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Abstract: This document summarizes the study on current and future technologies for collaborative working environments (CWEs) with the focus on whether the current CWEs and their future trends are suitable for large scale multi-national organizations. In this study, we have analyzed structure of ESA with respect to organization, geographical distribution, IT environments and presented a list of state-of-the-art of CWEs suitable for large scale organizations. A list of important criteria for evaluating CWEs have been introduced. Based on that state-of-the-art CWEs are selected, evaluated and compared. From the evaluation and comparison of CWEs products, we have found that existing CWEs provide many features required by large-scale and multination organizations but those features are not well-integrated into a single CWE. Due to the complexity of collaborative work within those organizations, often many CWEs are used and it is not easy to integrate those CWEs together. Furthermore, there is a trend of providing CWEs under the concept of Software as a Service and supporting the composition of those CWEs. However, how such a system can be used for organizations where security is a main concern is still an open question.

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Executive Summary on Current and Future Technologies for Collaborative Working Environments*

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Abstract

This document summarizes the study on current and future technologies for collaborative working environments (CWEs) with the focus on whether the current CWEs and their future trends are suitable for large scale multi-national organizations. In this study, we have analyzed the structure of ESA with respect to organization, geographical distribution, IT environment and presented a list of state-of-the-art CWEs suitable for large-scale organizations. A list of important criteria for evaluating CWEs have been introduced. Based on that products are selected, evaluated and compared. From the evaluation and comparison of CWE products, among main conclusions, we have found that existing CWEs provide many features required by large-scale and multinational organizations but those features are not well-integrated into a single CWE. Due to the complexity of collaborative work within those organizations, often many CWEs are used and it is not easy to integrate those CWEs together. Furthermore, there is a trend of providing CWEs under the concept of Software as a Service and supporting the composition of those CWEs. However, how such a system can be used for organizations where security and legal issues are main concerns is still an open question.

1 Introduction

Recent advances in hardware and software technologies have fostered the collaborative work across administrative/organizational boundaries. Various tools are available for users to conduct joint projects, regardless of the location and the organization of the users. For example, wikis[1], SVN[2], and document management systems[3] allow different users to share and coedit documents, instant messaging[4] and voice chat[5] allow multiple users to converse online, just to name a few. With the support of existing Collaborative Working Environments (CWEs), many new concepts, such as virtual teams and communities, are introduced and realized today. Furthermore, the concept of *user participation*, such as collaborative blogs[6] and collaborative tagging [5], substantially increases the interaction model among users in collaborative teams. This phenomenon is realized by what is referred to as the Web 2.0 era[7].

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[1] http://en.wikipedia.org/wiki/List_of_wiki_software
[2] http://subversion.tigris.org/
[3] http://en.wikipedia.org/wiki/Document_Management
[4] http://en.wikipedia.org/wiki/Instant_messaging
[5] http://en.wikipedia.org/wiki/Voice_chat
[6] http://en.wikipedia.org/wiki/Collaborative_blog
[7] http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html

However, whether the current CWEs and their future trends are suitable for large-scale, multinational organizations, e.g. European Space Agency (ESA), is still an open question that motivates the study of current technologies for CWEs and their trends in the future. The main objectives of this study [3] are

- to collect a list of state-of-the-art CWEs suitable for large-scale organizations (such as ESA),
- to review and revise proposed evaluation parameters, taking into account ESA's organization, geographical distribution and IT structure,
- to compare identified CWEs based on the evaluation parameters, and
- to identify possible future trends for CWEs.

To achieve the above-mentioned objectives, this study is split into three tasks: (1) collecting information about the IT structure and distribution of such organizations and enterprises in general, (2) refining a catalog of criteria which is initially given by ESA, and revising the catalog with new criteria suitable for evaluating CWEs fulfilling demands of large-scale organizations and selecting available CWE software, and (3) some applicable CWE software products are selected for an in-depth evaluation based on the first impressions and the finalized catalog of criteria.

This report is an executive summary of the study. For the full, detailed report, the reader should refer to [7] and the Web site of this study[8]. In the subsequent sections, we will summarize the results.

