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ABSTRACT

This paper reports on Education Direct, a project at Lulea University of Technology (Sweden) in which the next generation Internet technology, based on IP (Internet Protocols) multicasting, has been used in practice over large geographic distances involving a wide variety of secondary and postsecondary students and teachers. Education Direct utilizes the mStar tool suite, which exploits IP multicasting to provide fully symmetric use of audio, video, group-synchronized World Wide Web browsers, whiteboards, chat, voting, recording, replay, annotation, and editing. All are integrated into the end user's desktop computer, making education both more available, independent of place and time, as well as of higher perceived quality. This paper reports on the methodology, context, technology, and experiences gained over a year of practical use. Sections of the paper cover: (1) background and context of the project; (2) usage patterns and participant profiles, including technicians, advances users, end users, and technologists; (3) technology, including IP-multicast, components of the mStar environment, and protocol standards; (4) network and preparations, focusing on the basic communications platform; (5) experiences and observations; (6) the mStar system as an educational innovation; and (7) related work. Contains 11 references. (Author/DLS)

Education Direct - Entering the World Beyond the Web

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Abstract: This paper reports on a major and innovative project called Education Direct, where the next generation Internet technology, based on IP multicasting, has been used in practice over large geographic distances involving a wide variety of students and teachers. Education Direct utilizes the mStar tool suite, which exploits IP multicasting to provide fully symmetric use of audio, video, group-synchronized web-browscrs,whiteboards, chat, voting, recording, replay, annotation and editing. All integrated into the end users regular desktop computer, making education both more available, independent of place and to some extent time, as well as of higher perceived quality.

While many observers would judge the large scale application of this rather advanced technology less realistic, we can hereby report the contrary. The experience has been surprisingly positive, and the resulting environment is, by many people, considered to give better quality than the alternative of physically attending a lecture. The paper reports on the methodology, context, technology, and experiences gained over a year of practical use.

1.0 Background and Context

Education Direct is part of a larger effort to deploy new technology to better support all kinds of cooperation, interaction and information access. The goal is to create an environment where people can work, learn, do business, socialize and be entertained, with less regard for their geographic location. While this paper is about education, we believe it is important not to isolate this aspect from all other parts of life, but to integrate it. As a consequence of this philosophy, the tools used in this project have been designed to be equally useful in other contexts, such as distributed projects, marketing and support, and even media and entertainment.

The project is part of an ambitious effort of making the County of Norrbotten a pilot example of an electronic marketplace in a wide sense, where many of the everyday tasks should be possible to carry out over the network. This includes governmental and community services, marketing, purchase, and other business interactions, distributed work and consultation, medical support, education, media and entertainment.

The basic communication infrastructure consists of 155 mbit/s ATM links going to all communinty centers, which may be small villages down to a few thousand people. More important is however that multicast capable IP is run on top of this transport network, enabling the use of realtime streams of audio, video and data events to large audiences as part of the regular Internet connection. The Norrbotten County Network is actually just a segment of the Internet that happens to be unusually well equipped with quality of bandwidth and information contents.

Education Direct is part of this, and represents significant progress towards the vision of the electronic presentation and education environment, according to which most courses at the Luleå University of Technology and CDT will be possible to attend independent of physical location. While this would be enough of a challenge, the goal was in fact even broader than so: to transfer not only courses but the use of the technology itself to regional high-shools, secondary schools, small and medium sized companies.

The county of Norrbotten consists of the northernmost fourth of Sweden and covers an area of 400x400 kilometers. The population is sparse, with about 260.000 people. This has meant that many high-schools cannot gather the critical mass and competence to offer the courses and subjects that are possible at other places. The Education Direct project is part of the solution to this problem, because it allows schools to specialize in a subject and amortize its cost over more students than otherwise would be possible. By giving the courses over the network, a sufficient critical mass is generated,creating a county-wide virtual high-school with a breatdh and quality of subjects that would otherwise not be possible. The effects on society are evident.

