Mobile Collaboration Writing

Li Yushun Shi MeiLin
Department of Computer Science & Technology
Tsinghua University
Beijing, China.
lyshun@csnet4.cs.tsinghua.edu.cn

Abstract—*The rapid and accelerating move towards use of mobile technologies has increasingly provided people and organizations with the ability to work away from the office and on the move. Today , people have recognized that data access should not be the ultimate goal of Mobile Computing, and the abilitiy to support cooperative work on mobile terminals is more significant. This paper proposes the idea to construct mobile collaborative system based on adaptive wireless groupware technology, and a proof-of-concept prototype system called Mobile Collaboration Writing System(MCWS) is developed. On MCWS, it is possible for people to cooperate with collaboration document (co-document) on traditional PCs and Wireless terminals, and the system supports both asynchronous session and synchronous session. Besides, the collaborative ability of MCWS is seamlessly integrated at system level.*

Keywords-Mobile Computing; Mobile Colllaboration; CSCW; Adaptability; MCWS; mobile document work

I. INTRODUCTION

Technologies about mobility have been undergoing two generations: the first-generation technologies primarily focus on the ability to access information at anywhere, anytime, and the solutions include e-mail, calendaring, messaging and tracking. The second-generation technologies are just emerging, as a number of authors have commented, research on collaborative mobile work is now beginning to emerge as an important field in Mobile Computing ([4][9]). The rapid and accelerating move towards the use of mobile technologies has provided individuals and organizations with the ability to work in novel and previously unanticipated ways. These have the potential to provoke even more radical changes in work practices and encourage and even greater level of mobile work and distributed collaboration.

Documents are the most general artifacts used in collaborative activities, but traditional word processors/text editors mainly support functions for personal use, and few editors have facilities for collaborative writing. In fact, documents are primarily created by two or even more person in cooperation, and in some research field, more than 65% papers are finished by groups[5]. Collaborative writing system became a hot research field of Computer Supported Cooperative Work (CSCW) in 1990s, and many prototype systems were developed, such as Quilt, GROVE etc. Due to advances in technology, mobile terminals have become more pervasive, and with these ubiquitous mobile terminals, functions for writing/sharing documents collaboratively on mobile hosts are required, for example, mobile blue-collar workers use mobile hosts to create technology reports for maintaining large network (such as electronic networks, communication networks). Therefore, research on MCWS is meaningful for collaborative work, and co-documents are important artifacts for people to exchange information, to work cooperatively. Though collaboration writing is a hot research field in CSCW, but technologies having been developed primarily are suitable to wired network, not to wireless network. Besides, there also have some research works on mobile documents, but cooperative capabilities of these systems are very limited. This paper concerns the technologies about how cooperation can persist on both mobile terminals and traditional PCs with co-documents.

In the remainder of the paper, we describe the factors that should be considered to design MCWS (section II), and based on the analysis, the details of MCWS is introduced (section III). Related research is presented in section IV.

II. MCWS DESIGN

Mobile Collaboration closely relates to the fields of Mobile Computing and CSCW, and so MCWS design must consider the related technologies developing in Mobile Computing and in CSCW. Five factors have been considered in MCWS: technologies for successful groupware systems, co-document structure, collaborative awareness, system adaptability, and system capability for supporting both synchronous session and asynchronous session.

A. *Technologies for successful groupware systems*

There has been much debate over whether a centralized structure or a replicated structure more useful for groupware. The centralized structure is very simple for implementing synchronous control algorithms in groupware system. However, communication between clients and central server may be slow, and the communication bottleneck decreases responsiveness, which degrades coordination. The replicated structure has better response time because many actions can be

This work is co-supported by National Natural Science Foundation of China under grant No. 60073011, China National High Technology Research and Development Plan under contract No. 2001AA113150 and 985 Project "High Speed Network Based CSCW Application and Development Environment" of Tsinghua University.

