Multimedia Multipoint Teleteaching over the European ATM Pilot‡

Simon ZNATY[1], Thomas WALTER[2], Marcus BRUNNER[2], Jean-Pierre HUBAUX[1], Bernhard PLATTNER[2]

[1]TCOM Laboratory
Telecommunications Services Group
Swiss Federal Institute of Technology Lausanne
CH-1015 Lausanne
E-Mail: {znaty, hubaux}@tcom.epfl.ch

[2] Computer Engineering and Networks Laboratory
Swiss Federal Institute of Technology Zürich (ETH)
ETH Zentrum, Gloriastr. 35, CH-8092 Zürich
E-Mail: {walter, brunner, plattner}@tik.ee.ethz.ch

Abstract

In this paper, we present the design and implementation of the BETEUS (Broadband Exchange for Trans-European Usage) communication and application platform. BETEUS is a European project aiming at developing generic, stable, flexible and scalable communication and application platforms which provide support for a collaborative work environments. In terms of collaborative work, BETEUS concentrates on distributed classroom, tele-seminar, multimedia document archival and retrieval and tele-tutoring. The problems found during the realization of the BETEUS platform are outlined and the proposed solutions explained. The follow-up of BETEUS in Switzerland through the TELEPOLY project which concerns operational teleteaching between the two Swiss Federal Institutes of Technology (EPFL and ETHZ) is also presented.

1 Introduction

Support for Multimedia is an important issue that drives the request for ATM (Asynchronous Transfer Mode) communication. The usage of multimedia features in a *collaborative work environment* is the core of BETEUS - Broadband Exchange for Trans-European USage [1]. The functions that have been developed in the project are best captured by the so-called *virtual community paradigm*. A community is a group of people with common interests participating in a set of operations towards reaching a common goal. In the case of BETEUS the operations are *working*, *teaching*, *learning*, *project management* and *technical design* [2]. The virtuality of the community is due to the fact that people who participate in the common operations are located in geographically distant locations. The BETEUS platform provides the services required for

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interconnecting distant locations to establish a virtual community [3]. BETEUS concentrates on distributed classroom, tele-seminar, multimedia document archival and retrieval and tele-tutoring, as well as collaborative work environments.

The BETEUS communication platform, i.e. the part of the BETEUS platform providing services for interconnecting distant locations, is built on top of the European ATM pilot network. As services, both end-to-end native ATM and IP are provided. In its current implementation, the BETEUS application platform, i.e. the part of the BETEUS platform implementing services for collaborative work support, can communicate via UNIX-sockets [4]. This decision has been taken for practical reasons. Firstly, the development of the BETEUS application platform is thus independent from the actual support of the underlying communication infrastructure. Although all BETEUS user sites now run FORE ATM switches [5], this was not obvious when the design of the communication platform was started. However, at that time, it was apparent that IP connectivity was available for all partners either directly over ATM [6] [7] or SMDS (Switched Multimegabit Data Service). Secondly, the communication platform can be extended so that IP multicast facilities [8] can be used for point-to-multipoint communication as is requested by teleteaching applications.

The BETEUS application platform is not a stand-alone application like most of the today's collaborative teleconferencing systems, which implement all components, from low-level transmission and processing up to the user interface, from scratch. It is a platform for implementing different scenarios like distributed classroom (i.e. teleteaching) or tele-seminar (something like a virtual face-to-face meeting). Therefore, we could evolve the final scenarios out of a series of prototypes that could be tested on the BETEUS network. This led to a significantly reduced effort as compared to stand-alone prototype systems for every scenario.

The paper is structured as follows: Section 2 discusses the services offered by the European ATM pilot. BETEUS user sites are connected by a fully meshed network, based on the semi-permanent virtual path service (Section 2.2). Such a network is considered appropriate with respect to the design considerations of the BETEUS communication platform (Section 3.1). The realization of the BETEUS communication platform is discussed in Section 3.2. We give details on the overall network topology, the local site configurations and multicast. This section also introduces the BETEUS management platform responsible for the management of the communication and application platform. In Section 3.1 we briefly discuss the BETEUS application platform. Section 4 explains the use that has been made of the infrastructure and summarizes some pragmatic conclusions that have been drawn; it sketches future plans. We conclude with an assessment of our achievements.

