An analysis of IT platform and organizational requirements for multimedia cooperation on the Internet - a case study on the international office of the future

S. Dustdar

Center for Informatics Services, University of Art

Hauptplatz 8, A-4010 Linz, Austria, Tel: 785173, Fax: 783501

e-mail: dustdar@khsa.khs-linz.ac.at

Abstract

Office systems have gained a state of maturity in handling strictly defined business processes. Research on the 'international office of the future' shows that they are inappropriate for handling cooperation in general and are not well suited for the increasing numbers of multi-side/multi-time/multi-culture workgroups. Recent developments on multimedia systems and networking technology show that using desktop multimedia conferencing for group decision making and cooperative work on wide area networks such as the Internet is possible. In this paper the design, hardware and software requirements and organizational issues in a desktop multimedia conferencing system as a fundamental cooperative tool in the 'international office of the future' are reviewed. This article focuses on a case study on urban planning using desktop multimedia conferencing on the Internet. Further some implications for future research on desktop multimedia conferencing tools are discussed.

Keywords

desktop multimedia conferencing, MBone, CSCW, office of the future, Internet

1 INTRODUCTION

Office systems have gained a state of maturity in handling strictly defined business processes. Research on the 'international office of the future' (IOF) shows that they are inappropriate for handling cooperation in general and are not well suited for the increasing numbers of multi-side/multi-time/multi-culture workgroups (Traunmüller, 1995). Recent developments on multimedia systems, networking technology and their integration with cooperative tools on the Internet show that using desktop multimedia conferencing for cooperative work on wide area networks such as the Internet is possible (Macedonia and Brutzman, 1994). Researchers have often discussed the failure of video to support interpersonal communication (Egido, 1990). In this paper some of the conclusions others have reached about computer-supported communication-, coordination-, and cooperation tools are reviewed. Further the design, hardware and software requirements as well as organizational issues in desktop multimedia conferencing systems will be discussed. Prior to the conference discussed in this paper we participated in several desktop multimedia conferences across Europe to learn about the MBone tools as well as the technical and organizational issues. The focus of this paper is on a case study on urban planning using desktop multimedia conferencing on the Internet.

As Johansen (1988) shows, group work and hence group decision making is a natural way of doing business. Early groupware systems and electronic meeting systems lacked the ability of manipulating multiple media types such as audio, video and textual information in one integrated multimedia system. The merging of workstation technology and real-time computer conferencing has had a significant impact on CSCW and group decision making and lead to the term 'desktop conferencing' (Rodden, 1993). Research on early multimedia conferencing systems such as developed at AT&T Bell Laboratories (Ahuja et al., 1990), Bellcore (Root, 1988) or NEC (Watabe et al., 1990) had as their aim the provision of the facilities found at face-to-face meetings with remote groups. It is generally accepted that computer-supported decision making and communication results in many changes in communication patterns (Gaver et al., 1992; Hatcher, 1994), greater task orientation (Niemic, 1984) and shorter meetings (Harkness and Burke, 1984). Regarding the video component, Ishii et al. (1992) point out the importance of gaze awareness, the ability to monitor the direction of someone's gaze and thus the focus of the attention. Similar results were found by Heath and Luff (1991) and Mantei et al. (1991).

Short et al. (1976) caution the results found through laboratory settings and propose that they should be validated through case studies with true situational factors, such as real-life relationships and complex tasks. The case study presented in this article is not a laboratory setting of desktop multimedia conferencing. It reviews 'real' problems encountered before, during and after the conference and should be a valuable contribution towards the understanding of desktop multimedia conferencing and decision making processes through computer support.

2 CONFERENCE FRAMEWORK

Preparation and realization of desktop multimedia conferencing for cooperative office work has two aspects, the technical setup procedure and organizational issues which will be discussed in the following sections.

2.1 Technical requirements

The requirements for highly-integrated desktop multimedia conferencing on a packet-switched network, i.e. the IP (Internet Protocol) based Internet, can be divided into three categories:

1. Support for packetized data transport and routing of data packets by the network software.
2. Support of encoding audio and video streams and reassembling of audio and video packets into continuous audiovisual output. This should be accomplished by specialized hardware or software codecs (coder/decoders).
3. The control and application software should be integrated into the graphical user interface, i.e. the widespread X-Window system.

