Recent Activities in the MICE Conferencing Project

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Abstract

The MICE project has been piloting multimedia conferencing (audio, video and shared workspace) over the Internet in Europe, with links to the US, over the last two years. In this paper, we summarise our experience and discuss recent developments in several areas: tool improvement, their use over ISDN and ATM, security, management and control, multimedia servers, new application areas and a recently created network of support centres.

1 Introduction

The MICE project has been piloting multimedia conferencing over the Internet in Europe, and interworking with the US. A suite of multicast conferencing tools are now available in the public domain, from developers in the US and in Europe, which allow the use of audio, video and shared workspace from desktop workstations and conference rooms. The partners in the current project are: University College London (Co-ordinating Partner, UK), Universite Libre Bruxelles (Belgium), INRIA (France), GMD and RUS (Germany), the University of Oslo and Telenor (Norway), KTH and SICS (Sweden). In addition, UKERNA (the UK academic network provider) is providing valuable resources and feedback as a sponsoring partner. The motivation and aims of the project and early developments have been described in previous papers [1], [2].

Over the last couple of years, there have been further developments in multicast conferencing - many positive, but also a few detrimental ones. The positive ones are improvements in the technology - not only of the multimedia tools themselves, but also of the various activities around conferencing (e.g. servers, security, management, booking). A worrying observation is that the provision of network connectivity and bandwidth has in some areas not kept pace with the increase in traffic load. As a consequence, some sites perceive conferencing sessions to be less successful than they were two years ago.

The MICE project has successfully broadened the user base of multicast conferencing by demonstrating new applications of the technology, and by setting up a network of National Support Centres to distribute and support multicast software tools. Many more types of Wide Area Network (WAN) have become available; though not all of them have quite met their full promise yet.

Here we will discuss the recent developments in several areas: Tool Development (Section 2), Network Support (Section 3), Conference Control (Section 4), Security (Section 5), Multimedia Servers (Section 6), Network Monitoring (Section 7), New Applications (Section 8), National Support Centres (Section 9).

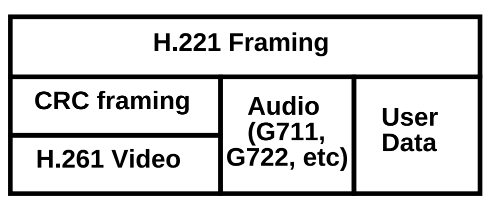
2 Tool Improvements

Multicast conferencing tools have been continuously improved by their developers over the past two years, and new tools have appeared. There is now a suite of tools available in the public domain, offering users a choice of audio, video and shared workspace tools.

The multicast backbone of the Internet (Mbone) [3] has grown over the past 2 years from about 200 sites to some 1500 sites today. In the process, it has become more organised, but also is starting to show some scaling problems. It is clear that the existing flat Mbone will not continue to scale, and that a hierarchical approach will be required. Work is in progress in the IETF inter-domain multicast routing working group to address these problems. It is hoped that this work can be deployed before the Mbone starts to become unusable.

2.1 Transport

The normal transport protocol for CCITT H.320 family teleconferencing applications is H.221 [4]. However, H.221 is unsuited to wide area internetworking for a number of reasons, including its total intolerance to packet loss.



The normal transport protocol for wide area internet conferences in now RTP [5], which is the product of the Audio-Video Transport working group of the IETF. Many of the tools mentioned below have been ported to work above RTP.

The CCITT T.120 [6] multi-party conferencing extensions to the H.320 protocol suite for conferencing are starting to be adopted by a number of industry consortia for wide area conferencing. It is currently not clear which parts of the T.120 suite will be used. However, the centralised model assumed by T.120 makes the protocol difficult (and possibly inappropriate) to apply to Mbone conferences. We expect to address the issue of gateways between the two in a future project - but not in MICE.

2.2 Video

For video, we have mainly used software codecs with three tools: nv [7] from Xerox, IVS [8] from INRIA and VIC [9] from Lawrence Berkeley Laboratories (LBL). These support several video compression algorithms, but the principle one used in MICE is the CCITT H.261 standard [10]. As workstations have become more powerful, and the video cards on the workstations have improved, these tools have improved in terms of the quality and frame rates that are achievable. In addition, some work has been done to make video more tolerant to packet loss. As an example of the last, Van Jacobson has shown that using only intra-frame encoding in H.261 (although still only sending the macroblocks that change) results in better quality video for any significant loss rate and only slightly increased data rates for the same frame rate, in addition to almost halving the processing cost of the video encoder.