2 European ATM Pilot - Topology and Services

The introduction of the *asynchronous transfer mode (ATM)* is currently being driven by the need for fast and hopefully cheap data communication in public and private networks.

In the context of the BETEUS project (a follow up to Betel [9]), ATM technology is used to provide end-to-end pure ATM communication between BETEUS sites: CERN in Geneva (Switzerland), EPFL (Switzerland), ETHZ (Switzerland), EURECOM in Sophia Antipolis (France), KTH in Stockholm (Sweden) and TUB in Berlin (Germany). The goal of the communication infrastructure is to run multipoint multimedia teleteaching applications such as *distributed classroom*, *tele-seminar* and *multimedia document archival and retrieval*.

2.1 European ATM Pilot Services

The European ATM pilot provides its users with two main services, a s*emi-permanent virtual path service* (Section 2.2) and *adaptation services*. Within the latter category, we find LAN bridging (Ethernet), circuit emulation (E1 emulation) and point-to-point SMDS (Switched Multimegabit Data Service).

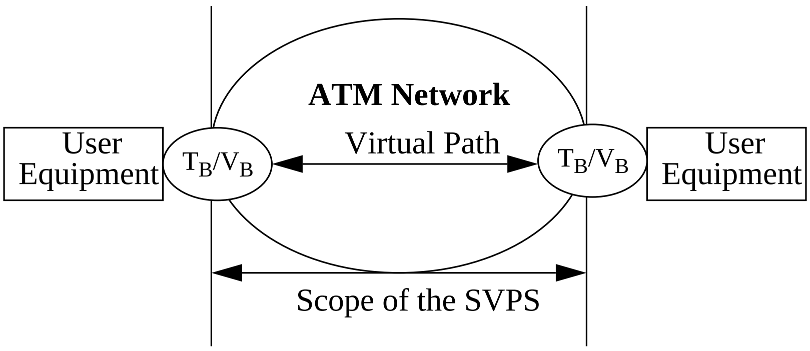

Figure 1: Semi-permanent Virtual Path Services

2.2 Semi-permanent Virtual Path Service (SVPS)

This service supports communication in both directions between reference points T_B/V_B (Figure 1). The establishment modes are either reserved (occasional or periodic) or *permanent*. Only the physical and the ATM layer are defined. Higher layers have end-to-end significance and can be chosen according to the needs of an application. In BETEUS we use IP over ATM adaptation layer 5. The provision of SVPS is based on virtual path (VP) connections in the ATM pilot network. The physical bandwidth at the access points is defined by the existing interfaces. For the ATM pilot, two interfaces, at 34 Mbit/s (E3 interface) and 155 Mbit/s (STM-1 interface) are used. A parameter "peak cell rate" is associated with each VP. The peak cell rate corresponds to the usable transfer bit rate, from the user's point of view, divided by the payload of an ATM cell in bits (48 * 8). A user can subscribe to any value of the usable information transfer peak cell rate that is available at the user interfaces.

3 The BETEUS Platform

The BETEUS platform consists of two parts: communication and application platform. The BETEUS communication platform interconnects BETEUS sites using semi-permanent virtual path services (SVPS). It provides the application platform with native ATM functions as well as a socket interface.

