An Architectural Model to Support Collaborative Work through Mobile Devices

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Abstract

Groupware applications play a major role in supporting distributed teams for working together collaboratively. Several groupware platforms have been developed to simplify the development of synchronous and asynchronous applications focusing on relieve developers from facing standard problems such as communication, synchronization, coordination or concurrency control. Upcoming communication technologies (e.g. wireless area networks, cellular telephones, PDAs, pagers, etc.) are a promising and interesting market for developing group support features. However research in groupware systems does not address the need to support individual tasks, which are part of group activities. As development and research in both areas grows and intermingle, we believe that this issue will acquire more relevance. In this paper, we propose an architecture that allows users to move seamlessly across four different scenarios: individual and collaborative work supported by portable devices and desktop computers.

Keywords: Mobile Work, Collaborative Activities.

1. INTRODUCTION

In Computer Supported Cooperative Work (CSCW) area it is widely recognized the benefits that collaborative interaction has on work groups and organizations. Collaboration is seen as "a principle-based process of working together that produces trust, integrity and break-through results by building true consensus, ownership and alignment" [17].

Current problems and modern work require different expertise, due to their complexity and size. Schrage defines collaboration as the "process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding" [22]. That is, as project size and complexity grows, workers face stressed cognitive demands to be efficient and react accurately and then, collaboration and networking can take advantage of distributed expertise and become a key factor for successful problem-solving activities [8].

Groupware systems are computer-based applications that support groups of people working together toward a common goal, by providing them a shared interface to their shared environment [7]. A typical example is a shared editor (also known as "collaborative editor" or "collaborative writing tool"), where "the writing of a document is performed for more than one author" [23].

On the other hand, information technology (IT) devices are becoming increasingly portable, powerful and affordable. The use of computer technologies is no longer confined to the desktop and office settings; users now have access to highly portable personal computing appliances, such as palmtop computers or Personal Digital Assistants (PDAs), which can be used "anytime, anywhere". Such devices have different functions; they can be used to record data, to access information resources or to communicate with other people. It has been argued, therefore, that mobile computing devices could be useful tools for supporting learning and workplace activities [9], either alone or in combination with desktop computers. Handheld computers are emerging as a flexible and portable solution that provides users with "ready to hand" support to engage in collaborative activities anytime, anywhere [16].

However, when we observe collaborative work, we may notice that there are some tasks or activities that need to be performed individually. For instance, when a group works together in a shared editor, users go through phases of self-organization (i.e. organizing their ideas, thoughts and critics) and then, once they have a clear picture of their contribution they go to a sharing phase where they share their thoughts, ideas or critics and can argue and negotiate. The central concern of this paper is that regardless exiting several successful applications that exploit PDAs in individual and shared environments, research in the area of collaborative systems does not address the need for supporting individual tasks, even when handheld devices (originally designed to support individuals) are used. Furthermore, we believe that as mobile devices become a promising technology for supporting work group, the need of supporting the seamless transition between individual and workgroup scenarios would increase.

In this paper, we present an architectural model and a Web-based application that supports the collaborative edition of a text document based on the model proposed. This tool has a handheld version. Section 2 presents some related work. In section 3 and 4 we describe the architecture proposed and the example application. Section 5 presents some benefits of or proposal and finally, in section 6 we present some conclusions.

2. Related Work

Most work on handheld devices for supporting individuals has focused on how can be used to replace stationary computers and how to take advantage of their affordances and mobility. Additionally, some researchers are focused on using handheld devices in group settings to support collaborative work (see [2, 19, 24]). Other approaches are listed below:

1. Mobile devices can serve as a means for people to augment their real time personal communication.
2. Mobile devices allow people downloading common information (such as information stored in databases), modify it, and upload it again.
3. Mobile devices allow people gathering personal information in the field, which can be downloaded into a common database, for example, in NotePals, participants at a conference session write meeting notes on their personal PDAs [5].
4. Some mobile systems synchronize and negotiate personal information across devices (i.e. 3Com Palm Pilot Hotsync Manager replicates information held in equivalent applications across both PDA and desktop computers [1]).
5. Synchronization systems are powerful tools that allow people synchronizing both their personal and public information across devices. Using Lotus EasySync, for example, information within Palm Pilot applications are synchronized with a Lotus notes database [15].
6. Another approach is to give mobile person access to one's workstation environment. For instance, PalmVC allows the mobile PDA user connecting to and browsing a portion of his workstation screen [18].

