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Building the next generation groupware: A survey of groupware and its impact on the virtual enterprise

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Executive Summary

This document explores the issues in building the "groupware of the future". The approach is twofold. First we briefly describe our vision of a "virtual enterprise" that is made up of a set of *services* through a composition of *components* that comply with a specific *contract* (specification). Two scenarios are presented which demonstrate the set of underlying requirements. Secondly, a review of the-state-of-the-art in groupware technology is presented which identifies a set of services provided by current groupware systems. An assessment of the relative importance of these services is then presented and a comparison made to the requirements specified in the part one. A more detailed presentation of a subset of "important" groupware projects or products clarifies the limitations of current approaches. These limitations, in conjunction to the current trends in software technology (object technology, component architectures, web technology etc), determine the next steps towards our vision. The document concludes with a presentation of our definition for the "groupware of the future" and the route towards it.

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1. Virtual Enterprise Vision

We are currently witnessing a convergence of several threads of technology and business imperatives. The idea of a virtual enterprise (VE) – a business built from both organisationally and geographically distributed units – is becoming an area of increasing interest to both computer scientists and business people. A number of technological phenomena (e.g. CORBA, World Wide Web, Java, etc) as well as business trends like downsizing and outsourcing make VE feasible and appealing.

The notion of VE provides a new perspective in groupware applications. The collaboration needs of VE impose a series of new challenges for groupware technology. The ability to face up these challenges will drive the development of the "groupware of the future".

1.1 Vision Presentation

The Internet has the potential to change the way in which industry, government, and academia work. In particular, millions of people use the World Wide Web (WWW) for information exchange on a daily basis. Nevertheless, this information is unstructured and difficult to use or integrate with current working practices. What are required are *global information infrastructures,* which span these organisations in a flexible manner. Such a global information infrastructure should be as flexible as today's telephone infrastructure. Just as you can currently set up a conference call connecting any arbitrary set of telephones from a pool of millions of telephones around the world, an organisation will be able to set up a collaborative session between an arbitrary group of people from a world-wide pool. These sessions will be unique and dynamic, requiring that documents, calendars, program code, and other software tools used in the session are easily managed and readily accessible irrespective of the location of the contributing members of the session. In addition, physical objects such as office printers, medical monitoring devices, scientific and home appliances, will need to be accessible during the session, and again this should not be constrained by their physical location. The lifetime of these sessions could vary from milliseconds to decades; these sessions will be able to monitor and respond to the state of processes and events; and these sessions will be able to communicate with other sessions. These dynamic properties distinguish the objects in question as *active sessions*. If these dynamic sessions can be constructed easily and managed readily, then we are much closer to providing for the VE.

So, a **virtual enterprise** is a collection of service providers who collaborate to deliver a product. The service providers are typically not *all* found within the same company. The need to collaborate outside the boundaries of the company is necessary. Further motivation is seen with the business imperative moving towards downsizing and outsourcing. A **service** is the unit of *skill* that a collaborator brings to the in the VE. For example, a skill can might be project management expertise, medical expertise, or legal expertise. Given that support for the static aspects of collaborative working are mostly solved, *what is required now to facilitate a virtual enterprise is support for dynamic collaboration*. In particular we need to be able to allow an arbitrary group of people to work together using an arbitrary set of resources and tools, where the collaborators are possibly geographically distributed. In addition, we need to allow the group of collaborators, tools, and locations to arbitrarily change over time. There are three basic elements needed to facilitate the virtual enterprise, these are:

1. Support for dynamic service composition;
2. Lightweight service composition; lightweight enough to deal with millions of services world-wide;
3. Ability to seamlessly combine existing tools (such as proprietary word processors and spreadsheets) with specialist tools during the collaboration.

1.2 "Groupware of the future" Requirements

In this section we present two different cases where the notion of VE can be deployed. Both cases involve quite common activities. Through those cases we try to form a better understanding on the broad width of the VE framework and of the requirements it imposes on "Groupware of the future". These two cases are not of course the only ones but show that a wide range of everyday activities can be considered inside the VE framework and can benefit by the provision of the underlying technology.

1.2.1 EU Project Scenario

At first we consider the case of an EU research project. We can identify three quite discrete phases in the process of developing an EU project. At first a consortium of partners that will carry out the project must formed. Then, a project proposal has to be written and submitted for funding form the EU. Finally, if the project proposal is accepted the project itself must be developed according to the contract that is signed between the consortium and the EU. It is important to note that EU demands that the members of the consortium are from different European countries and that there is some company, which will deploy the results of the research project. Below we analyse further each of the identified phases.

The whole process usually starts with a small group of partners (2 to 3). At the beginning the partners usually have some kind of informal contact (maybe through some other project they collaborated on the past or personal relationship) and identify a common research interest. This usually starts some informal discussions that lead to the election of a project leader (the partner responsible for the co-ordination of the first phase), an outline of the project proposal, which includes a set of preliminary requirements, and a list of potential partners. A series negotiations starts with each of the potential partners that lead to the extension of the group with the addition of more partners and the modification of the project outline since each new partner might impose new requirements and/or constraints to the project. As the group grows the communication between the members becomes more complex and thus must be more structured (all the group members must be informed in the progress of the negotiations with potential partners and the changes in the project outline they result). The whole process of the consortium formations is usually cyclical because during the process new partners are added and some of the older partners might withdraw. This leads to continuous changes in the group membership and the proposal outline. At some point the consortium is formed, the terms and conditions for each partner's participation are agreed and the rules under which the consortium will work are settled. At this stage the consortium is ready for the development of the project proposal.