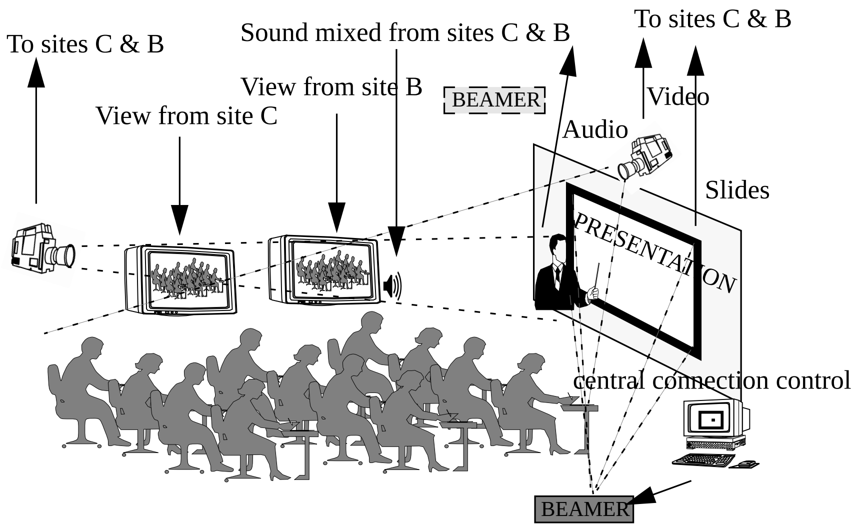

Figure 2: Distributed Classroom Scenario (Local Site A with Lecturer)

3.1 Design Considerations

The communication platform has been designed taking the following considerations into account:

- Networking considerations
  Since the BETEUS communication platform is built on top of the ATM pilot network, the design decisions must take into account the services offered by the ATM pilot (as described in Section 2) and the variations of the network configurations in the local sites. For instance, the maximum bandwidth is 34 Mbit/s for most of the BETEUS partners (except ETHZ which is operating two STM-1 links). ATM signalling and point-to-multipoint services at the ATM level are not provided by the ATM pilot, neither the switched virtual connections (SVC). These restrictions have consequences for the provision of multicast in the BETEUS communication platform (see Section 3.2).
- BETEUS application requirements
  The BETEUS applications are *interactive multimedia applications*. This class of applications imposes stringent network requirements as summarized as follows: guaranteed throughput, bounded end-to-end delay, low packet loss, connection oriented transport, multicast and support for real-time data services.
- Bandwidth requirements
  The different BETEUS supported scenarios have different bandwidth require-

ments. In the distributed classroom scenario (Figure 2), for instance, every distributed classroom sends its classroom view to all other classes and receives classroom views from them. Images of the speaker are also distributed to other classrooms where he/she is not physically present. Distributed classroom has predictable bandwidth requirements since the scenario and the maximum number of sites involved are generally fixed during the session. Tele-seminar, on the other hand, is quite more demanding with respect to bandwidth requirements, since users may freely join and leave sessions.

However, the bandwidth required for connecting *two* sites can (more or less) accurately be estimated. For running a distributed classroom session the bandwidth of a connection has been estimated to 3 Mbit/s, composed of low quality video streams at about 1 Mbit/s of a quarter of PAL resolution and with 12 frames per second (fps) for classroom views, a speaker image at the same resolution but with a higher quality video stream at 25 fps (~ 2 Mbit/s). Assuming use of medium quality audio at 64 Kbit/s and shared workspace application at 60 Kbit/s data exchange rate, the total bandwidth is about 3 Mbit/s per connection.

Experiences have shown that the described application requirements are met by the BETEUS communication platform.