0-7803-7822-9/03/$17.00 © 2003 IEEE.

done in parellel, and several copies of the groupware subsystems ensure that a single software failure will not affect all other session participants. The cost of quick response and high reliability is that replicated processes are difficult to be synchronized, and it requires complicated software to handle concurrency control and data sharing. The MCWS employs hybrid structure, which maintains co-document framework in centralized structure, while sustains synchronize session in replicated structure.

Besides, MCWS must have features of general groupware, which include two central parts: distributed systems and human-computer interfaces. Distributed systems are used to support communication. Responsiveness, robustness, and concurrency control should be considered in this part. Specialized interface is necessary to coordinate actions of people, and the interface can be very simple or very complex, which depends on special application. Different packages require varying amounts of network support, and full-featured interfaces are extremely useful in coordinating collaboration, but they place heavy demands on wireless link, and as a result, there will not be sufficient resources to run collaborative sessions.

Another factor should be considered is that the quality of a mobile connection can vary greatly, and this requires collaborative applications modify their behavior as the quality of the communication environment changes. Therefore, groupware systems used in wireless environment should make efficient use of network resources, and allow more limited form of collaboration to occur under more restrictive circumstances.

B. *Co-document structure*

Perfect MCWS should support all activities happened on co-documents, including brainstorming, planning, designing document structure, writing, remarking, and sharing document. Different trait may be strongly needed in different settings to form collaborative space with different characteristics. In order to support all activities on both wired terminals and wireless terminals, co-document must append cooperative information and employ special structure. In MCWS, co-document is organized in the structure described in XML. Structural document make it possible to display co-document in polymorphism model and poly morphism-display model on terminals with limited resources.

C. *Collaborative Awareness*

Mark Perry identified four key factors in mobile work[1], and the last one is about awareness. In CSCW community, awareness is defined as " ***an understanding of the activities of others, which provides a context for your own activity*** " by Dourish in 1992. Usually, collaboration can be classified into following stages: awareness, interactive, coordinate, cooperation, and virtual organization, therefore, collaborative awareness is the most important stage for cooperative activities, and it is the base for collaboration. In cooperative activities, collaborative awareness is used to assist collaborators in planning and executing low-level workspace actions to mesh seamlessly with others, help collaborators in noticing and managing transitions between individual and shared work, and aid collaborators in understanding the context where help is needed to be provided.

D. *System Adaptability*

Wireless communication has the following features:
1. Wireless network has less bandwidth than wired network; 2. Signal can easily be interfered: blocked by buildings, corrupted by noise, or attenuated by distance, and this lead to high error rates and frequent sudden disconnections; 3. Hand-off can also cause communication problems. In hand-off procedure, information must be transferred to the new cell, and host also need obtain communication resources, such as an unused frequency, which may be limited if a cell contains many users. Therefore, a hand-off can result in delays, short disconnections, and high error rates; 4. Mobile connectivity is highly variable, and bandwidth and reliability may change dramatically. It is obvious that variability and frequent disconnections can't be reduced by changing the application, and instead the application should handle disconnections gracefully. One fundamental approach is providing adaptability in system, which allows MCWS to take advantage of favourable network conditions and to react to difficult conditions as they occur. Adaptability is a key technology for application running in wireless environment, and adaptive wireless groupware will be the direction for groupware in wireless environment.