2.0 Participant profiles and usage patterns

The Education Direct involves, in various ways, several hundred people. It was initiated during the spring of 1996, and spent significant effort on getting a firm rooting among end-users outside the already knowledgeable kernel of technologists. The operational phase started during the fall of 1996. The project involves four kinds of people:

- *Technicians*, who must be able to manage computers and communication equipment to ensure continuous operation.
- *Advanced Users*, who should be able to utilize the technology for doing own productions, presentations, and information searches.
- *End Users*, who need to be able to use the technology to benefit from the information provided by others.
- *Technologists*, who in addition should have an overview of how the technology works, ongoing trends, and principles of the area.

In the first phase of the project an undergraduate course in Internet and distributed multimedia was distributed. The participants came from all over the county, many of which weresecondary-school teachers, (as those will act as local technology transfer persons) and local under-graduate students. The local students had the choice of following the course by attending the lectures physically or virtually using the mStar environment. By choosing the technology itself as the subject for the first main course, the transfer and introduction became much smoother. Explanation of technology, tools, and network became part of the subject rather than a distracting element. The students were in many cases high school teachers, which have become local competence centers and advocates for further deployment of the technology.

Since this first course, during the winter and spring 1996, dozens of courses and seminars have been distributed. All computer science graduate courses, and a growing number of underegraduate courses at the University of Luleå, have been carried out this way. Many seminars have been carried out between high schools, and the usage has even found its way down to rather exotic examples like sixth class students learning spanish in remote villages.

The mStar system allows for many different patterns of use. The initial, and most straightforward, approach was however been to mimic the traditional lecture where a teacher presents her view of the material to the students, using various forms of presentation material. As a basic measure, all material used is made available in WWW accessible form. The traditional overhead-slide projector is replaced by computers and screen projection equipment, (the latter for those who wish to attend the presentations physically), which also run the communication and distribution software. The presenter and the local audience has, therefore, continuous contact with all remote participants.

3.0 Technology

IP-multicast has been used for several years with success on a world global scale under the label of MBone, (www.mbone.com). In addition, it has proven its maturity in a multitude of local contexts, within regions, universities, and company Intranets. It is by most observers judged to be the best, (maybe only), way of providing large scale distribution of interactive multimedia. It tigthly integrates with other existing Internet technologies, including the World Wide Web. At an international level, the IP Multicast Initiative, (http://www.ipmulticast.com/), is a consortia of major industrial players promoting its deployment. Both the MBone and IP Multicast site include good tutorials on the subject. At the most basic level, multicasting ensures efficiency by duplicating data packets at distribution branching points, rather than using todays extremely inefficient and non-scalable use of duplicate streams of the same material for each viewer involved. Multicasting is however much more than so, but represents a rich body of standards on how to define, join, and leave distribution channels, and how to construct tools that utilize it. Because multicasting is inherently two-way, it also bears in it a new depth of meaning for the word "interactive" that has not been provided by previous technologies. The mStar environment, (http://www.cdt.luth.se/mstar) exploits this potential, and currently includes the following components:

- Audio. mAudio for telephone level quality audio, mRadio for high quality mono, and mIR for distribution of CD quality stereo, (using MPEG audio).
- Whiteboard. mWB for shared whiteboard, documents, and pictures. Distributed Presentations. mWeb is used for distributing web-pages and synchronizing audiences web-browsers on common pages.

- Chat. mChat for textual group intercations. Voting. mVote for definition, issuing, and immediate graphical visualization of voting alternatives.
- Video. mStar is reusing the well known "vic" application for low to medium quality video, (such as H.261).
- Floor control and attention getting. mWave allows for people to electronically "wave their hand" and maintain the order among multiple wavers.
- Application sharing. mShare for integration of application sharing system.
- Media Recording and Replay. mMOD records and replays multicast sessions, (not only audio/video, but all tools involved).
- Session/channel information. mSD is web-based application for presentation and joining of multicast channels.
- Session Editing. mEdit allows for Indexing, editing, and annotation of recorded sessions.
- Presentation authoring. SlideBurster allows for easy creation of Web based material for distributed presentations (as is used for mWeb above).
- Network adaptions. mTunnel is used for transfer and scaling of multicast traffic over unicast links, which is important for deployment in areas where multicasting is not completely settled.