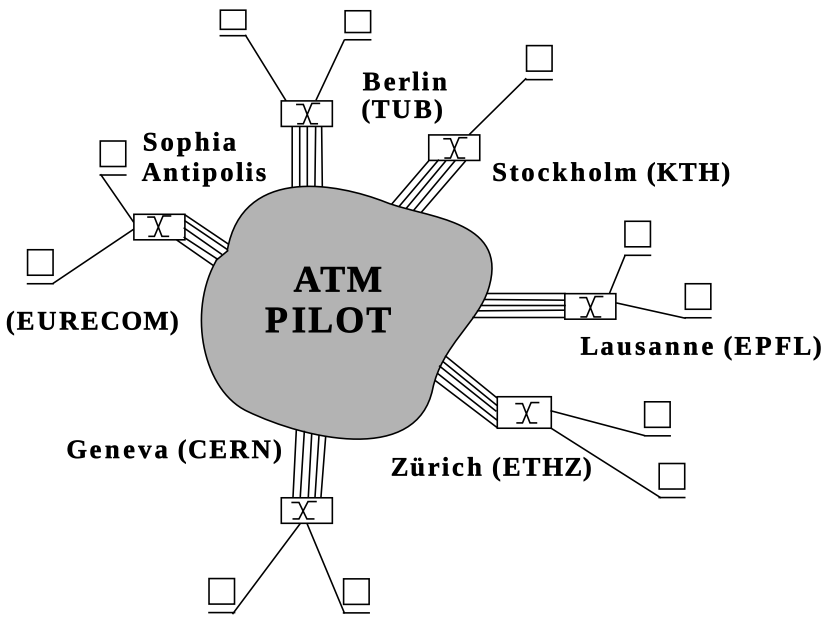

Figure 3: BETEUS Communication Platform Topology

3.2 Realization of the BETEUS Communication Platform

The BETEUS communication platform [3][10] is built on top of the ATM Pilot with a fully meshed VP topology network (Figure 3). Since access to the ATM pilot was not possible for all partners at the same time, the fully meshed network was the optimum solution for launching tests as early as possible.

Each site is connected with the other five sites through the ATM pilot by means of bi-directional VPs of 3Mbit/s peak bandwidth. On top of the VPs the Internet Protocol (IP) over ATM adaptation layer 5 is running [6]. The use of IP over ATM has been straightforward as the ATM hardware interfaces used with the workstations are supporting the necessary mapping.

Local Site Configuration

The BETEUS partners are using ASX-200 ATM switches from FORE Systems [5] and SUN workstations (Figure 4). The switch software is ForeThought version 3.2.0. The ATM switches are connected to the ATM pilot by E3 or STM-1 interfaces and to workstations by 100 Mbit/s TAXI interfaces. The workstations are equipped with a PARALLAX video board (with JPEG compression done on the video board) and with a SBA-200 ATM adapter card (also from FORE Systems [11]). The workstations are running SunOS 4.1.3, ForeThought 3.0.2 and SNMP agents.

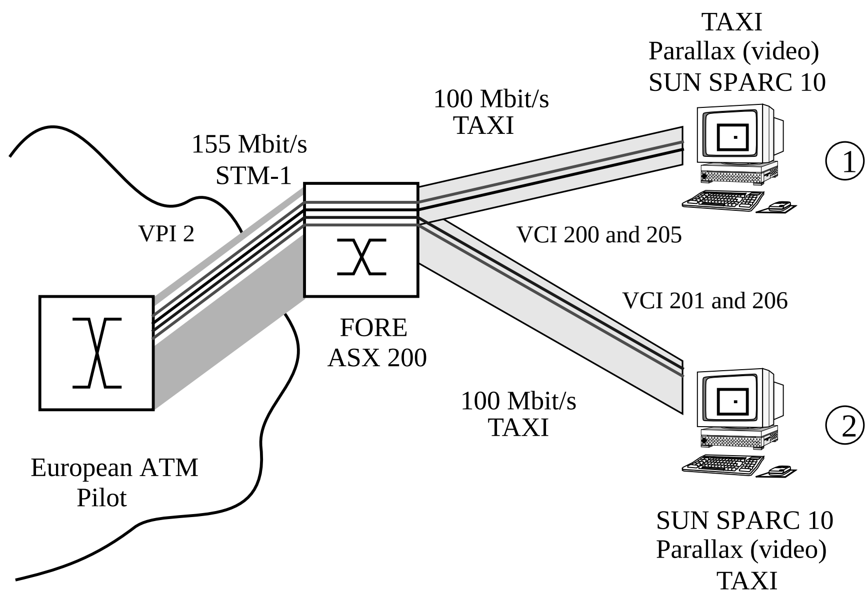

Figure 4: Example of Local Site VP/VC Configuration at ETHZ

The BETEUS field tests use at least two SPARC 10 workstations in every partner's site (Figure 4). The connections between workstations are set up manually by updating the ATM ARP tables. To have ATM connections between all workstations, we need to set up four virtual channels (VC) at each site (2 VCs per workstations). This configuration gives us the possibility to access every workstation in the BETEUS network from every other workstation.