Mobile computing encompasses the situation where people produce and share information in a mobile work setting. In the practice, however, the majority of mobile computing systems neglect the nuances between personal and public information exchange [10]. Our specific research interest is trying to understand the nuances of how people moves across personal and public information (in our case, within group boundaries) to share information or common data.

3. System Architecture

Designing PDAs-based applications requires to take into account both restrictions and opportunities. We consider as restrictions: PDAs' reduced screen size, limited available memory, heterogeneity [3], input facilities and processor

speed, small communications bandwidth and when wireless support is used, eventual interruptions in information interchange as a consequence of wireless communication intermittence [13]; if there is no support for wireless communication, interruption can be longer, and then reconnection and consistency management is required (synchronization tasks). Therefore, it is important to consider the following design issues:

- Design simple user interfaces that include few elements.
- Consider limited memory and storage. Most data stored in the PDA is volatile.
- Consider alternative data input devices. PDAs are slow and their design is not intended for supporting the input of large amounts of data.

Opportunities provided by handhelds include: great portability, short start-up and response times and ability for gathering and presenting small pieces of information. Thus, the following design characteristics are suggested by these opportunities:

- PDAs may be useful when user mobility is a main consideration during the operation of the system.
- Using PDAs when individual work is required in unusual, congested or uncomfortable places.
- Consider the use of PDAs when users can make timely short annotations that can be expanded into larger contributions afterwards.
- Consider the use of PDAs during periods of individual divergent work. These periods will probably be followed by a period of group convergent work, where individual production is appropriately merged and improved.

The role of individuals in collaborative work should not be overlooked. An interesting study exploring the opposing individual and collective views in the foundations of group work in organizations has been done by DeSanctis [6]. He argues that elements in existing theory related to IT-based group support systems must include: the recognition of the importance of socio-emotive communication in group functioning; the influence of group norms and values in information processing by groups; the diverse nature of group membership; and the issue of individual freedom versus managerial control and power. The people collaboration degree, and the degree to which tasks require collaboration, vary substantially, not only between jobs but also within jobs over time. Many jobs, tasks or activities can be thought of as moving continuously from being performed individually to being performed collaboratively. With those concerns, we have designed an application that allows a seamless transition between individual and shared activities. Figure 1 depicts the proposed system architecture. It is composed by four layers: (i) presentation, (ii) logic, (iii) synchronization and (iv) data.

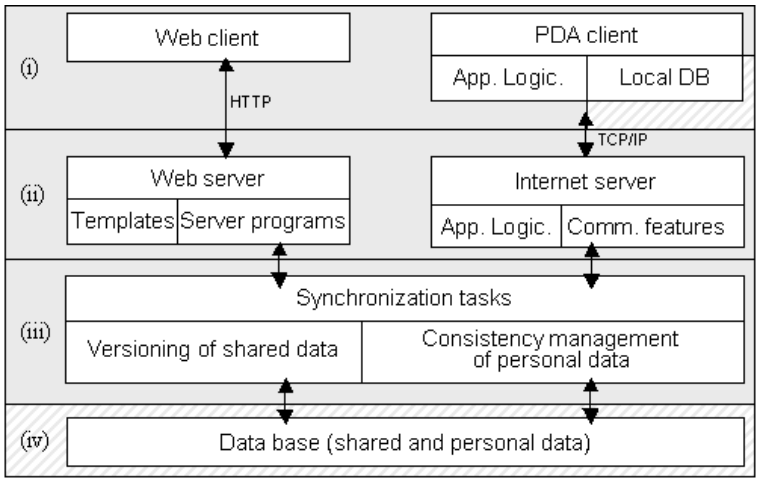

Fig. 1. System Architecture

In the presentation level, a Web client provides an interface to a Web version, which is a standard shared editor, while the PDA client allows users to edit documents on a PDA. In this case, a local copy is stored in the local database and application's logic is also included in order to provide "wireless unsupported" mode.