2 Structure of Large-scale Organizations

Whether a CWE is suitable for an organization is strongly dependent on the structure of the organization which includes, for example, the number of departments/sites, user roles, and collaboration goals. Large-scale enterprises/organizations are mostly divided into sites which are geographically distributed. Each site usually has its own IT infrastructure comprising networked services. The need for collaboration among people belonging to different sites requires the network in between to open access to certain services. To enable secure and reliable collaborative work between these sites many concerns have to be taken into account. In the simplest form, each site is connected to the Internet and secured by its own firewall, as shown in Figure 1. It is obvious that an appropriate security policy (accurate firewall settings, policy management for authentication and authorization, data encryption, etc.) is needed, depending on the collaborative software's mode of operation. A more advanced connection setting is to use a virtual private network (VPN)[9] which operates on top of the public Internet and offers advanced security capabilities for accessing corporation's IT resources during teamwork.

Since collaborative work requires the involvement of people and resources across the boundaries of departments/sites, there are mainly four ways in which CWE software may operate:

- **Use of P2P software**: in the P2P (peer-to-peer) model[10], a user uses locally installed software which communicates directly with an instance of the same software, or similar interoperable software implementing the same protocol, used by another user in the collaboration.
- **Use of classic client/server systems**: in a classic client/server scenario every user has an instance of a client software running on his/her machine. The client software communicates directly with one or more servers.
- **Use of web-based systems:** this model is similar to the the classic client/server model mentioned above. However, instead of using special client software, a web browser is all which is needed on the user's machine.

[8] `https://www.vitalab.tuwien.ac.at/autocompwiki/index.php/Main_Page`
[9] `http://en.wikipedia.org/wiki/VPN`
[10] `http://en.wikipedia.org/wiki/Peer-to-peer`

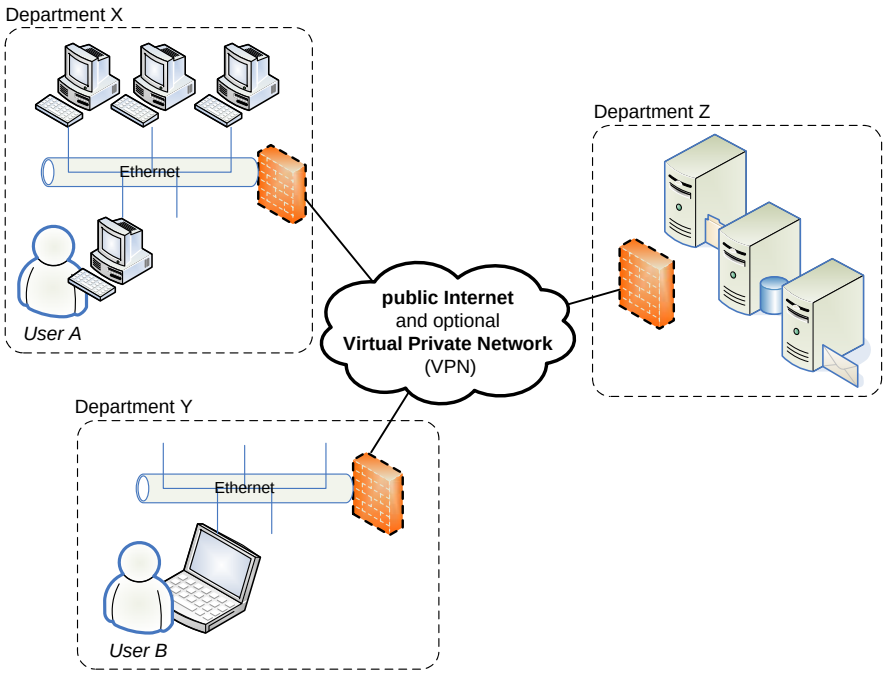

Figure 1: Simplified IT structure of an enterprise/organization formed by independent sites

- **Mixed client/server and P2P mode:** in this model, both client/server and P2P models are utilized. This occurs, especially, when a single model is not suitable, for example, in integrated software which offer diverse functionalities.