For example, the ATM switch at ETHZ (Figure 4) is configured to send all traffic to EPFL on virtual path identifier (VPI) 2. Workstation 1 at ETHZ reaches workstation 1 at EPFL using virtual channel identifier (VCI) 200 and workstation 2 at EPFL using VCI 205. Similarly for workstation 2 at ETHZ which reaches workstation 1 and 2 at EPFL using VCIs 201 and 206, respectively.

Multicast in BETEUS

Since the core of BETEUS applications is to provide multimedia features in a collaborative work environment, the BETEUS communication platform should support *multicast services* for point-to-multipoint connections.

Multicasting means that a group of recipients can be addressed in a single data transfer. In principle, ATM can support applications with multicast services. This is usually done by using signalling protocols, e.g. SPANS (Simple Protocol for ATM Network Signalling) [12] or UNI (ATM User-Network Interface) [13].

Currently no signalling is used in the BETEUS communication platform, mainly due to some ForeThought limitations, e.g. in the version we are using, signalling is only possible on VP 0. With it IP multicast couldn't be employed too.

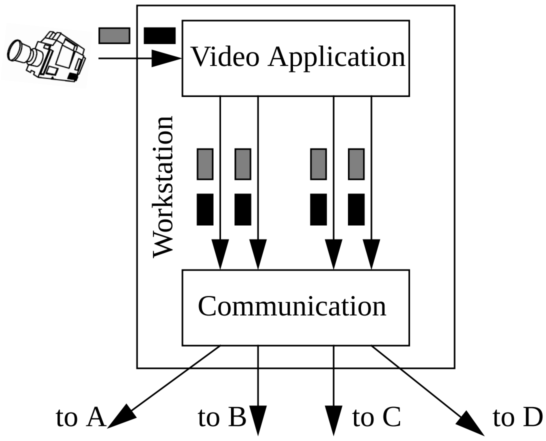

Figure 5: BETEUS Multicast Support

Within BETEUS we therefore have implemented multicast functions in the application as a short term solution. For instance, a video stream is transmitted to several remote sites by duplicating all video packets in the application (Figure 5). Quite obviously, this introduces an unnecessary load on an end system but, on the other hand, it has been easy in its realization.

BETEUS Network Management Platform

The BETEUS platform is managed by the BETEUS management platform. The BETEUS management architecture is compliant with the TMN principles [14]. A *telecommunications management network (TMN)* is a network to provide surveillance and control of another network. Two TMN management layers are considered within BETEUS: the *element management layer (EML)* which manages BETEUS sites on an individual basis and the *network management layer (NML)* which is responsible for the management of all BETEUS sites. The EML level makes use of the *simple network management protocol (*SNMP) [15] while the NML level operates with c*ommon management information protocol (*CMIP) [16] to exploit the capabilities of OSI management, such as event reporting. In each BETEUS site, a CMIP/SNMP gateway (EML level) is used to query the local SNMP agents (ATM switch, ATM adapter cards, host applications) on behalf of the network management centre (NMC) (Figure 6). This gateway is directly managed by the NMC using CMIP.