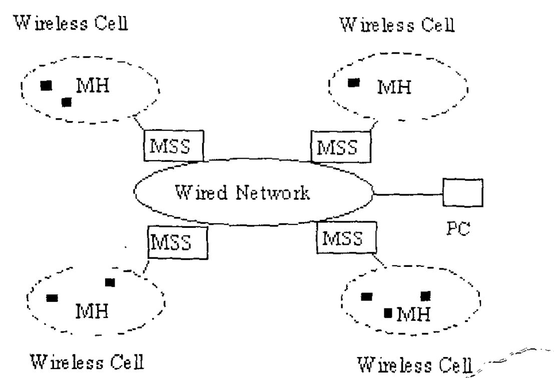

Figure 1 Mobile Computing Network Model

E. *System capability for supportting both synchronous session and asynchronous session*

The key criterion for judging integrative collaborative system is whether the system can support both synchronous session and asynchronous session or not. In MCWS, the procedure of creating co-document can alternate between synchronous session and asynchronous session. Asynchronous session supports collaborators to work on different segments, which make it possible for user to write co-document in off-line model, and this model match the characteristics of wireless communication. While synchronous session supports collaborators to write on same segment, and operation results simultaneously display on collaborators' terminals. The integrative cooperative capability makes it possible for completely utilization of both wired terminals and wireless terminals. For example, one mobile user can first apperceive workspace status in asynchronous session, and then he will switch to work on wired terminal through attending a synchronous session, which requires more resources.

III. SYSTEM IMPLEMENT

A. Network Model

The model in figure 1 [7] is used in MCWS, which consists of three components: a wired network, mobile hosts (MHs), and mobile support stations (MSSs). The geographical area (called ***cell***) that an MSS's wireless signal can cover is limited. An MH is assumed to be within the cell of its local MSS, and the MSS serves as an access point to the wired network for MHs. All messages related (directed to/ transmitted from) to an MH mh are first routed through mh's local MSS. MSS periodically broadcasts a beacon signal [8], which carries the MSS's identification, to all the MHs in its cell. When an MH switches from one MSS to another, a *hand-off* procedure is performed, the MH first sends a *register* message, which carries the identification of the previous local MSS, to the new local MSS. On receiving this message, the new local MSS informs the previous local the migration of this MH, in response to this message, the previous MSS will transmit relevant information associated with the MH to the current MSS.

B. Function Structure of MCWS

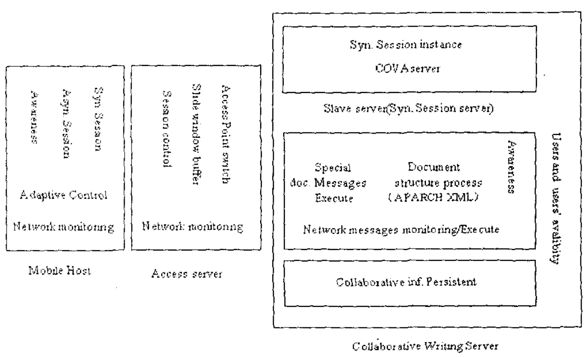

Figure 2 MCWS System Function

System functions (reference to figure 2) are comprised of three parts: functions on mobile terminal, functions on access server, and functions on collaborative writing server. Functions on mobile terminal include awareness information module, session modules, and modules related to adaptability. Access server takes charge of session relay function and session reliability function. Collaborative writing server is the core of MCWS, and it will be described in detail in the following paragraphs.

Co-document structure and related information is maintained on the collaborative writing server. When a co-document is active, it is represented by a special active process. Synchronous session server (called slave server) runs COVA (***Co****operative* ***a****pplication*) runtime system, which provides concurrent control [10] for synchronous session, and the control mechanism is realized with object operation transformation algorithm. The collaborative writing server distributes synchronous session to different slave servers.

Co-document structure function module is responsible for displaying co-document on wired terminals and wireless terminals through information abstraction. Information abstraction aims to reduce information content while maintaining semantics, and to ensure fundamental object integrity even on limited bandwidth and display-disadvantaged mobile wireless clients. For example, the module can only display overview information about co-document on terminals with limited resources, and from the overview information, collaborators can manipulate/browse detail information of the co-document. The procedure is adaptive, which is affected by three factors: capability of mobile terminals, quality of wireless link, and the co-document content described in XML, for example, if content of a segment can't be completely displayed on the wireless terminal, then the operation result is temporarily saved on the access server, and the information will send to the terminal step by step through slide window mechanism.