Network and transport protocol requirements

This article concentrates on the usage of packet switched networks. In a packet switched network, transmission lines are not reserved in advance, the data is sent in small portions, called datagrams, from the sender to the receiver or to a group of receivers. On the path from the sender to the receivers, the packets are forwarded by special machines, called routers. The packet switching approach is sometimes called connection-less or state-less delivery service, in contrast to the connection-oriented circuit switching method, where lines are reserved for the connections.

The world-wide Internet is a large packet-switched network, but it is widely believed that real-time traffic requires a connection-oriented network service. Recent research and experiences (Clark et al., 1992; Jacobson, 1994) revealed that packet switching, compared to circuit switching techniques, is not less efficient in meeting real-time scheduling and delivery constraints. The weaknesses of packet-switched networks, namely the variation in the delay of each packet, usually called jitter, and packet loss due to occasionally packet dropping by routers can be diminished by buffering of incoming packets and the usage of loss-tolerant coding methods. The network jitter results in variation of packet interarrival times and out of sequence packet delivery. The audio replay at the receiver without taking into account jitter will at least be hardly understandable. Network jitter is removed by buffering the incoming data packets at the receiver and replaying the signal with some delay. The chosen coding method for audio and video data must be able to reconstruct the data with minimal distortion despite of packet loss.

Due to the nature of video- and audioconferencing events, the need for distributing data to a group of participants, called multicasting, arises. Multicasting of packets differs from unicasting, where datagrams are delivered from one sender to one receiver, and broadcasting, where datagrams travel from one sender to all receivers, in a way that datagrams are only delivered to members in a so called multicast group. To manage dynamically changing multicast groups and individual memberships within these groups, the Internet Group Management Protocol (IGMP), which fits into the existing suite of Internet Protocols, has been suggested and implemented (Deering, 1989). Multicast is not only the native form of delivery in group communication, it also makes efficient use of the network resources as for a number of n receivers it is not necessary to send n copies of each packet, only one copy of each packet is multicasted and only duplicated at branches along the routing path.

The members of one multicast group are allowed to be located anywhere in the Internet. Packets are sent to a multicast group, i.e. audio packets in a conference, are routed to each group member regardless where he is located geographically. The routing of multicast packets is not yet implemented in most of the router boxes, therefore a virtual network connecting multicast-routers was set up. This virtual network is called the Multicast Backbone (MBone) of the Internet and connects more than 10,000 users on 1500 networks in 30 countries. The multicast-routers are connected through tunnels, where multicast packets encapsulated within normal IP packets are being

forwarded. A multicast-router can be a production router, e.g. a Cisco router, or a workstation class machine configured for the routing of multicast packets. Figure 1 shows the urban planning conference relevant part of the MBone. The squares represent multicast-routers involved, one at the University of Art at Linz, one at the Austrian Network Operation Center in Vienna and one at the Archlab in Vienna. ACOnet stands for 'Austrian Computer Network'. Multicast packets normally travel along the primary tunnels from Linz to the Archlab Vienna via the ACOnet router and vice versa. If the ACOnet router fails, the connection is established using the backup tunnel.

Figure 1 Conference view of the ACOnet MBone.

Each tunnel is associated with a metric and a threshold parameter. The metric counts for routing decisions, a numerical larger values denotes a more expensive path, e.g. a backup tunnel should have a higher metric than the primary path. The threshold is used for scoping of packets, each router compares the packets time to live (TTL) against the tunnels threshold and forwards the packet only if the TTL exceeds the threshold setting. Additionally every multicast router decrements the TTL by one (Casner, 1993).

Desktop machine requirements for cooperative multimedia work

The real-time processing of video and audio data requires adequate processing power, which is offered by workstation class machines. On most workstations Unix derived operating systems are in use, so research activities have focused on these machines. The necessary operating system kernel extensions have been implemented into the most common operating systems by the vendors, like Solaris, Irix and Nextstep. For BSD Unix derived operating systems, kernel modification source code and instruction is freely distributed (Thyagarajan and Deering, 1994).

Most workstations are equipped with audio capabilities, e.g. a build-in speaker or line-out plug, a build-in microphone or line-in plug and device driver software. For video capture a frame grabber board and a video camera is additionally required. The viewing of the video sequence requires a graphics display. Audio encoding and decoding is usually done in software. Video encoding can be done in hard- or software, decoding is usually done in software. Hardware encoding boards are expensive, so encoding on powerful workstations is often done in software. Figure 2 shows a common configuration for a desktop multimedia conferencing system.