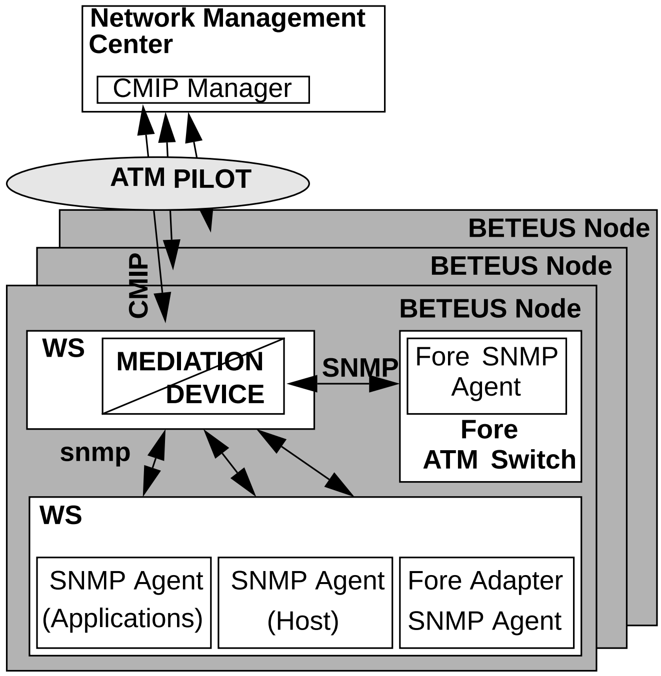

Figure 6: BETEUS Network Management Platform

The BETEUS network management platform focuses particularly on aspects like faults, performance and accounting management. Statistics are collected during multimedia sessions and analysed off line. This analysis enables the evaluation of the *grade of service* given by the European ATM pilot and the local ATM switches, correlated to the QoS measured and estimated by users.

In the following we present a sample of performance statistics [17] that have been collected during a BETEUS session at the ATM adapter card of the workstation dedicated to video applications. It should be noted that applications use JPEG video compression and performs a kind of traffic shaping by maintaining as much as possible a near constant throughput.

During three hours running a video application, we observe a stable behaviour generating AAL5 PDUs. An average of 73 ATM cells per AAL5 PDU with a standard deviation of 16.46 cells/AAL5 PDU were emitted. The average AAL PDU size then equals to 3504 bytes, including AAL5 PDU trailer and its payload data. Application data represent 98.74% of the payload of the 73 ATM cells (only 1.26% is due to protocol headers and tailers).

During three hours, 37 AAL5 PDUs were discarded out of 394'413 received PDUs, which leads to a AAL5 layer loss rate of 93.8E-6. If we assume that the cell loss occurrence is uniformly distributed over the time (pessimistic), then this results in an ATM cell loss rate of 1.28E-6.

3.3 The BETEUS Application Platform

The application platform [2][18] provides all the elements needed for running collaborative work sessions between several end points of the BETEUS virtual community. The application platform includes software for application set up, collaborative work and control.

Architectural Environment

The BETEUS applications exhibit the notion of a *site* (Figure 7). A site is a collection of workstations, media I/O devices and switching devices that are, in terms of control, tightly correlated.

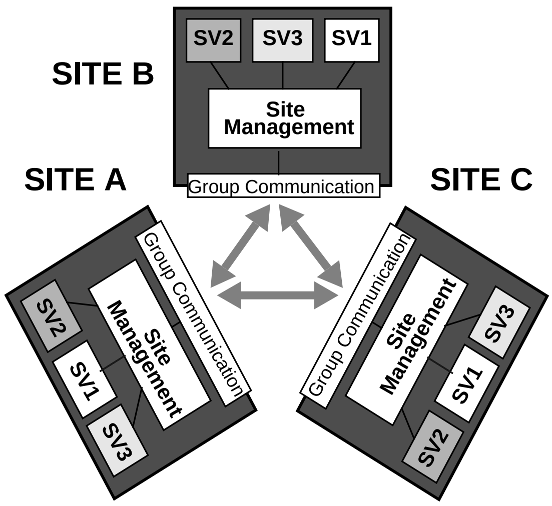

Figure 7: Inter-site Communication

Site control is centralized within the *site management*. The control aspects of an application within BETEUS are caught by the abstraction of a *session*. A session can be regarded as being typed with a certain application. The abstraction for an instantiation of an application within a site is a *session vertex (SV)*. A BETEUS application consists of a set of session vertices that are distributed over various sites (e.g. all *SV1* session vertices in Figure 7). Session vertices communicate with human users through user interfaces, with the local site management through the site management interface (SMI) and with each other by means of some specific functions that the site management interface provides (Figure 8). Connection management within a session is a function that is distributed to site management entities. Site management entities interact with each other by means of a group communication protocol.

Component Description

The site architecture is depicted in Figure 8. Plain blocks stand for entities that have only a single instantiation within a site. Hatched blocks can have many instantiations. The activities within a site are coordinated by the site management. The site management establishes local connection endpoints via the *connection management* on an abstract level. The connection management maps abstract device names to physical addresses and communicates with *station agents* for the establishment of audio, video and application sharing connections, and with *switch agents* for the establishment of *analog* connections within a site (if, for instance, a peripheral audio/video switch is used). A station agent is found in every workstation that can be source or sink of a audio, video or application sharing connection.