The writing of the project proposal is also a cyclical procedure. The members of the consortium start with the project outline agreed on the first stage and elaborate on it until they have a complete project proposal. This process involves usually a debate phase where ideas are presented and an agreement is reached for specific issues of the proposal. The conclusions of the debate phase are the directives for the writing of the proposal document. Each part of the document when is completed is presented to the consortium for evaluation. The evaluation might lead to a new debate phase or might lead to the acceptance of the document part. This sequence of phase continues until the entire document is written and accepted by all consortium members. There are two important notices that should be made on this cyclical process. First, the partners are not equally interested in the different parts of the document. So, it is quite common for the consortium to form subgroups of partners that will be responsible for different parts of the document. Each of these subgroups follows the phase cycle mention above, but on regular intervals they have to present their progress to the whole of the consortium and receive comments and new directions for the document parts of their responsibility. The process of reporting to the consortium and of document acceptance is agreed between partners at the formation of each subgroup. The subgroup members define the term and condition of the subgroup's operation. The other notice is that during this process some partners might realise that they are not really interested in the project and might withdraw from the consortium. Finally, when the proposal is ready it is submitted for founding from the EU.

If the EU accepts the proposal, then usually follow a phase of negotiation between the EU and the consortium for the terms and conditions of the contract. During this negotiation the partners have also to negotiate with each other to agree on the changes in the consortium's terms and conditions the EU negotiation is imposing. When an agreement is reached then the contracts are signed and the project starts. The goal of the consortium is now to carry out its conventional obligations dictated by the contract. The management of the project is usually done in two levels. At the top level is the project committee, which consists of one representative for each partner. The project committee has to elect the project co-ordinator and to watch the project's progress and report regularly to the EU. The project committee also assigns the different work-packages described in the contract to different subgroups of the consortium. At the lower level each work-package is managed. The work-package management involves a new cyclical process. At the beginning subgroup decides how its members are going to work. Then, each subgroup proceeds with close collaboration between its members to carry out the tasks assigned to it (notice that the subgroup might decide to be divided in subgroups, e.g. one at each partners location). This means that every member of the subgroup keeps track of everybody's progress and there are regular subgroup meeting for brainstorming and work assessment. In regular intervals all subgroups report back to the project committee. The committee evaluates each subgroup's progress and might decide correction actions when problems occur. This process continues until the project is completed and accepted by EU.

1.2.2 Healthcare Scenario

The second scenario comes from the healthcare domain. We examine the case of treating a patient, which involves his or her doctor, a number of consultants and experts and a set of medical exams. Important notices are first that although the doctor usually resides in the same place (city) with the patient, the consultants and the expert can be anywhere in the world. Second, the medical exams are usually performed with the use of special equipment that might not be available everywhere. Finally, each medical case may need short or long term treatment, and might be urgent or not.

We are more interested in medical cases that are not trivial, which means that they require the collaboration of a lot of consultants and experts and a lot of medical exams. In those cases the doctor first examines the patient and recommends some consultant for the case. The consultant examines the patient and his or her medical record provided by the doctor. This might mean that either the patient or the consultant has to move. The consultant, then, prescribes a set of exams that the patient must carry out. This might mean that the patient visits the appropriate medical centres for the exams or substances (e.g. blood samples) are transferred to the medical centres. When the results of all the exams come to the consultant he might consult his medical records, medical journals, or medical databases for similar cases and information for the disease. He might also recommend that other consultants must examine the patient, or ask for advice from experts, or call for a medical council of colleagues and specialists to discuss the case. The whole process may continue until a decision is reach for the appropriate treatment for the patient. After, a treatment is specified the patient starts using the prescribed medication and in specified intervals the consultants assess his health condition until the patient is healthy again. Each assessment might involve a new process of consults examining and discussing the case, additional search for information sources and changes in medication.

1.2.3 From scenarios to requirements

The two scenarios presented above share some central characteristics. Both involve groups of people that need to collaborate for achieving some goal, a research project in the first scenario, a medical treatment in the second. The groups involve in both cases have a set of common characteristics. First, they are not groups with a constant set of members. In fact they are groups that their members may change quite often and more importantly all members are not known from the beginning. So, the research consortium at the first stage has to consider potential partners, the doctor of the patient has to consider appropriate consultants or specialists. Besides that, in both cases members (partners or consultants) may leave or enter the group.

The second important characteristic of these groups is that the distribution of their members varies. So, in both cases there are groups that operate within one organisation at the same physical location (e.g. the research group of one institute or the medical team of a hospital). Or groups that span over organisations and countries (e.g. the project committee with members from all around Europe, or the medical council with specialist from all around the world).

The third important characteristic of these groups is that they have different communication needs in different stages of their lifecycle. So, the member of the project committee may meet in person every month and exchange document (research reports) in between meetings. Or the medical council may involve only consultants of the same hospital that meet in meeting room every week or may involve a virtual meeting (with the use of some teleconferencing or videoconferencing tool) of specialist that are spread around the globe. Or even involve every day virtual meetings (with the use of email) of the group member responsible for a project work-package or the team of consultants that monitors the patients everyday condition.

The fourth important characteristic of these groups is that they have different levels of freedom in their operation. So, the group responsible for writing the project proposal has usually very specific rules to follow (there are usually guidelines provided by the EU) and a usually a tight deadline. The case is similar when specific medical exams are performed. On the other hand, a group for some work-package or a team of consultant in a medical council is usually free to organise its time and modus operandi.

The final important characteristic of these groups is that their member have to exchange information and sometimes they have to exchange information with other groups too. The exchange of information may involve electronic artefacts (e.g. reports, exam results, x-ray images), or physical objets (e.g. blood samples, devices for testing), or even people (e.g. the patient goes to a consultant to be examined, or a researcher goes to a laboratory to perform some experiment).