Which model being used is strongly dependent on the capability of the CWE software and operational/organizational concerns. The IT infrastructure, e.g., the communication connections between different sites, influences the operational mode of users, especially the accessibility (the way how users access resources in the organization's network) and security concerns (how security issues are handled).

- **Accessibility**: this includes different types of access such as *Access from Office*, *Access from Home via public Internet:*, *Access from Home via VPN*, and *Access from Mobile Devices and on the move*. In particular, the current trend is to perform collaborative work from everywhere. Therefore, having an access from home and on the move is important.

- **Information security concerns**: To support diverse types of accessibility and interaction modes, security concerns have to be also addressed adequately in CWEs. Information security concerns[11], such as confidentiality, authentication and authorization, are general issues that have to be dealt with, especially when collaboration spans multiple sites. Based on these common three principles of security the following issues namely *user authentication and authorization*, *transport security*, and *closed structure* are taken into account during the evaluation of CWEs.

The structure of ESA from an IT point of view is quite similar to the model in Figure 1. ESA includes 7 different main sites located at different places[12]. The communication between ESA sites relies on internal network and access is controlled by security firewall. For better understanding requirements for CWEs suitable to large-scale and multinational organizations, we conducted a survey on the basic organizational structure of ESA based on preliminary information provided by ESA [9]. Based on this information some detailed knowledge about the roles of future users and their application requirements are obtained. Besides information about future users

[11] http://en.wikipedia.org/wiki/Information_security
[12] http://www.esa.int/SPECIALS/About_ESA/SEMY8TEVL2F_0.html

and ESA's structure, information about tasks to be supported by CWEs in ESA's case were also reviewed. Based on the information provided, we have performed a clustering of features required by ESA (see Figure 2) and the following observations were drawn:

- In the field of **Communication** e-mail and audio-/video-conferencing is highly needed, while the possibilities of online discussions, especially synchronous in form of chats, are only optional features.
- According to **Project Management** shared calendar management is important, other features are not absolutely needed, but would be fine.
- **Resource Management**, like management of files but also reservation of rooms and management of shared contacts, is an explicit demand.
- Real **Online Work**, like collaborative editing or shared desktops, would be fine, but is not needed at the moment.