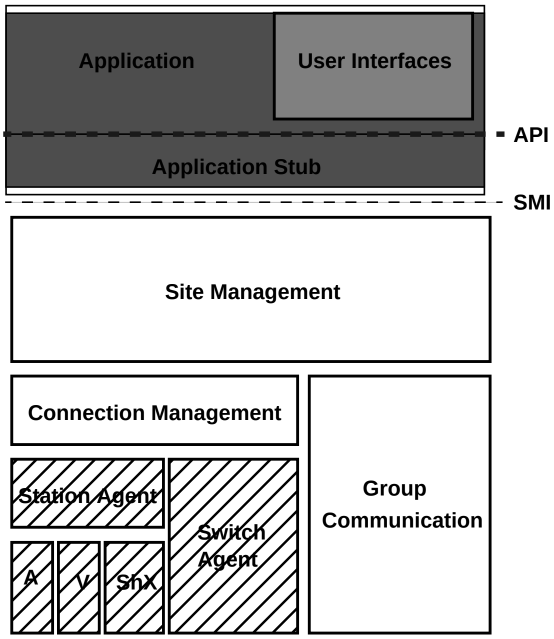

Figure 8: Site Architecture

The BETEUS audio component implements silence detection at the sending site with an adjustable threshold value and is built on top of the realtime transport protocol (RTP) [19], which in turn uses UDP for transmission. The receiving site supports audio mixing. Both sender and receiver generate activity events that can be graphically displayed on the user interface. The two audio encodings that are supported are 8kHz sampling rate with 8bit resolution and 16kHz sampling rate with 16bit resolution.

Video transmission is built around the XVideo board from Parallax. The compression of the Parallax board follows the JPEG standard for the compression of still images

[20]. On connection set up the video sender allows to specify a maximum data rate and a frame rate. The window size is adjustable during the lifetime of a connection. To enforce the maximum data rate, a control loop compares the maximum and the measured data rate and modifies the JPEG compression factor according to the result of the comparison. This allows to have a constant frame rate, which results in excellent video quality, because the human eye is extremely sensitive to frame rate irregularities.

The application sharing component (Xwedge [21]) allows BETEUS session members to share any X11 application running at his node with all other session members. Xwedge is a distributed shared window system that has agents running at all involved client and server sites. A distributed approach has been taken in order to improve performance. Another design goal of Xwedge has been to keep it policy-free, i.e., not to prescribe a default admission and floor control. The system that integrates Xwedge has thus the possibility to employ its own sharing policies.

A BETEUS application is built on top of the site management. It consists of a collection of (identical) processes that are distributed over various sites.

The site management exports a message based control interface (SMI) to the session vertices that use its services. To relieve the application programmer from message exchange semantics, a skeleton for the construction of applications is provided. This is the *application stub* in Figure 8. The actual application programming interface (API) is provided by the functions of the application stub rather than the site management itself. Asynchronous events of which the site management wants to notify a session vertex are treated by callback functions for which the application stub provides a framework.

4 Utilization and Future Work

The previously described infrastructure has been used between the different sites in order to support tele-seminar, teleteaching as well as multimedia document storage and retrieval. A major event has been the usage of the BETEUS platform during the first International Distributed Conference on High Performance Networking for Teleteaching November 1995, in order to distribute a panel session.

Tele-seminar is best understood as a “virtual face-to-face meeting”. Every participant has its own workstation. Every workstation acts as a communication unit that transmits, receives and processes multiple video, audio and data streams. A tele-seminar does not have a fixed structure but participants may join and leave a tele-seminar freely so the size (in terms of participants) of a tele-seminar varies dynamically.

As soon as a first prototype of the BETEUS platform was available we used this prototype for our own purposes, mainly for organizing weekly meeting. Every partner site operated its own workstations that were connected by the BETEUS communication platform. Video and audio connections and shared workspace connections were established. We were able to perform technical discussion and to prepare presentations, which includes the editing of slides. From our experiences we can conclude that the functionality of the BETEUS platform is sufficient in order to support collaborative work sessions.