So far successful collaboration is usually closely related to the movement of people and physical objects around the world, as it is obvious from the two scenarios. But a great part of these movements can be eliminated, if we look at these situations in a VE context and deploy the appropriate groupware. For example, although person-to-person meetings will never be totally eliminated, virtual meetings are usually easier to organise (nobody has to travel) and cheaper (the equipment is bought once and used for long periods). Physical object movement is usually more costly in time and money, and also sometimes impossible (e.g. the patient in our healthcare scenario might not be able to travel).

So, the "groupware of the future" should provide the support needed for the kinds of groups described above to collaborate effectively and efficiently. It should, also, take into account the complications imposed by the fact that the life duration of the groups differs significantly. It can be from a few hours for a medical emergency, to some days for an examination, to a few weeks for the writing of the proposal to a few years for the whole project. And the fact that the members of the groups are people those come from different backgrounds and are used to work with different tools and in different ways and the style of work and available equipment might be incompatible. And finally, that some part of the information used by the group is confidential (e.g. the patient's medical record or the research report for the development of a product). So, a lot of security and authentication issues are raised. And of course another degree of complexity comes from the fact that each group member (researcher or doctor) maybe involved in more than one group (medical teams or research projects) at each time. This means that each group member has to deal with both private and public information.

Summarising the VE has the following series of functional requirements:

- Support for dynamic group membership
- Support for dynamic organisational and geographical group member distribution
- Support for dynamic modes and different ways of communication
- Support of various group working practices and dynamic group member roles
- Support of various types of information exchange

And a series of non-functional requirements:

- Support of groups with different life duration
- Integration of currently used tools and support of current working customs
- Authentication and Security issues

2. Groupware Survey

The first section introduced the term “groupware of the future” for the description of the new generation of software tools that will support the enhanced collaboration needed by VE. But, the term groupware has a quite long history and a plethora of products or research projects refer to themselves as groupware. So, the question is what is groupware in general and especially what is the “groupware of the present”?

2.1 Groupware Definition and Focus

Many credit Peter and Trudy Johnson-Lenz for coining the term in 1978 [1, 2]. They defined groupware as “intentional group processes plus software to support them” [3, 4]. But, this definition is not widely accepted. It views group work as a set of processes and this is a very constraint view for groupware. Some [5, 6] adopt the definition provided by Johansen in [2]: “Groupware… a generic term for specialised computer aids that are designed for the use of collaborative work groups. Typically, these groups are small project-oriented teams that have important task and tight deadlines. Groupware can involve software hardware, services, and/or group process support”. This definition is not also widely accepted because it is considered too narrow. According to this definition categories of products that were not designed especially for supporting work groups, like email or shared databases, are not considered groupware. Besides that, it also focuses on small teams which is also constraint. Another view of groupware is: “computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment” by Ellis et al in [7]. This view of groupware is considered too broad, because although, it excludes multi-user systems, such as time-sharing systems, whose users may not share a common goal, it includes systems like shared database systems. And, many argue that shared database systems can not be considered groupware because they provide the illusion that every user has independent access. So, they are not “group-aware.” In general, as Grudin points out in [8] groupware means different things to different people. For the discussion here we adopt the definition of groupware that Greenberg gives in [9] as “software that supports and augments group work.” These definitions although quite broad captures almost all the products and projects that are identified as groupware.

The common denominator in all the above definitions, is the notion of group work. Groupware is designed to support teams of people working together. As such groupware provides a new focus in software technology from human – computer to human – human interaction. Human interactions have three key elements: communication, collaboration and co-ordination. The goal of groupware is to assist groups in communicating, in collaborating and in co-ordinating their activities [7]. So, for years groupware technology focused on communication, collaboration and co-ordination.

The fact that most groupware tools failed to be widely adopted made clear the need for a better understanding of how groups of people work together. A new research area emerged that is called: “Computer-Supported Collaborative Work (CSCW)”. The term CSCW was coined by Iren Greif of MIT and Paul Cashman of Digital Equipment Corporation who organised a workshop in 1984 for people interested in how groups work. Since then, the new area attracted a lot of interest. According to Greenberg [9] “CSCW is the scientific discipline that motivates and validates groupware design. It is the study and theory of how people work together, and how computer and related technologies affect group behaviour. CSCW is an umbrella collecting researchers from a variety of specialisations – computer science, cognitive science, psychology, sociology, anthropology, ethnography, management, information systems – each contributing a different perspective and methodology for acquiring knowledge of groups and for suggesting how the group’s work could be supported.” CSCW led to a better understanding of groups and made clear that group relationships are not based only on communication, collaboration and co-ordination. In fact as Kling points out in [10]: “In practice, many working relationships can be multivalent with and mix elements of co-operation, conflict, conviviality, competition, collaboration, commitment, caution, control, coercion, co-ordination and combat.”

2.2 Categories of Groupware Tools

In order to clarify the term groupware and to provide a better understanding of groupware technology we present a list of groupware research projects and commercial products. The purpose is not to provide a complete presentation, but to show the various categories of available groupware applications, and to show that groupware attracts a lot of research attention.

The first category of groupware applications is Electronic Mail Systems. Many believe that those systems are the only really successful groupware application [8]. Through the years Electronic Mail Systems evolved towards many different directions employing all the developments in computer technology. So, the contents of the message evolved from systems for the exchange of simple text messages, to systems for the exchange of compound documents (documents that include images, graphs, etc), to even multimedia documents (e.g. voice mail systems). In parallel they evolved from systems that maintained a flat collection of messages to hypertext systems (e.g. Hypermail [31]) or even complex systems for message handling like CLUES [60], that allows dynamic personalised message filtering, prioritising voice and text messages using personal information from the users workspace.

At the same time the exchange of messages moved from the support of one-to-one communication to the support of one-to-many or even many-to-many communication with the use of systems like Newsgroups or Bulletin Boards. Typical example of these systems is USENET where users subscribe to various subjects and are able to take part in the discussion by exchanging messages. Those systems followed also the developments in computer technology. So, now newsgroups are hypertext systems where the links between the messages follow the threads of discussion, or even systems like GroupLens [14] for collaborative filtering of the messages.