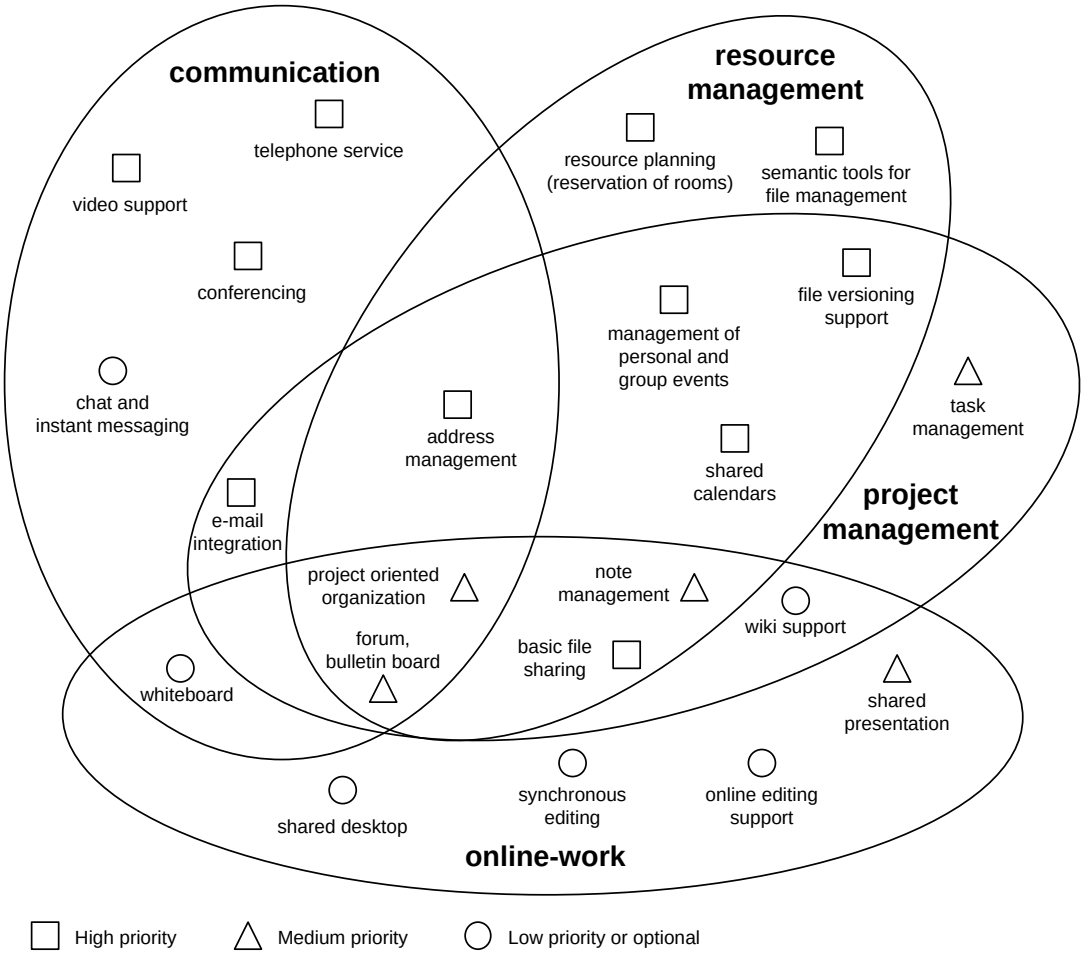

Figure 2: Importance of today's supported CWE tasks for ESA

Figure 2 shows that ESA's interests are in the area of *sharing information* on the one side (shared files and calendars, resource and address planning all having high importance) and *communication* on the other side (e-mail integration and conferencing via audio/video links is a demand too), while *collaborative work* in the sense of corporate task management or collaborative editing are only of medium importance or optional. We can see that nearly all required features with high importance for ESA lie in the fields of resource management and project management.

3 Evaluation Criteria

The evaluation of CWEs is based on a detailed list of criteria. For the purpose of this study - *CWEs software for large-scale multinational organizations/enterprises* - we focus criteria that are important to such CWEs, in contrast to standard single user applications.

In the field of enterprise software there must be a wide range of criteria, many neglected in home use software, which play a major role to the success of a CWE. Examples of such criteria are *security*, because confidential data is handled, *scalability*, because the size of working groups may often change rapidly, and *functionality*, because the software has to support users in the most (cost) effective way. All these criteria are independent from the type of software or their features and are strongly considered in this study.

In our study, each criterion is described briefly and the following information is provided:

- Name of the criterion.
- Short description including some information why it is important (in general or in particular for ESA) to investigate this criterion.
- The method in which this criterion is evaluated, e.g. by measurement or studying documentation, or the combination of different methods.
- Importance of the criterion (weighting); there may be criteria which are not relevant in general but may be important for ESA and vice-versa.

We have introduced a comprehensive catalog of criteria by elaborating and refining the initial proposed criteria provided by ESA with respect to the requirements figured out in Chapter 2. Most of the mentioned criteria are obtained from the initial draft [3], others from [6] and [2]. Furthermore, ESA provided its interest in each of the listed requirement [8]. Due to the short project run-time it will not be possible to examine all of the criteria in detail; especially those whose evaluation requires installed and completely configured systems. Thus, we focus only the most important criteria grouped into six sub-categories, described in the following.

General Information: General information provides a short overview and gives an introduction to a particular product. This information will be provided for every selected CWE software and obtained from official homepages and available documents. Examples of general information are versions, vendor, key features,etc.

Software Development and Organizational Criteria: Software development and organizational criteria are surveyed over the software's evolution, legal issues, popularity of the product, project organization and support available. This information can be obtained by studying corresponding Internet resource and available official documentations.

System Prerequisites and Installation: System prerequisites and installation, such as third party software, complexity of installation process and supported platforms, are mostly studied from official documentation and user forums. However, specific information about particular software dependencies on the one side and the grading of the installation process on the other side will probably only be possible with evaluation by installation and thus time-intensive.