While the usage scenario described here is distributed education, mStar is in fact largely developed within the ongoing Esprit project Mates (Esprit 20.598, http://mates.cdt.luth.se/), with the original purpose of supporting distributed engineering projects. Being written completely in Java, mStar is an example of the emergence of another important technology, the dynamically platform independent and mobile code approach. While Java has been a big step forward, we have not yet seen the arrival of its potentially most important aspect: the on-demand delivery of software in modular components. This is a property of utmost importance in a groupware context, where penetration and success depends on fast growth of a user community, and where the value of a service increases, (and cost decreases), with audience size.

The applications above, (as well as many other tools), are running on top of a rich set of protocol standards at many levels. The Realtime Transport Protocol, [RTP] , is a well known foundation, as well as implementations of reliable multicast based on extensions of SRM, [SRM, RMP]. Recent ITU standards such as H.323 have directly adopted multicasting and RTP, and are therefore inherently compatible to a large extent.

4.0 Network and Preparations

To ensure that the rather extensive software and networking technology would work at all sites, there has been several intensive courses given to local system administrators. The largest part of the prepartion work was however in ensuring the existence of a network with a quality sufficient to carry out the tasks. In this section, we describe the basiccommunication platform.

The Norrbotten county network is a TCP/IP broadband backbone network based on ATM. It is operational today, but has an extensive plan for further extending its capacity. Late 1997, 155 Mbit/s ATM links were established to 15 major connection points. This will support all 14 community centers, and the hospital areas, with broadband services. The backbone will be used for private networks and an open regional network with connection to Internet. Using connections to the open region network is preferred to get connectivity to other organizations as well as locally, regionally and globally through the Internet.

Connections to the open region network, (that is Internet), are universally available at very low prices. Connection speeds are ranging from ISDN up to 100 Mbit/s over optical fibercables and can quickly be upgraded in convenient steps. As part of this project every school, (down to first year), have at least an ISDN connection. This ensures an extremely wide coverage, giving potential for an unusually wide impact on society. During 1998, a major programme for launching ADSL/ADSL Lite technology is under deployment, which utilizes standard telephone copper wire for communication speeds in the order of 1-10 Mbit/s (downstream) and 256-800 kbit/s upstream. The early pilot network, in use from 1995 - 1997 was a TCP/IP leased line router network with 2 Mbit/s connections, with a 2 Mbit/s connection to the Internet. There were about 9000 connected systems in the region. Surrounding the University of Luleå, (where CDT is located), are 2000 appartments connected by 10 Mbit/s through LAN technology.

In many places IP-Multicast has been, and still is, regarded an area of research and experimental usage. Not so in this case, where it has been in native and productive use since 1995. As the pilot network has been a large network

with local administration it has been perfect for testing different ways of distributing multimedia with IP-Multicast. It should be noted that while the underlying transport technology is ATM, that is not really a concern of end user nor of applications. IP, (Internet Protocols), is run on top of the ATM transport and is the interface of concern - a pattern we believe is here to stay. Therefore speaking about "ATM networks" is less relevant.

5.0 Experiences and observations

While initial focus usually is on video distribution, our experince is that this medium is not the most important. Rather, most users regard it, after a while, as somewhat fun to have but not essential. Its most important role is actually as a "state-indicator", telling others that a person is actually in place, and maybe what he is doing, (listening, speaking in telephone or talking to someone else).

The reason for the decreased focus on video is probably the rich availability of other media, of which the "*mWeb*" application has proven to be essential. mWeb fulfills the role of the distributed slide projector, ensuring that all remote participants get to see exactly the slides/Web-pages that the presenter shows. It works by catching all Web-page requests at the presenters Web-browser, multicasting those to all participants, where the same pages are given to the local Web-browser. In this way, all participants get a high quality picture of what the presenter is referring to. This approach generates a surprisingly large number of extra benefits: Since the "slides" are now actually HTML pages presented by a local browser, every user can tune the font size and other layout details to his own preferences. For the same reason, the listener can easily browse back and forth in the teachers material, to further consider some part that was especially interesting, even while the teacher proceeds.

Furthermore, since the slides are regular Web pages, including links and Applets, each participant has the freedom to explore those individually. As a conseuqence of moving all presentation material to HTML, we have also noticed a sharp increase of quality of slides. Teachers now tend to include pointers to background material directly in their presentations.