The exchange of messages was not limited in the support of communication between users but also for the support of collaboration and co-ordination [29]. Message-based groupware includes applications like Lotus Notes [13], Novel GroupWise [12], and

MS Exchange [19]. On the other hand hypertext systems proved to be a powerful basis for the building of groupware systems. Those systems could either use hypertext to represent an underlined structure as in the case of gIBIS [36], a collaborative design system based on a method called Issue Based Information Systems for the design of complex systems, or as a basis for even adaptable groupware [30].

Groupware systems are limited in the support of message-based interactions, but they cover also direct person to person interaction through conferencing systems. Conferencing systems are a broad category of groupware that includes text based, audio and video conferencing. Typical example of text based conferencing are chat systems like IRC (Internet Relay Chat) or even Web conferencing systems like COW (Conferencing On the Web) [24]. Videoconferencing includes systems like CU-SeeMe [11], a desktop videoconferencing system for Macintosh computers developed at Cornell University, as well as a whole group of tools based on MBONE [38], the multicast backbone. Finally, there are systems like Sun ShowMe [16], which besides audio, video and data conferencing support application sharing and a shared whiteboard, or Intel TeamStation [20] (based on the ProShare videoconferencing technology) that support audio/video/data conferencing.

Another category of groupware applications is meeting support systems. In this category are tools like MS NetMeeting [18], which provides audio and video conferencing, application and data sharing, a whiteboard and a chat application. NewStar Sound IDEAS [25], which provides audio and data conferencing and a shared whiteboard is also in this category. And systems like GroCo [49], which text-based chat and shared whiteboard in Java, for meetings over the World Wide Web. In this category can be classified also tools like DOLPHIN [58], which supports the preparation and management of team meetings. Activities that are supported by DOLPHIN include meeting management, brainstorming, rating and organising of ideas, discussion, decision making, and presentation. Most of these activities are based on documents which were prepared before the meeting (e.g., agenda, list of issues, proposals, charts), presented and changed within the meeting, and finally result in new documents (e.g., minutes, decisions, annotated proposals). This material is quite often processed after the meeting and will be the starting point for subsequent meetings. Tools like DOLPHIN have a more organised view of meetings than the previously mentioned ones.

The category of products that most people think of when they discuss about groupware is the integrated groups support packages. This category includes tools like Lotus Notes [13], Novell GroupWise [12], MS Exchange [19], Netscape SuiteSpot [70], and SOFTARC FirstClass [17]. Those systems provide advances messaging facilities, document management, calendaring, group scheduling, task management, and workflow. The last years they provide also access through the World Wide Web.

One of the first approaches in providing support for group work was through the screen sharing of already existing single user applications. These applications are called group-unaware or collaboration transparent and form another groupware category. In this category are tools like Colab [27, 28], which was developed at Xerox Parc and coined the term WISIWYS (What I See Is What You See) or X-sharing applications like XMX [71] and XTV [72]. This category also includes application sharing tools like ShowMe SharedApp [16] or even application sharing environments like the one that consists of JVTOS (Joint Viewing and Tele-operation Service), GroupX, CoNus (Co-operative Networking for Groups) [40].

Another category is groupware environments. This category includes tools like EGRET [48], which is an environment for the development of domain-specific collaborative systems, and mStar [52], which is an environment for scalable distributed teamwork based on IP-multicast, and provides a whiteboard, a chat tool, a tool for meeting recording and shared web objects.

A new approach in groupware systems is to view groupware not as sessions of collaboration but as a shared workspace. A shared workspace is a place where there information and tools for processing it. Every user that enters this workspace can use the available tools and information. Examples of this kind of systems are Shared spaces [59], or GMD FIT BSCW (Basic Support for Co-operative Work) [22, 23], which provides a shared workspace over the World Wide Web, to more specialised systems like the one described in [33], which can be used for instructing. A whole subgroup of systems in this category is room-based systems. Those systems deploy the notion of a shared room where the collaboration takes places. The room-based approach is followed by systems like TeamRooms [61] or Mushroom [65], which is in fact a framework for room-based systems. The notion of a shared workspace in conjunction with ideas from virtual reality lead to another subgroup of groupware systems, Virtual Environments. For a short presentation on the research in virtual environments a good starting point is [32], while an example of this kind of systems Virtual Society [43], a distributed virtual environment. A special category of virtual environments that receives a lot of attention the last years is scientific collaboratories [73]. The term collaboratory comes from the concatenation of collaboration and laboratory and is used for systems designed for enhancing the collaboration between scientists especially for experimenting purposes. There are quite a few collaboratories already under development. One of the first ones is UARC [74], which was build with the use of CBE [62], an environment for building internet-based scientific collaboratories based on group-aware applets. Another interesting collaboratory is TANGO [68], which is a Java-based system for the World Wide Web. Finally, another groupware category that comes from the combination of the notion of a shared workspace with ideas from the MUD (Multi-user dungeons) and MOO (Object Oriented MUD) systems. Example of this kind of systems is Collaborative Virtual Workspace [53], a system that provides audio and video conferencing, document management, a chat tool, and a shared whiteboard.

Another category of groupware applications that attracted a lot of interest is Group Decision Support Systems (GDSS) [41, 42]. These systems are used for the support and enhancement of decision making during group meetings. Although this category of systems is definitely groupware, some times is consider as a totally different research area in computer science because each main focus is on decision making processes.