We have almost stopped using external hardware codecs. One reason is that a number of them are rather inflexible, and support only the H.221 transport layer; this is very difficult to support on many workstation hardware interfaces (I/Fs) at high speeds. In addition, few people are bothering to purchase the separate codecs, principally due to their cost.

A number of H.261 codec cards for PCs and workstations are starting to become available, but they cost significantly more than video framegrabber cards, and usually can only decode a single video stream in hardware. In addition, most of these cards are not sufficiently flexible to produce intra-coded video without sending the entire picture with each frame, which is unnecessary and inappropriate.

2.3 Audio

The most widely used audio tool for Mbone conferencing is vat [11]. Whilst vat has been constantly improved over the past two years, audio quality is still a problem in many conferences. Since insufficient audio quality is the most serious threat to the success of current multicast conferences, the MICE project has dedicated considerable resources to diagnosing and addressing audio problems.

Sometimes, bad audio is due to the peripherals (microphones and speaker boxes), whose quality varies considerably. The conferencing environment (echo and background noise) can cause more problems than newcomers to conferencing realise, particularly in conference rooms. Incorrect handling of tools by inexperienced users (setting of volume levels) also causes problems. All these can be addressed by users at their own sites.

The most persistent audio problem, however, is due to packet loss as a result of network congestion. Since this problem requires high-level concerted action, it is unlikely to be resolved in the near future. MICE partners have therefore put effort into counteracting the effects of packet loss on audio quality. One of the approaches, in which packet loss is repaired at the receiving end is described in the paper by Hardman et. al. in this volume [12].

2.4 Shared Workspace

Many tools have been investigated for shared workspaces over the last couple of years.

Tools for shared drawing have been developed by SICS (Multidraw) and INRIA (Mscrawl). These tools are not really ready for service use yet. There is a good discussion of the comparison between the systems in a MICE deliverable [13]. The most commonly used joint working tool is still wb [14] also from LBL. Whilst it is still the best developed such tool, it is not optimal for all shared workspace tasks.

The University of Oslo has been developing an electronic whiteboard to be used in distance learning. This is a combination of hardware and software designed specifically for distance teaching in a classroom environment

During the regular Mbone meetings held by the MICE partners, we have found it very important to have joint editing of documents. Although several such shared editors have emerged from the CSCW community, they all suffer from scaling problems which restrict their usefullness. To address this, we have developed one such network text editor (nt) [15], which allows scalable shared editing of the same document between Mbone sites.

The systems use many different paradigms for the shared workspace, some of these scale as one moves to tens or hundreds of sites; some do not scale very well. In general centralised approaches do not scale to more that a handful of sites. In contrast entirely distributed applications such as wb and nt, which use multicast and provide their own carefully designed protocols for dealing with inconsistency and retransmission can scale to hundreds of simultaneous users.

3 Different Networks

3.1 Internet in Europe

The MICE project has principally concentrated on Internet based conferencing. However this has taken many forms. The conventional 2 Mbps packet-switched European research networks have become much more widely deployed - but also increasingly congested. Most Mbone based conferences do not normally generate run at more than 512 Kbps, and often run at considerably lower data rates. Thus it should be possible to accommodate a few of these on the 2 Mbps Europanet facilities provided they are co-ordinated. However, links are now over-loaded, so that traffic losses of 10-40% are very common for multicast traffic on some routes. Whilst in many countries, and particularly in the UK and Scandinavia, national bandwidth has kept pace with demand, this has not been the case in some countries, most notably Germany. In addition, even between countries with good national networks, the international bandwidth has not increased sufficiently quickly to keep pace with increasing demand, particularly with that generated by the World Wide Web. It is planned, with partial support from the European Commision under the auspices of the Telematics programme, to upgrade the European research network infrastructure. However this upgrade is not expected before 1996.