Overall System Properties: Overall system properties (such as, application integration, basic architecture, collaboration model, etc.) can mostly be examined through available documentation. It would be interesting to examine some of the points through experimental measurements, especially properties concerning scalability. However, due to short project duration this was not included.

Application and Task Support Criteria: This type of criteria characterizes CWE specific properties and which tasks are supported by the software. Software products will be basically selected for evaluation, when they either cover most of the demands with high importance or when they offer special capabilities in one of the essential fields another software does not have and is therefore worth a closer look. It should be mentioned here that application criteria are strongly dependent on the type of applications to be surveyed.

Usage Criteria: Most of the usage criteria, basically covering mobile use and usability, can be in general evaluated by reading documentation. However, some of them concerning overall

usability are closely related to application and task support criteria and have, therefore, to be evaluated by testing on real systems (e.g. by using installed version or Web demos, if available). Semantic capabilities are often part of an advanced search system, (semi-)automatic indexing support or interface to other semantic products.

4 Selection and Evaluation of CWEs

There exist different classification models for collaborative software products in literature. A detailed list of common taxonomies with their intentions can be found in [4]. However, as our study is focused on evaluating concrete existing products, a more practical approach is more suitable. Therefore, based on an Internet survey and several Web pages which itemize an extensive list of collaborative software [10, 1, 11], the following classes for CWEs have been defined in this study:

- **File management systems:** such systems are used for proper handling of file based resources. Version control systems (VCS) are well-known and widely used today, not exclusively but basically as source code repositories in the field of software development. Other approaches like modern document management systems (DMS) extend the basic versioning capabilities of VCS systems by adding more advanced features, such as metadata handling, indexing and advanced search capabilities, which are needed for comfortable and efficient handling of text and binary documents.

- **Groupware systems:** they focus the communication between project participants on the one side and the management of common information, like contact data, notes, project progress and news, on the other side.

- **Hosted Online office applications:** they are Web applications which basically provide the same applications like traditional office products: word processor, spreadsheets and/or presentation software. Note that this kind of software is usually hosted on the third party servers (like Google) and not within organizations (e.g., ESA).

- **Real-time audio, video and data collaboration systems:** commonly known as instant messaging tools for audio and video communication; maybe with integrated whiteboard, shared presentation or similar data collaboration. Focusing on clients with open standard protocols like the "Extensible Messaging and Presence Protocol (XMPP)", "Secure Internet Live Conferencing (SILC)" or "Session Initiation Protocol (SIP)" guarantees maximum interoperability and independence from specific vendors and proprietary software products.

- **Wiki-based coediting systems:** those systems are used for creating, coediting and linking web pages.

Based on the identified general requirements of large-scale organizations on the one side and ESA's specific interests on the other side we narrow an extensive list of products and choose 15 representative CWEs for detailed evaluation and comparison (see Table 1).

Note that commercial software is in our case harder to evaluate than open source projects. Our main evaluation method is gathering information by official documentation, reports, comparisons and other papers on the internet. For commercial products it is much more difficult to find trustworthy sources and retrieving reliable facts and not collect marketing statements or "soft facts" from sponsored reviews. Furthermore, evaluation of commercial products by installing, running and testing a complete system is too short and expensive for this study.

The evaluation investigates the selected CWE software with respect to the reviewed catalog of criteria in Section 3. The aim of the following evaluation is to provide a comprehensive and broad overview about available groups of collaborative tools and their basic features instead of evaluating only some particular products in detail.

There are basically four different types of evaluation distinguished:

File Management Systems	
Alfresco (open source)	winner of several comparisons on the internet
BSCW (commercial)	simple and widely used
Plone (open source)	famous and matured open source product
MS Sharepoint (commercial)	popular, because of good MS Windows/Office integration
Subversion (open source)	most widely-used version control system
Groupware Systems	
Collanos	using interesting P2P approach
eGroupware	one example for popular PHP-based collaboration software
Oracle Collaboration Suite	example for a commercial product
Simple Groupware	wide-range of add-ons and supported features
Real-time Office Applications	
CoOffice	MS Office add-on for synchronous real-time editing
GoogleDocs	most famous online office product
Real-time Audio, Video and Data Collaboration Systems	
Coccinella	Jabber client for IM with whiteboarding features
Skype	well-known VoIP software
Wiki-based Systems	
MediaWiki	used in Wikipedia thus one of the highly distributed wiki engines
Mindtouch Dekiwiki	based on the famous Mediawiki[13], extended with add-ons for enterprise usage

Table 1: Selected products for the final evaluation

1. **Evaluation by Installation.** This includes all information which can be retrieved just during the installation process, like ease of installation or certain software dependencies. This type of evaluation is of course only possible if there is a free version available on the web and can be time-intensive.