In the logic layer it is also implemented communication and security features. Web server answers Web client requests for transactions on the database. It has two sub-layers one supporting presentation tasks through Templates adapted to users' roles (i.e. reading through, making comments, etc.) and programs running on the Web Server that implement the logic itself. The Internet server is a network host that handles PDA client communications' tasks (i.e. yellow pages). In the synchronization level the code supporting the versioning of documents created in group or "collaborative" mode is implemented. Users manipulate those versions from the Web or the PDA client. Individual work is supported trough consistency checking routines, that is, users can create personal notes that are treated separately and integrated in shared versions when users demand it. Finally the data layer contains a database that comprehends group versions as well as personal notes.

4. A SAMPLE APPLICATION

Based on the architecture presented in the previosu section we have implemented a software tool named Ecomov. This tool is a collaborative writing tool composed of four modules: a user management component, a Web editing module, a PDA text-editing module, and a communication and synchronization component.

Work supported by PDAs may be done in two ways: network-connected (on-line) and off-line. When working on-line, document synchronization is automatic, while off-line PDA work occurs when the co-author steps outside the range of the wireless network. In the latter case, the PDA stores a "copy" of the original document and enables co-authors to perform text editing as desired. Of course, after off-line work, the performed changes are synchronized with the master document and a new version (of the master document) is stored. This implies that all stored versions must be merged (synchronized) from time to time. A coordinator does this merging and usually this involves discussion with the other co-authors in order to keep document coherence. This task must be done with the agreement of the other co-authors (they are aware of the occurrence of this task), so that, previous coordination tasks must be performed.

4.1. WEB EDITING MODULE

This module allows users to create, edit and share documents through the Web. When a group member creates a new document, s/he must provide the list of co-authors and their roles (the current version just considers reader and reader/writer roles). When a co-author modifies a document, it is blocked and after making changes, s/he must unblock it. This module also allows co-authors to generate a new document version. Finally, co-authors can add their own personal annotations and see annotations provided by other users. Figure 2 shows a document being edited via Web.