In the UK, there are now 54 sites on SuperJanet's IP over SMDS service [16], which performs extremely well for real-time traffic and Mbone usage. In contrast, the SuperJanet ATM pilot in the UK, which was started around the same time is still not really usable for this traffic, due to a combination of equipment performance and configuration and interoperability problems. However, in the medium term these problems should be resolved and we hope this will give us higher bandwidth than is available from SMDS.

3.2 ATM

Amongst the MICE partners, access to ATM national networks is so far available only to UCL. Internationally, the European PNOs have set up a large scale pan-european ATM pilot (EATMP). The MICE project has been using this pilot to establish Mbone links between some of the MICE sites.

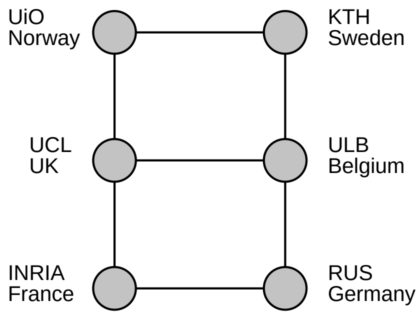
Whilst some MICE sites have direct ATM connectivity to the PNO pilot, UCL will have ATM access via the SuperJanet ATM pilot and a couple of sites have access provided via SMDS. However, in all cases we use this to provide IP connectivity.

Moving the Mbone technology to these ATM networks requires a considerable amount of setup of the underlying ATM circuits; because of the lack of multicast capability inside the national research networks or the EATMP, we are constructing an IP multicast overlay consisting of IP tunnels over ATM PVCs. Currently, each VC has to be manually configured at every switch, and careful setup of ATM traffic shaping is required at the borders to the ATM network in order for the traffic not to be policed out in the EATMP. In particular, at the time of writing, the traffic shaping in most ATM host cards is insufficient for this purpose.

As we wish to configure an experimental multicast backbone rather than a replacement for the European Mbone, we have to interconnect with the existing Mbone at multiple points. Currently, this is restricting our choice of multicast routing technology to DVMRP. However, we have the added restriction that we are not supposed to carry "production" Mbone transit traffic over these links. Unfortunately DVMRP (or any other single metric algorithm) is not really sufficiently configurable for this purpose, and some impact on "production" Mbone routing is inevitable. To allow us to experiment with higher rate multicast than the 512Kbps that the existing Mbone is engineered for, we have been attempting to limit the fanout from any of these ATM Mbone multicast routers to 3 tunnels over the EATMP and one local tunnel.

We have found the use of the national networks and the EATMP quite feasible, and the performance good - once we have learnt the idiosyncrasies of using the ATM technology. Currently the networks require knowledge of the maximum traffic required on each virtual path (VP), and can police only this maximum; thus the access networks must ensure that this maximum is not exceeded - otherwise traffic will be discarded. However, learning the necessary shaping parameters can be a long and tortuous process, and the prohibitive expense of ATM analysis equipment can make analysis of problems extremely difficult.

It would require a separate paper to detail our experiences with the use of ATM technology for MICE. In the small scale it has been very successful; a four site demonstration was made for the G7 summit in Brussels in February 1995, and a demonstration seminar was held for the French Prime Minister early in March. These demonstrations included Belgium, France, Germany and the UK - and involved connecting in the German SMDS over ATM access via UCL to the normal ATM access. We are still bringing up a larger numbers of sites during 1995. The planned connectivity for summer 1995 is shown below.



Planned International ATM Mbone Connectivity for MICE

3.3 Traffic Prioritisation

We have been experimenting with providing resource allocation to ease congestion at gateways and on the links between them. One of the systems is called class-based-queuing (CBQ) [17] - which was discussed at INET two years ago. This is being piloted on certain portions of the MBONE - particularly the link between the UK and the US. It requires further installation of equipment on the US side of the link, but should improve considerably the performance of the link for the multimedia traffic. Eventually we expect that RSVP will allow such reservations to be performed routinely on congested links - but this is still some time away from wide deployment.