Another category of groupware applications that at least in the past was considered a separate research area in computer science for the same reasons as GDSS are knowledge-based systems. Recently the groupware community realised that knowledge management is an important aspect of group activity, this lead to the integration of knowledge management techniques in groupware applications. An example of this kind of systems is Object Lens [37], an intelligent system for information sharing and co-ordination that integrates hypertext, object-oriented databases, electronic messaging, and rule-based intelligent agents. This system provides also a knowledge-based environment for developing co-operative work applications.

A very important category of groupware is workflow applications. Workflow systems were the first systems used for group co-ordination and a lot of big organisations use such systems today. Workflow technology is a very reach research area and its presentation would require a whole new document. So, we give here just a few examples of workflow systems without entering into details on their operation. Commercial workflow systems include systems like Lotus Notes [13] and IBM FlowMark [75]. Research systems include systems like DartFlow [76], METEOR [77], WebFlow [51], and WWWorkflow [54].

Other categories of groupware applications are shared editors like NCSA Collage [15], a collaborative data analysis tool for data viewing, data analysis, animations, shared text-editing, shared whiteboard, HDF browser data object selector, and screen capture, and tools for Co-operative Design [34].

The significant difficulties encountered in the development of groupware lead to the design of groupware toolkits. Groupware toolkits usually provide to the developers a set of ready algorithms for group communication and co-ordinations and also some groupware widgets like shared scrollbars or telepointers for group awareness. In this category of groupware applications belong toolkits like COAST [57], which is an object-oriented toolkit for synchronous groupware, or GroupKit [67], which is one of the first groupware toolkits. GroupKit is a Tcl/Tk groupware toolkit from the University of Calgary. It is already used for building a lot of real-time applications such as drawing tools, editors and meeting tools.

As another approach for overcoming the difficulties in the development of groupware some proposed new programming languages. An example of this kind of language is Clock [64], a language intended to support the development of interactive software, including the development of distributed multi-media groupware.

The big number of different groupware categories imposed a lot of problems in group collaboration, because different members had different applications which were not usually compatible and also each user had also to deal with incompatibilities in his own groupware applications. Groupware frameworks were proposed as the solution to these problems. Although the idea of groupware frameworks is not very old there is a significant number of frameworks already available. For example there is Promondia [63], which is a Java-based framework for real-time group communication in the web, Mushroom [65], which is a generic software framework that supports collaboration and group interaction for the Internet. Another groupware frameworks are Habanero [66], which is a collaborative framework and a set of applications that allow users to share tasks from remote locations in real time over the Internet, wOrlds project [55, 56], which is computer-based collaboration support for distributed groups based on the locales framework.

Finally, a separate category of groupware applications is group communication platforms like Totem [44], Transis [45], Rampart [46], and Horus [47].

2.3 Aspects of Groupware

In the previous section we presented a plethora of groupware categories. Each category includes a plethora of commercial products and research projects. Examining all these projects and products we can identify some common aspects that characterise groupware applications in general. As it is expected in each of these aspects there is a whole range of approaches and each project or product covers a specific part of it.

2.3.1 Communication Strategy

One of the main aspects of groupware is communication. Communication plays a central role in groupware systems. Whole categories of applications presented in the previous section focus in group communication (e.g. conferencing systems, electronic messaging systems). We can identify to discrete types of communication synchronous and asynchronous. Synchronous communication requires that all the participants be present at the same time. Applications like chat tools and audio or video conferencing systems support synchronous communication. On the contrary electronic messaging systems, newsgroups and web conferencing systems support asynchronous communication. Finally, applications for integrated group support usually provide tool for both kinds of communication as they include asynchronous messaging (e.g. electronic mail) and synchronous chatting.

2.3.2 Co-ordination

Co-ordination is another one of the main groupware aspects. Different types of group process have usually different types of co-ordination requirements. For example, in brainstorming sessions group members can freely express their ideas and comments, while on conference sessions group members are supposed to talk in turns. So, each kind of group activities requires varying degrees of flexibility in co-ordination. For the co-ordination of group activities techniques like floor-control or locking are employed. Although most collaborative applications require some degree of co-ordination, workflow and meeting support systems focus mainly in it.

2.3.3 Distribution

Another aspect of groupware is group distribution. The member of the group could either be at the same place or at geographically remote place. Different applications are intended for different group distributions. For example Colab [27, 28] was designed to support meetings where all group member are in the same room, while applications like web conferencing are designed to support discussions between people spread through out the world.

The aspect of group distribution became a bit blurry the last years. The use of room-based systems made the distinction between same and different place difficult to discern. So, now we are talking about virtually collocated group members. At the same time the development in mobile computing require a new way of thinking about location, since people can be at one point in time in the same geographical place and at next point in very distant places.

2.3.4 Scalability

Scalability refers to the number of users that a groupware application can support and it is a very important aspect of groupware. Some groupware systems are limited to groups with a small number of users, for example Colab [27, 28] is for up to about 10 users, or NewStar Sound IDEAS [25] for up to 32 users. On the other hand web-based systems can support an almost indefinite number of user[1].

2.3.5 Openness

Openness refers to the flexibility of a groupware systems in integrating other groupware applications, to work on different hardware platforms and to use different concurrency control or awareness mechanisms. Groupware systems traditionally were characterised as rigid systems (especially workflow systems), which meant that usually it was almost impossible to change anything in the system, the system was in fact a black box to its users. As mentioned in the previous section, in order to overcome this problem groupware frameworks were proposed. The new approach although it solved the inflexibility problem caused new problems since now you need to program everything you want in the groupware system.

2.3.6 Non-functional characteristics

Another aspect of groupware is the interest in non-functional system characteristics. Non-functional characteristics include things like fault-tolerance, security, safety, integrity, etc. Most commercial groupware systems and especially the integrated group support systems consider security and safety a very important aspect of a groupware application. So, they deploy encryption mechanisms, secure communication and data protection. For example Lotus Note [13] uses RSA encryption and secure sockets. On the other hand, fault-tolerance and integrity are usually more difficult to ensure, so in most groupware systems the approach is quite simple.