Figure 2 Desktop multimedia conferencing system.

Common coding techniques are Pulse Code Modulation (PCM) for audio, which results in a bit rate of 64 kBit/sec for 8 Bit resolution audio sampled at 8 kHz. The packet overhead, resulting from the address and control information inserted into the packets, raises the bit rate to 75 kBit/sec if the Real-Time Transport Protocol (RTP) is used (Schulzrinne et al., 1994). The RTP adds timing and sequencing information into the packets, which is used to reduce distortion caused by network jitter and packet loss. For the urban planning conference we chose a rate of 64 kBit/sec, although lower audio data rates are possible, due to the reasons discussed in the next section.

For video coding a commonly used value for the data rate is 128 kBit/sec. To reduce the impact on the network one is free to choose a lower rate, i.e. 66 kBit/sec have been used in the described conference. These extremely low rates are achieved through data compression techniques. The methods of video compression implemented in the video tools we used are based on frame prediction, motion estimation and transform coding techniques.

One disadvantage of such a low bandwidth allocation is the low frame rate in the order of magnitude of 2 frames/sec, depending on the motion in the picture. A quick changing image sequence results in unpredictable frames and thus an increased data rate, as frames have to be coded without prediction. Fortunately, in a conference session quick scene changes occur seldom, the small movements of the conference participants can be effectively coded using motion estimation. In motion estimation a displacement vector related to a block of pixels in the previous frame is coded rather than the image content itself.

2.2 Organizational context

Conferencing events on the Internet can be divided into two categories, open conferences where everybody can join in, and conferences for closed groups. Open conferences are usually announced a few weeks ahead by sending an electronic mail to the appropriate mailing lists (Casner, 1993), i.e. the Mbone-AT mailing list, which has been set up to coordinate the Austrian (AT) Mbone activities, in our case. Before the conference actually starts, an announcement in the session directory (sd), an X-Window application program, is made (McCanne and Jacobson, 1994). The sd entry is flooded, according to the conference scope, over the Internet and contains the conference name, a short description, multicast group addresses, coding format, scope and extent of the conference. The conference extend can be any combination of audio-, video and whiteboard-sessions.

The scope of the open urban planning conference, a combined audio-, video and whiteboard-session, was limited to Austria, which was guaranteed by choosing an initial TTL of 40 for all

packets. The multicast-router connecting Austria via Paris to other countries has a threshold of 64 on the Vienna-Paris tunnel and therefore refuses to forward packets with TTL lower or equal to 64 along this tunnel.

An alternative to session announcements by sending an e-mail to a list is to use World-Wide-Web (WWW, W3) based forms. The WWW approach provides a better overview on conferences and collision detection, e.g. two conferences at the same time with overlapping scope, could not be registered automatically in a WWW based form. Another feature of the described desktop multimedia conferencing technology is the possibility of ad-hoc conferences, which has been performed for a few times by the system administrators ahead of the actual conference.

Beyond the announcement of the conference training of the conference participants and preparation of the desktop multimedia conferencing facilities is necessary. Specifically the conference participants have to know to use the tools, i.e. how to mute the microphone in the audio tool vat (Jacobson and McCanne, 1994), how to resize windows in one of the video tools like nv (Frederick, 1994) or vic (Jacobson, 1994) or how to load postscript slides into the whiteboard wb (Jacobson and McCanne, 1994). Additionally the surrounding of each participant has to be adjusted, i.e. avoid background noise, locate microphone, speakers and camera close to the human interactor and provide natural lighting conditions. The peculiarity of the urban planning conference was that in Linz a group of people joined the conference, the special setup which was necessary therefore can be seen in Figure 3. Finally one important aspect is to remind the conference participants to take care on discipline, i.e. not to speak concurrently.

Figure 3 Room layout for group participation.

During the conference one participant should act as moderator responsible for the conference schedule, serving of speak requests and trouble shooting. The trouble shooting in fact is the responsibility of technical staff. If the conference is transmitted to an audience using overhead

projection, as it was in our case, additional staff is necessary. Speak requests from the audience has to be coordinated by this person.