3.4 ISDN usage

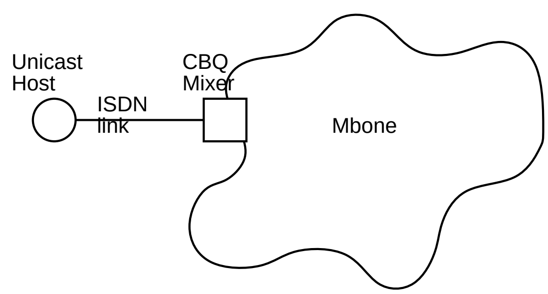
While the research networks have become increasingly higher speed and more prevalent, at least in some European countries, narrow-band ISDN access remains important for industry; we have started providing national, and sometimes international, multi-channel ISDN access via ISDN relays. Several of the MICE sites have put in Primary Rate ISDN facilities (UCL, KTH and RUS have them operation).

We have had considerable difficulty in getting the ISDN facilities into production use. Some groups have wanted to use PNO-supplied workstations based on the videophone offerings as part of MICE. Because of their use of H.221 as a transport protocol (cf. section 2.1), it was difficult to support these in the Unix workstations used for most of the MICE activity. Moreover, these workstations usually work only up to 128 Kbps - which gives rather poor quality facilities. The early work in interworking between the ISDN and Internet use for multimedia conferencing is discussed in [18].

Recently we have installed two types of equipment which has become available. The SparcStation workstations we use for much of our work now have ISDN interfaces which operate using the PPP protocol [19] at the transport level at 64 Kbps. However, this is not sufficient bandwidth for many conferences. We have also installed primary rate IP over ISDN routers at a few sites; these operate at up to 2 Mbps (30 channels), and any number of channels can be bonded together. In principle, these devices should solve our problems for intermittent Mbone connectivity. However, they have often failed to live up to their manufacturers claims for performance or configurability.

We are currently investigating the use of Class Based Queuing gateways to allow ISDN links to operate at close to their link capacity without bursts in video or whiteboard traffic either causing new links to open unnecessarily, or causing unnecessary audio packet loss.

It is clear that the existing DVMRP multicast routing software is not sufficiently interactively configurable to conveniently support Mbone on demand links.



Using a CBQ mixer to connect a unicast host to an Mbone conference over ISDN

4 Conference Control

Most of the conferencing on the Mbone and in the MICE project has been without explicit conference control. The Mbone makes possible the lightweight session model, where all sites are equal, and any site can send if it wishes - sites causing trouble are simply muted at the receiver. Lightweight sessions also have the property that their membership is defined by the membership of a multicast group (and possibly by the possession of an encryption key), rather than by an explicit membership mechanism. It is these properties that help Mbone conferences to scale to user groups that are larger than any other form of conferencing short of broadcast.

However, there are a number of occasions when this equality can be counter productive, and where a more cooperative (and possibly restrictive) conference control scheme would be useful. An example might be to trade limited video bandwidth off between a speaker and questioners under the control of a conference chair.

There is much discussion in the MMUSIC group of the IETf and elsewhere about how such conference control should be implemented, but the Mbone community has not yet decided on a solution. The contribution from the MICE project in this area is the Conference Control Channel Protocol (CCCP, [20]), which is a multicast based foundation upon which detailed conference policy can be implemented.

The area of meta-conference management (the advertising and creating of conferences) is also starting to undergo some changes. For the past two years, this has been done solely using the SD tool from LBL. The MMUSIC group of the IETF is now attempting to extend and standardise this protocol as the Session Description Protocol (SDP), with the intention that conference descriptions can be communicated, not just by sd's multicast announcement, but also by email, WWW and other means.

5 Security

It has long been agreed that the provision of confidentiality in multimedia conferences is an essential attribute. Many of the tools of section 2 already have the capability of being encrypted already in the code. There are, however, sometimes government restrictions on the export both of such code and on descriptions of how it is used. The activities under MICE are therefore to encrypt many of the interchanges, and to publish details of how the encryption is done - with the intention that many organisations who might not be permitted to export such code will still implement it. In addition, we are working on providing the infrastructure for key distribution.

5.1 Provision of Confidentiality.

We have started introducing confidentiality into conferences through the use of encryption. We have retrofitted encryption using DES [21] on certain of the tools to which we have source code, using our own standards compliant encryption routines developed in the context of the PASSWORD project [22]. UCL has implemented the encryption for VIC and is doing so for its own audio tool BAT [12]. INRIA is providing similar facilities for IVS. To allow different keys lists per media to be easily distributed UCL is also adding encryption to the session announcements of the Session Directory.