2.3.7 Web exploitation

The World Wide Web was designed to assist the dissemination of information between scientists. Right now the Web provides a huge pool of publicly available documents and a primitive base for collaboration through the exchange of document. The success of the Web in combination with the usual failure of groupware systems led in considering it as an appropriate basis for groupware applications [39, 50]. So, the exploitation of the Web becomes an important aspect of groupware. Most of the commercial groupware systems are moving in this direction while a plethora of web-based research projects is also available at it is obvious from the previous section.

3. What’s missing from current groupware applications?

In the previous sections we identified the virtual enterprise as an appealing new trend in business organisation and we introduced the term “groupware of the future” to describe the software tools that will support it. We, also, defined the term groupware and the different categories of groupware applications available today were presented.

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[1] Degradations in the performance of an application can also impose a limit to the number of users it actually supports.

So, the next question is why current groupware applications are insufficient for supporting the virtual enterprise? Why we need a "groupware of the future" and how far is it?

3.1 Groupware Characteristics and VE requirements

Groupware technology and business organisational structures evolve in close interaction to each other. Both are taking part in a cyclical evolution process, where the different steps are difficult to discern. The adoption of a new business organisational structure requires new groupware tools, thus pushes groupware technology forward. At the same time, the adoption of new groupware tools in the business environment challenges existing business organisational structure [35] and makes necessary the restructuring of business organisations. The Virtual Enterprise is the new direction in business organisational structures and, as expected, pushes groupware technology a step forward, towards the "groupware of the future". The Virtual Enterprise imposes a series of functional and non-functional requirements in groupware technology (see 1.2.3). These requirements can be summed up in two basic directions:

(a) increased flexibility by groupware applications and

(b) increased support of dynamism by groupware technology.

Increased flexibility translates into support for all the different aspects of groupware described in 2.3. It, also, means support of the whole range of approaches for each aspect. This results in groupware applications, which are able to support every kind of collaboration. That is important because Virtual Enterprises, as mentioned before, can be formed for any kind of collaborative activity. Increased support of dynamism translates into groupware technology that not only provides the basis for flexible groupware applications but also enables them to exploit the whole range of available flexibility on the fly. This results in groupware applications that are able to change between different approaches in all the aspects during their operation. That is important because Virtual Enterprises are not only formed for every kind of collaborative activity but also need different kinds of collaboration during the various stages of a collaborative activity.

The need for increased flexibility in groupware applications has already been pointed out to the groupware research community [40]. So, from the presentation of the various categories of groupware we can identify categories like integrated group support systems, groupware environments, or groupware frameworks that are moving towards this direction. But so far no research project or commercial product addresses the whole range of aspects.

On the other hand the need for increased dynamism was realised quite recently, mainly through the work for scientific collaboratories that present some analogies to the Virtual Enterprise. But scientific collaboratories have a more limited focus and address only a portion of the vast number of different kinds of collaboration. This means that the need for dynamism is limited to, only, some of the aspects of groupware, mainly communication strategy and co-ordination.

So, current groupware technology does not cover the whole spectrum of Virtual Enterprise requirements. The "groupware of the future" is not yet a reality. The important question that arises is how fundamentally different the “groupware of the future” will be?

3.2 “Evaluation” of groupware characteristics and VE requirements

Although certain categories of groupware, as mentioned above, are already following the two directions that the Virtual Enterprise draws for groupware future, the “groupware of the future” is not as close as it might seem. During the last years a lot of work has been in order to circumvent the problems that the various approaches for each groupware aspect have. Of course there are still unsolved problems but it is reasonable to expect that most of them will be solved in the next few years, since none of them seems fundamental. So, the “groupware of the future” should not try reinvent the wheel and must adopt all the available knowledge and experience. On the other hand, the adoption of any new groupware application is almost always problematic. Users do not like to change the way they work, especially, if they have already spent a significant amount of time and money in training. So, if the “groupware of the future” wants to be successful it must make sure that the transition from traditional groupware will be as easy as possible. The research in Computer-Supported Collaborative Work provides the necessary understanding of group process, group dynamics and organisational issues that could help in this transition.

So, as it is clear, the required basis for “the groupware of the future” is almost already available. There are two main problems that need to be solved. One is to lift the boundaries imposed by proprietary technology and software and hardware incompatibilities. And second, to provide scalable solutions. Traditional approaches to groupware do not seem to provide solutions. What is needed is a new way of looking at groupware. The new approach must deploy all current knowledge and experience in groupware development, must support the use of already popular tools and must be based on open widely accepted protocols.

The decomposition of groupware into a set of services and the viewing of current popular applications also as services might be provide the necessary framework where this new approach can be based. This framework should allow the dynamic composition and configuration of these services in order to provide the full flexibility the Virtual Enterprise requires. It should also allow on the fly re-composition and reconfiguration of services, in order to provide the needed dynamism. Besides that, it should be based on open widely accepted protocols, in order to avoid the problems of the current groupware approach. Finally since, as it is expected, the number of these services will be very high, the framework should also be scalable.

3.3 “Important” Projects/Products Presentation

In this section we present some “interesting” groupware projects / products. “Interesting” means groupware development approached that seem to realise the limitations of the traditional development approach and move a step forward. These approaches are close in supporting the full range of the needed flexibility. They support a significant part of the whole range of dynamism. And also provide a framework for groupware application development that has a lot of the characteristics that “groupware of the future” approach should have.