As for teleteaching, a few courses have been broadcast from EPFL to the other sites. Each of the five sites involved received a video stream from all of the other sites. The audio produced by a given site was broadcast to all other sites; on each site, the four incoming audio streams were mixed in order to let everybody be able to discuss with everybody at any time.

The courses were given by Professor Rossi from EPFL and covered the area of acoustics in multimedia communication; a few acoustic (music, voice) samples were provided to illustrate the concepts introduced during the course. The following conclusions have been drawn from this experiment:

- The application and communication platforms of BETEUS does allow to support this kind of course. With appropriate precautions, it is indeed possible to send complex audio samples to remote sites.
- Conventional transparencies are acceptable and can be read by people at the remote sites, if they are properly designed (larger fonts than usual, simple graphics); electronic slides shared by means of a distributed application are obviously better, but a pointing device is mandatory.
- From the point of view of the lecturer, it is highly desirable to be able to monitor the cameras (rotation and zooming functions) located in the other sites. This allows him or her to glance in the direction of the pair of remote participants whose concentration is reducing and whose (noisy) chats may disturb the other attendees of that class.

The third function, multimedia document storage and retrieval, was also tested in the framework of the project. At CERN several audio/video clips were stored on a server equipped with Uniflix from Paradise software. JPEG is used with this solution. Both hardware and software compression techniques were experimented, demonstrating a clear (and expected) superiority of the former. An application developed by the consortium allows to access a Web page displaying available video clips. When selecting a given clip, the full potential of ATM is exploited: instead of transferring the whole file from the server to the requesting end system, as it is usually done on the Web, the video is immediately read on the server, transmitted and played at the same pace as recorded on the end system. As an example, a session was played with 20 frames per second and SuperCIF format. It required a bit rate of 5 Mbit/s.

Based on the experience gained within the BETEUS project, EPFL and ETHZ have decided to start a follow up project called TELEPOLY which aims at providing an operational teleteaching system between the two Institutes.

Three phases are foreseen within this project. The first phase (early 1996) consists in weekly seminars between both sites, on the topic of networking and multimedia systems. During the second phase (Spring 1996), a regular course of the 6th semester on Computer Networks (in English) will be transmitted from Lausanne to Zurich. Finally, in phase 3 (Fall 1996), a first year course of mathematics or physics will be transmitted from Zurich to Lausanne. The intention here is to have the course given in German, in order to favour the integration at EPFL of students whose mother language is German. In this way, teleteaching can foster mobility within a multilingual country such as Switzerland.

5 Conclusions

In this paper we have discussed the realization of the BETEUS communication platform which is used in the BETEUS project to support distributed multimedia applications like distributed classroom, tele-seminar and multimedia document archival and retrieval. We have started out from a discussion of ATM network services offered by the public network operators. It has turned out that some essential networking features which would have been advantageous for the realization of the BETEUS communication platform have not been available. Essential features would have been the signalling over the European ATM pilot and with this the possibility of multicasting in the ATM network. Therefore, we have decided to build up an alternative. This has mainly affected the multicast functionality of the BETEUS application platform. Providing multicast services by the BETEUS communication platform rather than by the BETEUS application is still an unresolved issue. Although a new ATM switch software release has been provided by FORE, no optimal solution is available. Nonetheless, we have been able to implement a communication platform which is stable, flexible and scalable. Furthermore, the important application requirements (as discussed in Section 3) are fulfilled. Five sites (i.e. CERN, EPFL, ETHZ, EURECOM and TUB) have been connected. All BETEUS scenarios are supported and tests have been conducted to interconnect to another European project IBER, which has similar goals, but explores a different technical approach.

We expect that a fully operational ATM infrastructure providing all ATM services, particularly signalling and multicast, will improve utilization of resources in the BETEUS community. For instance, we expect that the error prone manual installation of VP and VC connections will be improved by ATM signalling functions.

To go further in teleteaching over broadband networks, EPFL and ETHZ have launched the TELEPOLY project, which should be operational from beginning on January 96.

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