After the conference is closed by the moderator a few tasks remain to be carried out by the conference organizers. A very useful information, especially for people planning a conference, might be an electronically recorded conference protocol. We will do that using the WWW infrastructure. Conferences of wide interest should be retransmitted, especially if a conference is held in a different timezone, i.e. conference events originating in North America should be retransmitted at a time suited for Europe. For individual access it is possible to make conference recordings accessible from a Media-On-Demand server (MOD), as the one located in Sweden (Klemets, 1994). Table 1 summarizes actions to be taken before, during and after a desktop multimedia conferencing conference.

Table 1 Actions to be taken in desktop multimedia conferencing

<i>before</i>	<i>during</i>	<i>after</i>
Announcement	Moderation	Report
Parameter settings	Trouble shooting	Retransmission
User training		Media on demand

3 COLLABORATIVE WORK ON URBAN PLANNING

After discussing the conference framework, this section concentrates on the conference itself. The conference was jointly organized by the Center for Informatics Services at the University of Art and Industrial Design at Linz and the Institute of Urban Planning at the Technical University of Vienna and lasted two hours. The distance between these two sites is 250 kilometres. The purpose of the conference was to discuss issues of urban planning and urban development. Since the conference was announced on the MBone, interested people with Internet-MBone access could participate in the conference as well. At Linz there were five active conference participants, who were members of the municipal authority of Linz, two system administrators, one camera man and several interested students. There were three multimedia workstations each equipped with video- and audio facilities for the active conference participants in Linz. In Vienna there were five active conference participants who presented new projects of urban planning and development in the city of Linz, two system administrators, one camera man, one conference moderator and several interested students. The conference was recorded by Austrian Television and some parts were shown on the same evening, since this was the first national multimedia conference on the Austrian part of the Internet.

The Institute of Urban Planning had prepared digital material on urban planning and wanted to present the plans and digital models to the municipal authority of Linz. These plans and models regarded some buildings and streets of Linz. The purpose of the conference was to present the work done at the Institute of Urban Planning and to initiate a decision making process about the implementation of the presented models in the real world. Following the framework presented in Table 1, we will discuss some problems regarding the desktop multimedia conference.

Before the actual conference we witnessed some technical problems. Several times the tunnel between the two sites went down and so we decided to configure an alternate route (tunnel) between Linz and Vienna in case the main tunnel breaks down during the conference. We prepared a second conference room in which students could participate actively in the conference. The room was equipped with a multimedia workstation connected to the Internet-MBone and to a display unit

which projected the workstation screen. Due to the fact that the conference was multicasted in Austria and we did not want to cause too much traffic on the national network, we decided to limit the bandwidth to 66 kBit/sec. Figure 4 shows one conference participant in front of his multimedia workstation.

Figure 4 Conference participant with multimedia workstation.

During the conference we had several problems. The first problem was that the active conference participants had no experience regarding desktop multimedia conferencing. Hence the system administrators had to handle the switching between the used software. After one hour the Austrian part of the Internet, AConet, went down and hence no transmission was possible. The time - five minutes - which was needed to fix the problem in Vienna, the conference participants in Linz used to discuss the issues raised during the conference. Since the conference participants had no time to discuss the issues amongst themselves during the conference, they seemed to be quite happy to have the possibility to talk and not being 'broadcasted' all over Austria.

After the conference we interviewed the conference participants. They liked the idea of desktop multimedia conferencing because the municipal authority needed to discuss urban planning issues very often with the researchers in Vienna. In the past they had to travel to Vienna and these journeys slowed down the decision making processes. The second positive point which the conference participants mentioned was the fact that it helped the municipal authority to save travel expenses. Johansen questioned the assumption that conferencing would reduce travel (Johansen, 1984; Johansen and Bullen, 1988). We found that it was the subjective feeling of conference participants that they saved a lot of time and hence travel costs and they did not necessarily calculate the real costs and compare. They did not regard this desktop multimedia conference as a substitute to face-to-face meetings. The participants wanted to use the system for their convenience to be able to hold meetings more often. Except the five minutes breakdown of the network in Austria we had no technical problems. Since the municipal authority used conferencing technology for the first time, we asked them how they experienced the audio and video quality. The system administrators decided to limit the video bandwidth to some 2 frames per second and keep the rest for audio and shared whiteboarding, which they thought would be more important than full motion 25 frames per second 'talking heads'. The reason the system administrators limited the bandwidth for video was that they wanted to keep bandwidth for shared data such as city plans and 3-D computer generated models. Some tests before the conference had shown that if the transmission of the conference was with top video quality, a lot of data packets would get lost. This was a point of critique by the municipal

authority. In spite of the fact that there was no audio packet loss, the conference participants criticized the jitter in the video transmission.