2. **Evaluation by Measurement.** This can be done after installing the system and includes measurement of some typical system parameters like scalability or measurement of required bandwidth by appropriate means. That's only possible if the software is freely available and can be successfully installed. Moreover some typical scenarios have to be set up to establish a real system environment. For that purpose maybe some additional software to simulate user interactions have to be developed and set up. *Thus this evaluation method is extremely extensive and is therefore not used in this study.*

3. **Evaluation by Performing Tasks.** This means performing some typical tasks like planning a meeting, publishing memos, sharing some documents and recording the effort, steps and time needed to do that. Some common tasks can be performed with installed software or also with use of public available web demos. In some cases web demos may not be appropriate if some features are not available or the installation is restricted in any other way.

4. **Evaluation by Reading Documentation.** This means doing some examinations of official documents (like manuals, FAQs, user forums) from the developer or other unofficial resources available on the Web. *This method is the main evaluation procedure agreed in the statement of work [3].*

Due to the nature of this study the following restrictions for evaluation exist:

- **Test Environment.** It is hardly possible to set up a test system which matches real conditions, this means using the same real (distributed) servers with optimized operating systems and the same type of network connections which shall be used in productive phase as well and simulate real user behavior. We could carry out performance tests pretty well

if the system offers web services for which test clients could be developed. But it might be hard to establish a real user scenario, particularly when the real user behavior is unknow at the time of performing this study.

- **Evaluation Coverage.** It is not possible to test all features of the selected tools or to take all criteria into account. There may be commercial add-ons or tricky time-intensive installation procedures which prevent a detailed analysis.
- **Server Installation.** Because we are not using real server hardware (multi-core CPUs and gigabytes of RAM) it is not be possible to simulate the load which would occur in large multi-national organizations, even when the software interface allows us to write dummy clients as mentioned before. Therefore we will try to find trustworthy performance case studies of every particular software platform used in the products.
- **Commercial Products.** Commercial Products can only be partially considered, especially if there are no free test versions or if their functionality is limited in any way.
- **WorkFlow Systems.** According to [6] work flow systems can be part of modern CWE software. While it is easy to determine if a certain product has a work flow system at all, it is currently nearly impossible to evaluate if it is appropriate (or if it can be adapted to be so). This would need a deeper examination of work processes which cannot be performed in the short project run-time.

We perform the survey by evaluating the selected products according to the compiled catalog of criteria, where ESA annotated their interest for every single criterion. We further apply a methodology where all criteria marked with *high importance* must be evaluated, those with medium priority shall be and points with low priority should be evaluated. For some criteria it does not make sense to grade, e.g. platform details or specific customer focus. In these cases we only mention the desired information. All the others are reviewed using the following classification:

- *low.* This means a feature is still supported, but not very well or the overall quality is poor.
- *medium.* This grade is applied to criteria which are basically supported.
- *high.* A product fulfills a requirement excellently.

A detailed resulting evaluation for selected CWEs in Table 1 is given in the full report[7]. Furthermore, we provide detailed comparison of CWEs based on criteria categories and CWE classes on the official Web site of this study[14].

5 Findings and Trends

From the analysis of ESA requirements, we found that the main interests of ESA when using CWEs are to share information on the one side and to perform communication in collaborations on the other side, while collaborative work in the sense of corporate task management or collaborative editing are only of medium importance or optional (see Figure 2).