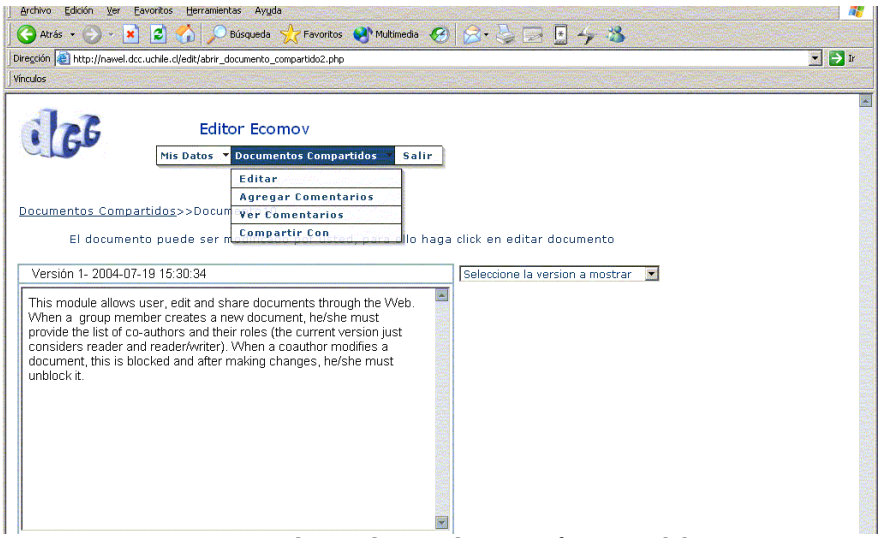

Fig. 2. Ecomov editor: Editing a document from a Web browser

4.2. PDA EDITING MODULE

In the design, we tried to make the Web and PDA editing modules as similar as possible. However, considering the strategy outlined in Sect. 4, the PDA module should be very compact, with a simple user interface, and using little storage and at the same time, it should still provide the main functionality of the Web module.

Co-authors may create new documents or open previous ones. These may be personal or shared. A typical use may be to create a personal document with an outline of ideas; these are expanded later in a shared document. Shared documents may have several versions, which can be browsed by the co-author. The user can also place annotations on any document from this software module.

Figures 3a and 3b show the PDA editing module user interface. Users can open shared or personal files (File options), in both cases an interface presenting a list of the available documents is shown. For the case of shared files, the status (modified or not) as well as the co-author name that made the last modification is also presented (Fig. 3a). Once the user pick-ups a document, it is presented for editing. In this case additional information such as the document version is also presented (upper part of Fig. 3b). The middle part of the screen shows the document, and the lower part contains the application menu. Fig. 3b shows the "File" menu options. The file menu allows users to save the current version or generate a new one, as well as to synchronize local versions with the central server. The editing menu has an option to work on various versions: the buttons labelled "<<" and ">>" allow users to move forward or backwards on the local document versions.

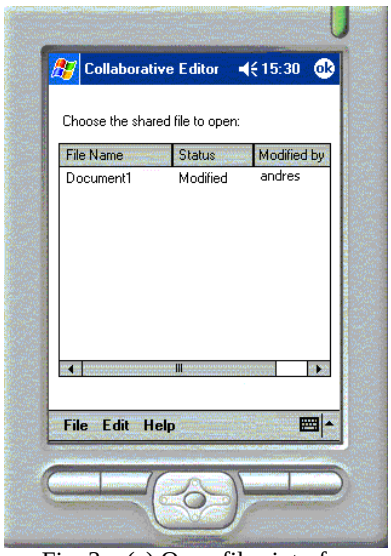

Fig. 3. (a) Open files interface

(b) File menu options and editing interface

4.3. COMMUNICATION AND SYNCHRONIZATION MODULE

This module allows communication and synchronization between PDAs and the server database. Users must choose the local version they want to synchronize with the server database. As the Web editing modules also accesses the central database, the main difficulties solved by the communication module concerns concurrency and consistency, since several co-authors could be editing the same document at the same time. The module also solves the document versions management problem. Keys for a simple solution to these problems are the locking mechanism already mentioned and a time stamp associated by the system to each document version. Time stamps are then used by the system itself to guide co-authors on which versions are appropriate for merging.

The locking mechanism is paired with a unique version of the document, called the master document, as introduced above. When a co-author has blocked the master document, other co-authors can make annotations over copies of the master document. If different changes have been made to the document, they are manages as if they were annotations: at a later time, a co-author can modify the master document based on all her colleagues' annotations. For such task, the

system lets visualize all document copies associated to a master document as separate windows. Annotations are shown in color to make them easily distinguishable.

5. DISCUSSION

One of the main advantages of handheld computers is that they are portable. Also, initial vendor-supplied software encouraged individual rather than collaborative use. Even now, most handheld applications often reinforce the idea of a handheld computer as a personal digital assistant. Nevertheless, recent articles describe group or collaborative applications based on this kind of devices (see [14]). In particular, some developers may be interested on designing systems to support people doing cooperative tasks. However, a few relevant questions should be asked: are handhelds appropriate components for collaborative applications? If so, which are the tasks they support the best? There are several mobile applications that successfully support individuals but not in a collaborative or work group setting. On the other hand, mobile applications that support collaborative activities are mainly focused on the group component of activities, neglecting the individual work component. So, does it make sense to treat them as separated development environments, leaving users the responsibility of making the necessary compatibility changes? Or, due to their nature, are they separated environments?