To ensure interoperability of conference tools with encryption it is vital that key transport and processing operations are accurately defined. UCL is publishing its exact encryption mechanisms in the IETF [23]. This will be published more widely, after the UCL proposals have been agreed in the IETF arena. We appreciate this is not a very satisfactory method of achieving interoperability or of producing common tools. However, we do not yet see an alternate approach in view of the current situation on regulation in this area.

5.2 Key Distribution

The encryption routines of Section 5.2 require a key pair IV/EK to be known to all the participants. There are several ways that this pair can be made known. They can be sent by MIME[24] PEM[22] or announced (encrypted) using the Session Description Protocol (SDP,[25]) of the Session Directory. In either case, only authorised participants of the conference should be permitted to obtain the decryption key pair.

We are still defining the exact mechanisms we will adopt for this key distribution. The simplest is to encrypt part of the SD announcement with another key specific to the group of participants authorised to participate; these will be sent by other means (possibly again PEM/MIME) the requisite decryption key of this group of conferences. An alternate is to send out the keys by PEM/MIME specifically to all authorised participants. There are variants on these schemes which we may well adopt eventually; an example is where a proposed conference is announced by SD, and interested participants are invited to request the keys from the conference organiser. The keys are then returned to those who have both requested the key and been so authorised by PEM/MIME or Secure HTTP [26].

For all the above, it is necessary to send some information securely to authorised participants. These participants can either have circulated their public keys to conference organisers, or may list them in a publicly available directory.

We intend to start using secured conferencing prior to INET. We expect that the mechanisms to be used for key distribution will be modified in the light of experience.

6 Multimedia Server

We have started including a multimedia server (MMS) into the conferences; both the salient features of the design, and early results will be reported at the conference. The main objectives of the MMS are the following:

- To record multicast conference data whose source may be any of the conferees
- To playback recorded material either directly to one user or into another multicast conference;

- To allow users to create their own edits of recorded material, and create their own material for playback;
- To supply a large repository of archive space which is accessible to authorised network users who wish to record or playback multimedia data;
- To allow synchronisation between streams from each source;

In order to achieve the above, a system called the Video Conference Recorder (VCR) is under development [27]. VCR has been designed as a client/server system, in which the server (i) acts as a single point of contact for recording and playback, thus avoiding the use of multiple tools for different media, each of which may have a different interface, and (ii) has access to large amounts of disc space, which saves the user searching for enough space for each recording as is common at present. For this purpose UCL has access to a large (180GB) magneto-optical jukebox donated to UCL by Hewlett Packard as part of their Distance Learning Initiative.

On the client side, there are currently three interfaces; one for recording, one for playback, and one for editing.

The record interface will let the user start a recording of the audio and/or the video for one or many of the source streams, and to add a text description of the recording. The playback mechanism will allow the user to peruse all the online archives, and then to select one or more streams for playback. The editing client will provide sophisticated facilities to edit, annotate, and retrieve sub-items inside a recorded stream.

One of the main design concepts of VCR is the index. These indexes allow access to the source streams in a multitude of ways. The primary index used in VCR is created when a stream is originally recorded. For each source of a media, the incoming data will be saved together with an entry in this index. Each index entry contains a reference to the data, the time it arrived at the recorder, and a reference to some meta-data, which will initially be empty. At the end of a recording, each source will have a stream of data and a stream of index entries. It is the editing client which allows the user to manipulate these indexes in order to gain the flexibility required. For example, the user can add a text annotation to any part of the recording, and VCR will attach this to the source stream in the relevant place in the index by updating the meta-data field of an index entry.

Unlike some other systems designed for the purpose of multimedia recording, VCR provides a unified interface to the users so that recordings of different media can be started together; Moreover, because it is available over the network to authorised users and because a large store is guaranteed to be available for the purpose, remote clients can rely on it. Finally, the system is being integrated with the World Wide Web, so that WWW tools can be used for the retrieval and playback process.