4 RESEARCH AND DESIGN STRATEGIES FOR THE IOF

To summarize, it is very important to train the prospective users of desktop multimedia conferencing systems regarding the usage of software and to give guidelines of usage of the conferencing tools. In some situations it was not obvious to the participants that if two participants talked at the same time some audio packets could get lost. The second proposition is that prospective users of desktop multimedia conferencing systems should have a clear idea of what quality they can expect. Particularly we witnessed a high degree in user expectation regarding video quality. The video quality needs to have a minimum frame refresh rate of 15 frames per second to give the impression of real full motion video. This refresh rate can only be achieved in high bandwidth networks.

The conference participants needed some 'private-time' during decision making processes to discuss issues amongst themselves, without the feeling of being 'broadcasted'. Hence we propose the implementation of the functionality to direct video and audio streams to certain users within a decision making group and to implement features in software which shows the remote participant that the local site has switched to mute and therefore is not able to receive audio or video. This would help users to have a feeling of privacy and enhance security. Regarding security and privacy one major problem on the MBone is that it is only possible to configure multimedia conferences reaching the site of the organisation, a region or the world but it is not possible to configure a multimedia conference as a closed conference. Everyone within the scope of the TTL-value is able to receive and send packets. There is no anonymity and the only security measure is that conference participants can see through the e-mail address (or alias), who joins a conference. This restricts the use of multimedia conferencing on the MBone. Interested organizations who have full Internet access can use the MBone for their internal multimedia conferences between distributed sites but they will not be private. Table 2 summarizes the organizational lessons we learned during this desktop multimedia conference on the MBone and contains some proposals for future research regarding the integration of desktop multimedia cooperations tools into standard office tools.

Table 2 Organizational lessons learned in MBone desktop multimedia conferencing

<i>before</i>	<i>during</i>	<i>after</i>
check user expectations	leave/join mechanisms for participants	integration of results into standard user tools (organizational memory)
software training	private conversations with some conference participants	retrieval of
explain multimedia conferencing 'rules'	integration of conferencing tools with user tools	conference results

Research on desktop multimedia conferencing and its application in decision making processes is interlinked with other information processing, communication and coordination activities (Angehrn and Jelassi, 1994; Chin et al., 1991). Desktop multimedia conferencing is not a substitute to face-to-face meetings, but enables and - as we saw in the case - forces people to change decision making processes and communication patterns. Daft and Lengel's (1984) theory of information richness

states that face-to-face meetings have the highest degree of media richness. We argue that desktop multimedia conferencing enables decision making processes and communication processes on a new dimension. The question is not if desktop multimedia is about to substitute face-to-face meetings, but which 'new qualities' or 'opportunity enhancements' (Johansen, 1984) it can offer. For productive use of desktop multimedia cooperation software on the Internet, MBone tools need better integration into standard Internet tools such as WWW browsers. Integration of synchronous communication- and cooperation tools into the WWW infrastructure is a key to widespread use of desktop multimedia cooperation in the Internet.

Further research needs to be undertaken regarding design and implementation issues of desktop multimedia conferencing systems in decision making processes. The author is convinced that this research area needs interdisciplinary efforts since multimedia and CSCW are interdisciplinary fields. We expect new impulses to the emerging field of multimedia systems and propose joint research of the research communities of computer science, communication research, organization design, CSCW and information systems. As Ishii et al. (1994) state, we are interacting not *with* computers, but *through* computers.

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6 BIOGRAPHY

Dr. Schahram Dustdar is head of the Center for Informatics Services at the University of Art at Linz, an associate lecturer for multimedia systems at the IS-Department, University of Regensburg in Germany and a visiting professor at the MIS-Department, University of Tuscon, Arizona during 1996. He heads the Austrian MICE National Support Center (Multimedia Integrated Conferencing for European Researchers), a research project by the European Union. He co-authored the book 'Multimedia Information Systems' (Prentice Hall, 1996). He was a post-doctoral visiting fellow at the IS-Department at the London School of Economics during 1993/94.