not designed with scalability as a primary concern. (Because our respondents reported sharing with an average of 7 individuals and groups, we did not make scalability a high-priority aspect of this particular prototype’s design.) Future iterations on the palette might address the scalability issue by providing alternate visualizations based on the local user’s recent interactions with the desktop computer, shared files, or the palette itself.

³ The Bonjour protocol is also known as Rendezvous, OpenTalk, and the multicast DNS aspect of zero-configuration networking.

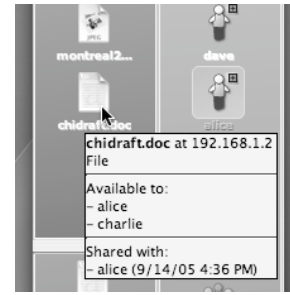


Figure 5. Determining the state of a shared file. A combination of tooltips and icon highlights are used to track sharing state. In this case, the file *chidraft.doc* is available to the users *alice* and *charlie*, and a copy has recently been retrieved by *charlie*.

A Unified Model of File Sharing

The sharing palette prototype provides a single point of interaction for a variety of file sharing styles, introduces a new model for sharing that address some of the limitations of existing sharing modalities, and can easily be extended to more closely emulate traditional push- and pull-oriented sharing mechanisms.

Creating and maintaining access control lists is unnecessary with the sharing palette—sharing a file is as simple as dragging an icon from the local user’s side of the palette onto the intended recipient or group’s icon. Creation of groups is straightforward and requires no changes at the administrative or network level. The sharing palette operates under the principles of usable security: changing access rights is incidental to the act of sharing [6, 22] and the default configuration is a secure system [25].

The sharing palette’s default sharing modality lies at the intersection between traditional push- and pull-oriented sharing. This sharing modality:

- Requires little effort and attention on the part of the sender, since the sender only has to drag the resource to be shared onto the desired receiver’s icon to initiate sharing;
- Requires some effort and attention on the part of the receiver to retrieve and process the shared information; and
- Requires no *a priori* knowledge on the part of the sender or receiver, since all eligible receivers are visible on the sender’s palette and newly shared information is brought to the receiver’s attention through icon highlight animations on his or her palette.

This hybrid sharing modality takes advantage of the useful aspects of push- and pull-oriented sharing and simplifies the user interaction necessary to undertake the act of sharing since all of the knowledge needed to accomplish the sharing from both the sender and receiver’s perspectives are reflected in the interface. Using this modality, agency is shared between the sender and the receiver, as both have a role in accomplishing the sharing interaction. However, for both participants, this role is relatively small.

The sharing palette's default sharing modality is similar to pull-oriented sharing, since files dropped onto the *public* pane or a group icon are simply made available for the receiver to retrieve at his or her convenience. However, by default, this behavior also provides a visual notification to the receiver that new content is available, a capability that echoes the affordances of push-oriented sharing. If a receiver would like to enable one or more senders to share files using a pull-oriented modality and *not* generate a notification highlight each time the shared content changes, they can simply share a folder from their file system with those individuals or make it publicly available. When a sender drops a file into the shared folder, no notification is generated and the agency of retrieving that information lies solely with the receiver, just as if the sender had published the file to a shared network folder or web site.

In our current prototype, the sharing palette serves as a front end to a custom peer-to-peer file sharing infrastructure. This infrastructure can manage shared files in one of two ways: (1) shared files can be stored on the sender's machine until actively retrieved by a recipient, or (2) files can be encrypted and copied over the network to all eligible recipients when shared, and the encryption key distributed when a recipient acts to "retrieve" the file. These implementation details aside, we believe that the user interface design of the sharing palette is to a large degree independent of the underlying infrastructure used to manage and share files. We envision that the sharing palette user interface could easily be extended to serve as the front end for a variety of traditional push- and pull-oriented sharing infrastructures such as email or shared folders.