C. Structural co-document

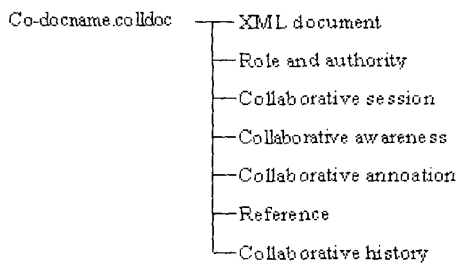

Figure 3 Structural Co-document

Technologies about structural co-document are comprised of two parts: one is that the co-document's format is structural, and the other is that structure and the content of co-document are separated.

1. Co-document's format is structural, which includes information about document framework, role and authority etc. (Reference to figure 3). Traditional document is flat and it only contains content information, while collaborative information is discarded. Collaborative information is important for creating/sharing co-documents, for example, awareness information is useful for enhancing cooperation, reducing collision, and synchronizing co-document status on mobile terminals. MCWS also provides function for converting co-document from structural co-document

format to traditional document format, and this function improves compatibility and flexibility of MCWS.

2. The structure and the content of co-documents are separated. Traditional document structure is embedded in its content, and the strategy makes it impossible to operate co-documents on mobile hosts. Co-document's structure (Reference to figure 3) described in XML includes both structure information and other attributes about content, such as attributes of lock state information about co-document (including exclusive lock, shared lock), and these attributes can be used to produce awareness information, to tailor co-documents. Other attributes can be extended according collaborative settings.

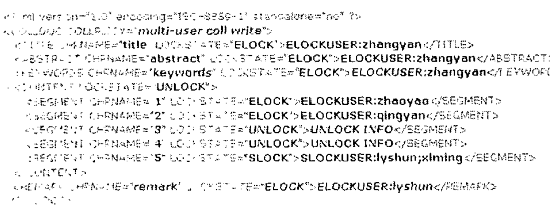

Figure 4 Co-document structure in XML

D. *Collaborative Awareness*

In MCWS, collaborative awareness is classified into synchronous awareness and asynchronous awareness. Synchronous awareness is related to synchronous session, which provides information of real-time status about collaborators. and enhances friendliness and presence. One important mechanism for synchronous awareness is tele-pointers delegating different collaborators. In MCWS, asynchronous awareness is composed of the following information: awareness information about users and their availability, awareness information about collaborative history and awareness information about asynchronous lock. Awareness information about collaborative history can provide information about operating history on co-documents, and with these information collaborators can comprehend history of the workspace. Awareness information about asynchronous lock can be used to synchronize the co-document state on mobile terminals, for example, when one segment is tagged with exclusive lock, local user temporarily can't execute any operations on the segment, and while one collaborator releases the exclusive lock and submit the result of his operations, the system will notifies others to synchronize co-document status in time, and the notice messages are emitted through awareness protocol. The messages will be used to update related interface element of other collaborators. Asynchronous awareness provides the following functions: reduce collaborative collisions, enhance coupling degree among collaborators, and synchronize the co-document statues on different mobile terminals.

E. *Session relay function*

Session is base element for collaborative system, and MCWS must provide session relay function in order to support cooperation on wireless terminals. Session coordination can be disrupted if participants are disconnected, particularly if the software does not notify other collaborators the fact that one or more session members are temporarily unable to participate. Wireless session should have the following features: maintain session even if connection broken, re-establish session on different transport medium, self-healing connections, drop line during idle time and re-establish when needed. Solutions for these features boil down to two elements: reduce delay and handle disconnections gracefully. Session relay function can overcome the difficulties caused by frequently disconnection, such as lost work, crash application, which will results in losing time and increasing user's frustration.

In MCWS, function of wireless session relay is cooperatively implemented through mobile host and access server. Information of mobile terminal sessions is stored in access server, thus medial collaborative information of a session is saved even mobile host disconnects from the communication network.

In asynchronous session, artifacts such as segments need to be modified/edited will be saved on access server if the terminal has limited resources, and the mobile terminal will display information through slide window mechanism. Slide information and operation results will be timely updated to access server. In a hand-off procedure, these information will be switched to the new access point of the host, therefore, the asynchronous session persist.