3.3.1 Lotus Domino

Domino [26] is Lotus' new approach for business groupware. It combines Lotus Notes [13] and Web Technology. Domino is an applications and messaging server with an integrated set of services that enables easy creation of secure, interactive business applications for the Internet and corporate intranets. Domino's object store can handle any number of objects and data types (e.g. text, images, graphics, sound, video, structured data, embedded objects and applets). It also supports indexing and searching of documents and allows applications to present customised views of information. Domino's directory service is used for server and network configuration, application management and security. The directory service is LDAP compliant. Domino's security model supports user authentication, digital signatures, flexible access control and encryption. Support for wide range distribution is based on replication technology. Replicated information and applications are automatically distributed and synchronised. Replication technology is also deployed for server clustering, which allows enhanced scalability, failure protection and high availability. The messaging system is based on client/server architecture and supports standard protocols like SMTP/MIME, x.400. Any kind of mail clients (e.g. POP3, IMAP4, MAPI, etc) can be used. Domino, also, provides the necessary infrastructure for connecting to legacy systems (e.g. relational databases and transaction processing systems) as well as other information systems, both in real-time or batch level. So, it can be used as the basis for integrating existing information technology solutions. Besides that, Domino includes a workflow engine that allows distribution; routing and tracking of documents according to application defined processes. Through the workflow engine Domino enables co-ordination and streamlining of critical activities. Domino, also, enables automation of frequently performed processes with the use of agents that can be triggered by time or events. Finally, Notes Designer provides an integrated environment for building multimedia Java applets based on Java Beans and also for running applications in many different languages.

3.3.2 TANGO

TANGO [68] is a Java-based collaboratory system for the World Wide Web. The purpose of the project is to build a collaborative software infrastructure and integration framework to better utilise the Internet and, more specifically, World Wide Web environment for co-operative work. The focus is on collaborative applications for education and distance learning, command and control, health care, and computer steering. TANGO is an open, extensible system that provides a technological framework for building collaborative systems. It is fused with Web on both functional design and implementation levels and provides complete collaboratory runtime for both synchronous and asynchronous sessions. It is possible to build collaboratory systems of arbitrary complexity using TANGO framework.

TANGO Interactive is written in Java. Most system modules are implemented as applets. The applets interact with each other and can control each other behaviour. Applet interaction in TANGO goes much further than trivial communication between few applets on an HTML page. TANGO applets can come from different name spaces. There is no requirement that all applets or even different instances of the same applet come from the same http server. The applets can be loaded when needed and released at any time, ensuring that the system is lean and agile. TANGO Interactive implements a very flexible and powerful architecture.

Instead, of writing applets TANGO allows the use of JavaSctipts or even pre-Web applications written in C or C++. Finally, it, also, supports the construct of 3D virtual worlds, with the use of VRML, JavaScript and EAI, and provides a whole set of collaborative applications.

3.3.3 Mushroom Project

Mushroom [65] is a generic software framework that supports collaboration and group interaction for the Internet using the World Wide Web. Mushroom provides Mrooms: working spaces for groups of collaborating users. Mrooms contain representations of the users who are present in them, and they contain information objects that these users share, such as documents, multimedia presentations and whiteboards. Users also share tools for communication with other users in the Mroom. Information objects include group-aware objects written in Java, as well as 'legacy' objects such as conventional documents.

Users work or interact in Mrooms at the same or different times, and an Mroom and its contents persist even when no user is present. Unlike the Web, if a user updates an object, then others see the change almost immediately. Mushroom makes the objects stored in Mrooms highly available despite network delays, disconnection or single server failure.

To avoid conflicts and promote collaboration, it provides users with information about one another's activity within Mrooms. Mushroom provides mechanisms for integrity and access control, for when users attempt to import objects into an Mroom. It provides general concurrency control mechanisms, for when users update shared objects in Mrooms. It provides security and privacy guarantees. Mushroom is open with respect to the types of application and object that can be shared in Mrooms, and with respect to the security and integrity control policies that Mroom users choose to apply.

3.3.4 wOrlds Project

The wOrlds project [55, 56] caters to the needs of distributed work-groups. The project goal is to create a software collaboration framework, which leverages recent sociological theory on the nature of work, cutting-edge distributed systems research and existing results in the field of computer-supported co-operative work (CSCW). The project is currently developing a "next generation" collaboration environment called Orbit, which supports the development, evolution and working practices of workgroups. Orbit aims to avoid some of the problems of classic groupware such as a focus on small problems in isolation or overly rigid mechanisms for collaboration support. The Orbit environment will allow seamless integration of existing tools and support for a wide range of collaborative activities (from casual encounters through highly structured processes) in a variety of domains (for example, software engineering, office activities and collaborative choreography).

The project is based on the notion of locales. A locale is a conceptual place in which a group of people can come together to work on a shared activity. A locale can be thought of as a "focal point" around which to define, structure, and relate the relevant people, objects, tools, and resources germane to a particular collaborative activity. The locale foundation aspect captures the basic structuring and furnishing of domains of work. Locale foundations is therefore about: identifying the social worlds of concern, providing adequate media and mechanisms in available domains to support sharing of objects, tools and resources, supporting a group's notion of membership and related processes, and facilitating appropriate privacy and access mechanisms.

The wOrlds support things such as ubiquitous audio/video conferencing, a persistent distributed object infrastructure, seamless integration with mail and the web, and navigation metaphors. It also allows users to participate in more than one locale or activity at a time, support for individual user view, support for awareness of other user actions, an ability to project one's presence into the collaborative world, and the provision of trajectory or history information.

3.3.5 Habanero - ISAAC

Habanero [66] is a collaborative framework and set of applications that allow users to share tasks from remote locations in real time over the Internet. It also enables developers of groupware applications to build powerful collaborative software. Habanero is written in Java. The Habanero framework, or API, provides the necessary libraries that developers can call upon to create or convert existing applications into collaborative applications. The Habanero applications consist of a client, a server and a variety of tools.