CONCLUSION AND FUTURE WORK

Supporting file sharing is an important user interface challenge, particularly because file sharing is becoming increasingly common and increasingly important to computer-supported collaboration. Currently, controlling which files are shared, as well as with whom and by what mechanism, is a complex activity, requiring users to navigate a variety of interfaces with different models of access control. However, improving user interface mechanisms for file sharing requires an understanding of users' existing sharing practices.

In this paper, we drew on existing research in information sharing and examined experts' current file sharing practices in the workplace. We noted that our respondents shared a wide variety of file types, that they determine their sharing practices with respect to a combination of individual users and groups, and that they typically select from a small number of mechanisms for sharing, most commonly sending files by email due to its simplicity and universality. The breakdowns in sharing that were reported were often related to the poor visibility of sharing settings in the user interface.

Based on the results of our analysis, we identified a number of critical characteristics of file sharing mechanisms, including universality, addressing, visibility, notification, and a positioning along the spectrum between *push* and

pull. One of our key observations is that users typically chose which sharing modality to use based less on that modality's implicit characteristics and more on the "side effect" affordances of particular implementations of these modalities.

We presented a new user interface for file sharing called a *sharing palette*. The sharing palette features a hybrid sharing modality incorporating some aspects of push-oriented sharing and some aspects of pull-oriented sharing. It also features flexible addressing through the ability to share files publicly, with individual recipients, or with ad hoc, semantically-meaningful groups of recipients. The palette interface provides persistent visibility of shared files and potential recipients, and it includes a variety of notification features, which are designed to promote awareness of changes to the sharing state.

This work also suggests a number of directions for future research. While our user findings have been instrumental in informing our discussions of sharing modalities and the development of our sharing palette prototype, they are by no means exhaustive, nor do they represent the complete spectrum of file sharing practices in use. For example, our study of existing practice focused on sharing in the workplace, but respondents still reported about sharing practices involving family members and friends. Exploring the sharing practices outside the workplace would provide additional depth to our understanding of file sharing. Also, our discussion of implementation-independent sharing modalities suggest that users perceive sharing mechanisms differently based on the "baggage" they include; empirical studies could help to identify the best combinations of sharing modalities and implementation-specific "side effects" for enabling users to accomplish different goals. Finally, a field deployment of our sharing palette prototype would enable a longitudinal investigation of how sharing practices evolve over time as users adopt and appropriate new sharing technologies.

Looking ahead, we also envision some practical extensions to the sharing palette. Given the screen real estate required to maintain a persistent display of shared files and the already-present ability of the palette to reflect the online status of colleagues, it would make sense to integrate the palette with other awareness tools (e.g., an instant messaging "buddy list" or a focus/nimbus-style visualization as suggested by Rodden [19]).

Another possibility is the integration of service sharing capabilities into the palette. Just as current file sharing mechanisms require the use of many sharing tools, sharing live information or services provided by a device (e.g., electronically controlling a common projector, sharing a computer's internet connection, or enabling distributed compilation) also requires configuration using numerous interfaces and different access control representations. An extended version of the sharing palette could provide a common interface for sharing files and services (e.g., [24]).

Over the last year, we have had several opportunities to demonstrate the sharing palette interface to a variety of

computer users with varying degrees of technical expertise. While these demonstrations were not intended to substitute for a formal evaluation of the prototype, we did receive informative feedback from these potential users. Many of them believed that a “one-stop” interface for managing their file sharing would be useful and cited the visibility of all available recipients and shared files as a desirable aspect of the interface design. Others questioned how the sharing palette would interact with existing sharing mechanisms and whether future versions could support digital rights management to prevent unwanted propagation of shared files. While we acknowledge that our interface does not yet address all of the complexities inherent in file sharing (including some scalability and security concerns), this feedback does suggest that our work provides a compelling alternative to existing sharing interfaces.

We believe that the sharing palette design, informed by real-world sharing practices, embodies and instantiates a new, unified model of file sharing and provides a useful point of departure for future research in this area.

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