From the evaluation and comparison of CWEs products, we have found that existing CWEs provide many features required by large-scale and multi-nation organizations but those features are not well-integrated into a single CWE. Due to the complexity of collaborative work within those organizations, often many CWEs are used and it is not easy to integrate those CWEs together. In particular, we found that:

- *enterprises with centralized IT structure are the main focus*: most CWEs focus on enterprise use with centralized IT structure. Many products incorporate into existing IT structure using central LDAP server and authentication server, and supporting single sign-on.

[14] `https://www.vitalab.tuwien.ac.at/autocompwiki/index.php/Main_Page`

- *security is well supported*: most products focus security needs, including transport security (SSL, TLS), several authentication methods, and file encryption in repository.
- *open standards are widely employed*: the use of open standards for data exchange is slightly increasing, such as iCal, vCard, WebDAV, and RSS, instead of proprietary file formats (which are often still used too).
- *open source software targets to enterprise*: many open source CWEs are suitable for enterprises, though some adaption might be required. Although open source projects generally have only limited development resources, they highly re-use well-known and well-approved frameworks/software like Apache Web server, Postgres database, PHP, Python.
- *support of synchronous real-time editing is increasing*: The support and use of synchronous real-time editing is increasing (MS Groove is available only since beginning of 2007) because fast, reliable and cheap Internet connections are available now.
- *Commodity/utility of CWE services is in increasing use*: CWEs tend to utilize commodity/utility components, such as third party utilities for VoIP and instant messaging. This trend is also shown in the widely integration of Google tools into existing CWEs.

On the other hand, still there are many remaining issues for CWEs to support the current highly dynamic working environment:

- *lack of mobility support*: the current trend is to work from everywhere using many types of devices. However, most CWEs lack mobility support, e.g., interfaces and security for performing collaborative work from mobile devices
- *lack of a well-integrated CWEs which cover different aspects*: the complexity of collaboration in multinational, large-scale organizations require different features, ranging from file management to VoIP to email, into an integrated system. However, most CWEs support a particular type of features. Therefore, the user normally employs multiple CWEs in the collaboration.
- *semantics support is limited*: the employment of semantics, such as ontology and collaborative tagging, is limited. Using semantic annotation will help increasing the search and interoperability in collaboration tasks.
- *existing CWEs do not support large-scale/multinational organizations well*: as most CWEs focus to organizations with centralized IT structure, many open issues remain when employing those CWEs for collaborative work spanning multiple ESA sites (or countries) having different IT structures and being connected through Internet.
- *context management is not well supported*: context information is important source for performing collaborative work. However, most CWEs provide very limited information about context of the users and their activities.
- *lack of extensibility to allow CWEs being integrated into SOA environments:* still many CWEs provide Web interfaces and GUI for the end user. Many popular CWEs lack Web services support so it is difficult to integrate them into SOA-based environments.

We observed that currently there are many projects[15] addressing some of the above-mentioned issues. The SaaS model has impacted strongly on the design and implementation of CWEs as more and more CWEs provide Web services to support composition. Furthermore, supporting the collaborative work for e-workers on the move is increased. For example, the inContext project[16] tackles the context- and interaction-based collaborative work by focusing on context management and collaboration services, while the ECOSPACE project[17] focuses on collaboration services and tools integration into CWEs for eProfessionals. Another aspect is to support

[15] e.g., see `http://www.ami-communities.eu/wiki/Projects`
[16] `http://www.in-context.eu`
[17] `http://www.ip-ecospace.org/`

the collaborative work spanning different departments/sites of the same organization or different organizations/SMEs has recently attracted many attention. For instance, the ECOLEAD project[18] and the COIN[19] project works on various aspects in Enterprise Collaboration for networked SMEs that require CWEs for multiple/virtual organizations.

6 Conclusion

This study on current and future technology trends of collaborative working environments was performed within two months. As follow-up, we suggest to further conduct the evaluation of the composition and integration of commodity CWEs for large-scale and multinational organizations. It's also needed to evaluate some particular criteria by experimental work, such as scalability and usability, as analyzing documents is not enough. Further analysis on current and future trends of CWE technologies and tools for networks of enterprises would also be strongly related to this study. Current detailed results are available at
`https://www.vitalab.tuwien.ac.at/autocompwiki/index.php/Main_Page`.

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