Concurrency algorithm used in synchronous session runs on access server instead of running on mobile terminals, here it is assumed that protocols between mobile terminal and access server provide FIFO-order delivery[6]. Operation transformation algorithm and related data structures used in synchronous session, which include State Vector (SV), operation history buffer, and pending operations buffer, are on access server. This configuration assures synchronous session relay, and the reliability of synchronous session is putted on the edge of the wired network, therefore, the infection of frequently disconnection can be avoided.

F. *Network statue monitor and adaptability*

System adaptability is an effective technology to frequent disconnection and continuous variety of bandwidth. In MCWS, system adaptability is realized within two areas: one is that content of co-documents can be polymorphism displayed. According to the resources of collaborator's terminal, system can send polymorphism data (include content modality and information modality) of cooperative information to collaborator. XML and related XML technologies are utilized for describing co-document's structure and organizing/sharing co-document. Another adaptive feature is implemented in application of MCWS, which is achieved through adaptive application actions, and these actions will be described in the following paragraph.

To make full use of wireless link, application should adapt itself according to the link state, which requires network information source. In MCWS, network information is collected by network monitoring module, which provides information about real-time state of wireless network, and these variables can be used for two purposes: one is designed to allow the application to adapt, and the other is to give collaborators more information about network conditions that could affect a collaborative session, for example, information about signal strength could be sent to other collaborators, then an overall picture of the session stability could be used to make the session more coherent. If everyone knows that a particular collaborator is not strongly connected, then they will know that he may be out of contact for a few moments.

A set of network variables/values is required so that MCWS can use them to determine when to switch modes of operation, and also the appropriate code is needed to provide the different levels of supported features. Parameters being provided by network monitoring module include: bandwidth, error rates, signal strength, latency, and probability of disconnection. If a user knows that updates are slow, he will not expect other users to respond immediately. Probability of disconnection could be derived from the strength of the channel signal, and if the signal is weak, then the mobile host may be about to cross a cell boundary or disconnect, and this could suggests that collaborators should backup a co-document in order to weather a disconnection. Using information of these parameters, MCWS adapts its behavior about the following objects:

- Compress the operation messages which are transmitted on wireless link;
- Adjust the redundant degree of awareness information, such as adapting interval of tele-pointers messages;
- Adapt content selection about co-document in MCMS;
- Adaptively replay multimedia content in co-document, such as audio section and video section;
- Network status about other collaborators which are displayed on the interface also need network resources to update, for example, information about signal strength might be updated every 10 seconds, and each user might send this information to all other participants every time. It was updated in order to maintain a complete and recent picture of the stability of the session. This network information traffic might consume too many network resources and interfere with the editing session. Thus, it would be included in the overall adaptive interface, if condition worsened, fewer updates could be sent, or collaborators may request stopping update messages sent to their machines.

Now, collaborative writing server of the prototype system has been implemented, and functions on wired network have been finished, from the elementary practice, collaborative awareness has been tested, and it can really enhances collaboration between users, and integration of asynchronous session and synchronous session provide flexibility to system users.

IV. RELEATED RESEARCH

Satchel system is the pioneer project which focus on mobile document work, ant it is designed to provide access to any document, any time, and anywhere. The fundamental Satchel concept is the use of tokens to represent documents on the mobile device[2]. Satchel system only provide method to access traditional document from mobile hosts, and the system is not used for collaboration. Tara Whalen et al. research on the technologies for groupware in wireless networks, and they modified features of Calliope, which is a GroupKit-based multi-user text editor, for wireless use. Calliope system is a real time system, which don't support asynchronous session.

V. CONCLUSION

The paper proposes that adaptive wireless groupware is the appropriate technology for supporting mobile cooperative work, which can seamlessly integrate collaborative capability of wired and wireless terminals, and the practice of developing MCWS has showed that it is possible to integrate mobile terminals into collaborative workspace. With further development of MCWS, the idea will be further validated. The results presented in the research could be used to create more collaborative software for use with structures that support adaptive applications.

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