7 Multicast Measurements

In the course of the several of the activities described in this paper, it has been necessary to do extensive traffic measurements. It is now routine that packet loss is measured at each site during a MICE seminar (see Section 8); this allows congestion and error conditions to pin-pointed accurately. We have instituted an extensive measurement activity around many of our uses of the different networks using the rtpmon software written at UCL. With the ISDN, this has helped us identify traffic forwarding limitations in the ISDN gateway; this has led to changes being required in buffering strategies in the gateway equipment. In the SMDS over ATM activity, the measurements have identified some anomalies - for example, one of our links showed a traffic capacity of 1.5 Mbps in one direction and only 1 Mbps in the reverse on a 2Mbps VC before loss rates started to increase; thus allowing identification of shaping/policing problems in intervening nodes.

The measurements have been invaluable in deciding how to route traffic. The results are often not obvious intuitively. For example, a Cisco router has better ATM traffic shaping characteristics than some of our ATM host interface cards; we can obtain better traffic shaping by merely going into, and then again back out of, such a router from one of our ATM switches to another than going through the switch alone.

As part of the design of the VCR of Section 6, there has been extensive measurements of the actual traffic characteristics of the multimedia tools themselves. Ideally each traffic source should present traffic to the network at regular intervals, such that there would be a near constant inter-packet gap. Our measurements show that some tools present packets with varying inter-packet gaps together with bursts of back-to-back packets. When this traffic is introduced to switches with their own buffering problems, traffic loss becomes more likely. With many of the tools, we can only inform the tool developers, and suggest that the tools be modified. With the VCR, however, while these characteristics cannot be totally eliminated in playout, we are using these measurements to carefully design media-specific playout strategies. Another set of measurements are designed to see what is really occurring. in the network by using a reference traffic generator.

8 New Applications

Some new applications have been attempted - seminars, medical operations and interactive art; each is discussed below.

8.1 The Mice Seminars

The International Research Seminar Series [28], started in October 1993, and has been continued on a two-weekly basis between the partners. Running successful seminars still requires considerable resources and effort, as well as suitably equipped conference rooms. The seminars are announced using the Session Directory (SD), and each seminar is publicised to a mailing list giving the author's particulars and an abstract. The speaker is requested also to provide an ASCII or postscript version of his/her overheads, which is read into wb before the talk. Audio is sent using vat, and video with IVS or vic. The audio and wb shared whiteboard are under the control of the speaker or a moderator acting on behalf of the speaker.

During the lecture itself, the audio is run in *mike-mutes-net* mode; this means the speaker cannot be accidentally interrupted. During a question period, vat is changed to *net-mutes-mike* mode, so that any member of the remote audience can ask questions and be answered. This is in lieu of full echo cancellation in the conference rooms, which is often impossible. Video is usually transmitted from the speaker's site and one or two remote audiences in conference rooms.

Full details of the seminars and our experiences with them is given in [28]. Since the time of that paper, several of the MICE participants have redesigned the audio environment and their lighting in the conference rooms to counteract problems observed. We have become even firmer in our insistence of advance testing of the facilities - not least because the recent congestion of the European Internet has made unacceptable levels of packet loss only too common. We have also got into the habit of running a second wb session only for the purpose of exchanging information about the seminar between technicians at the different sites.

8.2 The Medical Workshop

The MICE project demonstrated the potential of multicast conferencing to the medical community by showing two live operations (one each from the Sahlgrenska Hospital in Gothenburg, Sweden and the UCSF Hospital in San Francisco, US) during a workshop on minimally invasive surgery in London on November 11, 1994 [29]. In addition, live video was transmitted from approximately twelve operations and the workshop itself in London to a small audience in Gothenburg. The video either showed the a view of the surgeon operating or the output of ultrasonic scans from endoscope probes inside the body of the patient, or radiographic ones images. The video was comparatively low quality, since only had about 100 Kbps available was available on the day. Nevertheless, the audience was able to follow the operations and appreciated the novel minimal invasive surgery techniques demonstrated.

This type of event requires even more coordination and planning than the research seminars or conference multicasts which the project has been involved with. More cameras and personnel are involved, so more coordination, monitoring, and fast switching is required. Another interesting conclusion was that the really important question in this type of event was whether the hospital itself was equipped to run its operations with video capture in mind. If such facilities exist, as they did at the London hospital, the transition from local presentation in a near-by lecture room (using high-bandwidth fibre links) to multicast presentation took little extra effort. A first attempt at multicasting from the hospitals was made only the day before.