Sharing and managing expertise appear, almost by definition, to be activities that require collaboration between people, consequently, we envision and design systems for expertise management that assume collaboration as the starting point. Unfortunately, this view is naive, because it does not recognize that individuals' concern is more than likely, developing, using and creating their own expertise. The need to share expertise takes place later, perhaps when others demand it, or by serendipity, or perhaps as a side effect of a group's need to coordinate and share their knowledge in order to develop a project or solve a hard problem.

Everyday working styles of people, including the way of sharing expertise, shift regularly and easily between individual and group activity. This implies that software should support both individual and group needs. Unfortunately, most systems are categorized either as a single-user application or as multi-user groupware and the gap created for people moving between individual and group activities force them switching tools, causing frustration and additional work on them.

Single-user applications offer little or no explicit support for people who want to work together through computers. While people do often use single user systems collaboratively [20], the effort to do so across time and distance barriers is high. Nardi's 1991 study of spreadsheet users, for example, clearly describes how co-located people share expertise over spreadsheets: one person developing the content of a spreadsheet is helped by another who understands how to program spreadsheets; this style of interaction is far more difficult when people are geographically distributed. On the other hand, groupware built to fit only group needs is often inadequate for supporting individual work. The gap between these categories often means that people cannot use the same tools for tasks that are conceptually similar but cross over individual and group work [12]. People must take on the additional burden of shifting between tools, and learning how to use new tools. They must translate common artifacts, such as documents, into formats amenable to both single and groupware systems. Cockburn and Thimbleby suggest that CSCW environments must not only support group activity, but must also cater to individual requirements [4].

The transition between individual and collaborative work could be very fluid, in the same way that transition between task-oriented and non task-oriented activities or between several tasks [21]. Various in-depth studies have shown how apparently separated working people collaborate now and then in a very subtle way [11]. So, although collaborative work generally refers to situations where two or more people act together explicitly, to achieve a common goal, the actual extent of "togetherness" can vary substantially. Designers of collaboration technology should therefore take account of the fact that all collaborative tasks are a combination of individual and collaborative activities. Group work is also individual work. Group work is a mixture of collaborative activities and individual or subgroup task performance.

6. CONCLUSIONS

Collaborative applications significantly differ from single-user applications. Many users provide input (often simultaneously), output has to be processed for many users and shared data have to be kept consistent. On the other

hand, when we observe a collaborative work activity we may notice there are some tasks, which are performed individually in many cases. Workers are autonomous and tend to distribute their workload, so their need for ongoing coordination and planning is minimized. This implies that work division is mutually understood within the group so that workers do not need to check constantly with each other. Of course, it is not obvious if handhelds may be adequate for ambitious systems involving several people with many complex interactions among them.

There are several problems that must be solved in collaborative environments supported by mobile devices. Collaborative and mobile applications have to keep data consistent. Applications which are collaborative and mobile at the same time double the problem of data consistency. Collaborative applications have to synchronize concurrent data manipulations, mobile applications have to keep data consistent when devices are moved inside the network or are disconnected from the network.

The model proposed in this paper could be useful to design groupware application taking into account the transition between individual and shared activities. However, what is clear is that mobile devices such as PDAs can support efficiently individual tasks that are developed in a collaborative context and implies users' mobility mainly in environments where there are no network supports (off-line). For instance, reading a document while you are in the subway. When these applications are used in more complex environments like large organizations, we must recognize that beyond personal support, users are involved in work group and move constantly from an isolated working mode to a sharing phase where they coordinate their actions and collaborate, and then, a seamless transition between those phases could ease their work and lessen their frustration due to additional workload.

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