ISAAC [78] research focuses on making computer-assisted collaboration in science, engineering and real-time decision support domains more natural, more powerful, and more responsive to the multi-modal communications needs of users. Historically, trying to work together via extant computer tools has been chronically limiting. The ISAAC collaboration system will enable users to function in an information immersion environment, able to retrieve, forward, and re-use information regardless of the temporal nature of its source or destination. Ongoing collaborative work may include sections that are real-time as well as asynchronous contributions. Group members unable to participate in portions of an ongoing collaboration will not be deprived of information. The system will function through a combination of techniques, including capture and replay of real-time discussions and analyses, automated analysis and indexing of captured material, incorporation of asynchronously generated materials into the collaboration stream, and object annotation support for the workgroup. The ISAAC system is based on an extended version of Habanero.

4. What's the next step in groupware technology?

The new view in groupware development presented in 3.2 defines the direction that groupware technology should follow in the future in order to realise the vision of Virtual Enterprise. So, the next question is which current technologies are going to be the driving forces towards this direction? The presentation of the "interesting" projects and products in the previous section helps us in identifying these technologies.

The World Wide Web seems to be one of the technologies that have the potential of push groupware forward, since all "interesting" project and product are either based on or moving towards it. As we pointed out in 2.3, the exploitation of the Web is considered an important aspect in current groupware technology. There are to main reasons for that. One reason is that the Web provides already a platform for basic collaboration, through the its shared information space. And the second reason is that the Web, in contrast to most groupware applications, is very successful. The groupware's community interest in Web exploitation is proved by the number of groupware applications that use the Web and by the fact that special workshops are examining the potential of the Web as a platform for groupware applications [79]. On the other hand Web technology seems to have some fundamental difficulties in supporting groupware applications [50]. The Web Consortium considers collaboration an important part of Web technology and has formed a working group for that (for more details see [80]). So, it is expected that Web technology will be closely related to groupware in the future.

The second important technology seems to be Java [81]. Java is a programming language that supports machine independent code production, through the use of the Java Virtual Machine. Hardware dependencies are one of the major problems in groupware applications. So, a language that solves this problem will be a major driving force for groupware technology in the future. All the "interesting" projects and products seem to realise that and deploy Java technology. Another important thing about Java is that it, also, seems to be the language of the Web. Java applets are the only widely acceptable way of providing running code through the Web. Finally, Java recognising the strong influence that already has in groupware development is moving towards adding collaboration support in the language through the Java Shared Data Toolkit.

The latest developments in object technology seem to be the third technological push for groupware. Object technology already provided a significant push in groupware. The separation of behaviour and presentation that is basic in object-oriented languages makes groupware development a lot easier for two reasons. First, it is easier to support customisable applications, because you can program different presentations for the information objects without needing re-writing the object handling code. Second, you can abstract on information objects and support a unified handling for the various types of multimedia objects. Customisability and the deployment of multimedia were major pushes for groupware technology. The resent development in object technology is distributed objects frameworks like the Object Management's Group (OMG) Common Request Broker Architecture (CORBA) [82]. CORBA provides a framework that allows distributed objects to invoke methods on each either and exchange information. It, also, provides a trader that enables objects to locate and invoke methods from other objects in a transparent way. Distributed object frameworks are a step forward towards the new approach in groupware development we described in 3.2, because they allow the de-coupling of the various components that form groupware applications.

Finally, groupware technology is expected to have significant gains by the research in compositional systems and component architectures. Compositional systems are systems built from interacting components. Component architectures seem to provide the framework for viewing groupware development as dynamic service composition and configuration. The research in this area includes projects like Infospheres [69] and Aurora [83]. So far, the research in this area is in a quite primitive state and addresses the whole subject from a general distributed systems point of view. The intricacies of groupware need to be addressed if groupware technology is to deploy these methods.

5. Conclusions

We started by presenting a vision for collaborative activities. The vision was based on the notion of Virtual Enterprise that brings together expertise from humans and enables the use of special software and hardware in order to complete certain activities that require collaboration. The Virtual Enterprise requires a new generation of groupware applications, referred as "groupware of the future", that will be based on a set of functional and non-functional requirements. These requirements can be summed up in two big categories: (a) increased flexibility in groupware by groupware applications and (b) increased support of dynamism by groupware technology.

Having these two categories of requirements we tried to define groupware and have an image of what current groupware technology consists of. Since, there is no widely accepted definition of groupware and the term usually means different things to different people, we tried to identify the various categories of groupware applications. Through the presentation of these categories we formed a picture of groupware's scope and we were able to identify the major aspects of current groupware technology: communication strategy, co-ordination, distribution, scalability, openness, non-functional characteristic (e.g. security and fault-tolerance) and web exploitation.

The identification of groupware aspects allowed an interpretation of the two categories of Virtual Enterprise requirements. So, increased flexibility translated into support for the whole range of every groupware aspect, and increased dynamism translated into on the fly exploitation of flexibility. The presentation of groupware categories, then, provided some examples of groupware applications that move towards these two goals. But, we could see that the current approach in groupware development is an impediment in this move. A new approach of viewing groupware as framework for composing services based on open widely accepted protocols could lift the barriers imposed by the current approach. Some projects and products seem to realise that and move towards this direction.

Finally, we identified four technology developments as potential driving forces towards the new approach in groupware development. These technologies are:

a. the World Wide Web,

b. Java,

c. distributed object frameworks, and

d. compositional systems and component architectures.

The special characteristics of each of these technologies that form the basis for they potential are described and the necessary steps forward are identified. The significant remark on these technologies is that they realise their influence in groupware and try to add features that will make their deployment by groupware technology easier.

Summarising the discussion, the Virtual Enterprise vision although it is not yet immediately feasible seems to be realistic. The "groupware of the future", that will support the Virtual Enterprise, will be based on the combination of the already accumulated knowledge in groupware development with the new view of groupware that current technologies support.

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