It should be noted that minimally invasive surgery is a field that lends itself particularly well to multimedia conferencing for teaching purposes, as it is inherently a visual process, and as endoscope video cameras are routinely used. In some applications, the use of video is non-essential - in surgery it is vital, and so this is a particularly testing application. In should also be noted that this is an area where privacy and hence security is essential, and so encryption should be used to ensure confidentiality.

8.3 The ArtAids Application

We have used the technology in an interactive art application [30]. In that activity, the picture themselves are put on a video server, and artists, art students, or the public can browse the collection. In the official opening of the project, the artists from London, Melbourne, Stuttgart, Stockholm and Sydney. All described the meaning of their pictures to the distributed viewers. This project will culminate in a further such conference on World Aids Day on a much bigger scale at the end of 1995.

In that application, the pictures themselves were produced using Photoshop, mainly with Macintosh computers. The server was put up as part of the WWW, and the pictures were shown using wb. In this application, much better picture resolution was needed than in most of the seminar applications. It was particularly important that the picture quality be good; it would have been quite inadequate to use merely a video camera. Partly the pictures were actually produced electronically, partly they were scanned in with high resolution scanners. The use of wb with these images meant it might take longer to transmit the high quality image, but we were able to use the modest 30-40 Kbps available to Australia.

9 National Support Centres

In order to distribute and support the multicast tools to a wider user community, a network of MICE National Support Centres (MICE-NSCs, [31]) has been set up in Europe. Apart from the countries represented in the MICE project, 6 other European countries now have such a MICE-NSC. Apart from testing public-domain multicast conferencing tools and porting them to a range of hardware platforms, they provide documentation, starter guides and help desk facilities. Distribution is mainly through the WWW, but general information and starter material is available in printed form for interested users who are not yet connected to the Internet. These have been reprinted many times following articles on the MICE project in national newspapers and computer and related professional magazines.

10 The Future

The technology has certainly left the experimental phase, but has not quite reached the stage where it is robust enough to be used for regular services, at least not on an international scale. Within the UK, multicast technology has been tried and tested by a number of SuperJanet sites through the JIPS Mbone pilot. As a result of that pilot, UKERNA (the UK academic network provider) will offer multicast as a service to the academic community during 1995. This will open up conferencing to the research and higher education community as a whole, and not just to computing and science subjects. These new users, however, will not be able to apply the tools as currently offered without guidance and support. Backup through the support centres such as MICE-NSCs is essential, and UKERNA's example of funding support centres prior to offering multicast as a service is a good one.

Using multicast on an international scale, there are problems with connectivity and congestion which need to be resolved. The European MICE-NSCs aim to support international user groups and act as a liaison with the national and international network providers. Users need more time and hand-on experience to apply the technology in a productive manner. Developers will have to tailor or advance existing tools to meet the requirements for specific applications. The sector which has shown the most active interest is the education one, where multimedia conferencing over the Internet could help to share resources and gain access to scarce expertise and up-to-date results.

Many potential users in distance education, however, do not have access to the hardware platforms on which the tools currently run. A number of developers have started to port multicast tools to PCs and Macintoshes or develop their own. The MICE project will contribute to the migration of tools to these platforms, and test and evaluate the solutions for a number of user groups and conferencing tasks and environments.

Technical work on the project will also continue. Apart from continuous improvement of the software tools and integrated user interfaces, technical work planned include further work on conference control, and much more work on improving real-time support in the networks themselves.

If the Mbone is to survive and continue its rapid growth, it will also have to evolve, with the deployment of hierarchical multicast. There is also much debate in IETF circles about whether reservation of network resources is necessary or desirable. It is clear that in some parts of the internet where congestion is a serious problem, increasing the network provision is necessary. However, it is likely that for real-time traffic to be usable on such congested links, reservation is necessary, and the next year should see initial deployment of RSVP.

Although the media tools themselves have evolved considerably over the past two years, conference control mechanisms have not evolved along with them. This is likely to change in the next year, as there is a very real requirement here.

Increasingly, the Mbone will start to be put to uses where confidentiality is a prime requirement - an example being the MICE surgery teaching demonstration. The tools are starting to exist to enable this to happen - it is not clear though what the political implications of this will be.

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