The quality achieved is far outperforming any alternative known, like document cameras and the previously much used Internet whiteboard tool wb. It may sound impossible to some readers, but fact is that many people, including the authors, mostly prefer to attend lectures over the network. The reason is simple: the perceived quality is better than attending live sessions. It has also been observed that the other media, like Chat and Whiteboard, are creating an orthogonal communication pattern, where comments and questions are circulating, and being answered, during presentations.

Another component which has become especially essential is the multicast Media on Demand server, *mMOD*, which allows for recording and replay of any presentation session. This has created a freedom in the time-dimension that was not possible before, and has been used extensively. Collisions of events and lectures become less serious, and many students go through selected parts after initial presentations, and can directly mail the teacher any questions. *mMOD* also allows for indexes, (comparable to bookmarks), to be inserted at any place in the presentation, and later be used for quick jumping between various places. This facility also adds another view on the concept of annotations. Besides using indexes for giving the presentation an overall structure, (such as a table of contents), it can be used as a link between a point in a presentation and a comment of any kind, (which in principle can be another multimedia presentation). From an educational point of view, the mStar offers support for many aspects of the educational process. The table below shows examples of it's possible usage.

Teacher activities	**Student activities**	**Support**
Planning and cooperation with other teatchers	Cooperation with other students	Technical support
Lecturing	Participating in lectures	
Tutoring	Participating in tutoring sessions	
Creation of learning resources (recorded lectures, html documents with links, etc.)	Time independent usage of learning resources	
Creating group work sessions for students	Participation in group work	

An important aspect of the mStar system is that although it's most prominent feature is the possibility to work in a synchronous mode, the possibility to record and review lectures and sessions adds an asynchronous mode of usage. This means that although the system has been built on the metaphor of the traditional lecture with slides, the teacher using thesystem, must take the possible asynchronous use into account while planning his lectures. Further-

more, the practical use of the mStar system indicates the need of a knowledge of methods for distance teaching involving a more active behaviour on the teacher's part towards remote students. The system has already in it's development phase shown a remarkable reliability, which together with user-friendliness is of high importance in educational use. Regarding user friendliness, experiences from the use of mStar by secondary school teachers indicate that it takes some learning to master the system and that more development work needs to be done in this area.

Searching for negative aspects, it is clear that the current tools create an disadvantage for teachers who like to improvise, emphasize their points by drawing on the whiteboard, or depend on a dynamic body language. The reason is obvious from the above, which emphasize well and in advance prepared material. While it is certainly possible to use the distributed whiteboard for all written presentations, it requires more investments in peripheral equipment like large electronic whiteboards and electronic pens.

6.0 The mStar system as an Educational Innovation

An innovation, according to [Rogers, EM, 1995] is an idea, practice or object percieved as new by the adopting unit whether it is an individual or an organization. A technolgy as the mStar system has a hardware aspect consisting of the tool that embodies the technology as a material or physical object and a software aspect consisting of the knowledge base for the tool. The software aspects also contain the underlying ideas on how the technology can be used and on the possible social embedding of the technology. Innovations are also related to some kind of change in the practices of the adoption unit. An educational innovation is something that is new to adopting units in the educational system. Some educational innovations consist of ideas and theories, other educational innovations also contain some kind of technology. In the Swedish educational system, innovations and change have been closely related, though research results [Ekholm &Sandström 1984] indicate that the process of adoption and change is slower than in business and industry.

While the underlying metaphor for the design of mStar has been the traditional lecture, which most of it's tools support, it is a distributed and distance bridging system that can be used in an synchronous as well as an asynchronous mode. It is therefore no doubt regarded as an educational innovation, or as an innovation capable of strongly sponsoring educational innovations.

Diffusion is a process by which an innovation is communicated through certain channels over time among the members of a social system. Results from research on the diffusion of innovations have shown that the diffusion process follows a certain pattern resulting in a S-shaped curve, if time is plotted along the x-axis and the number of adopters on the y-axis. It has also been noted that adopters can be grouped according to their innovativeness (the degree to which a unit of adoption is relatively earlier in adopting new ideas compared to other members of a social system). It is also familiar that adopter distributions follow a bell-shaped curve over time and approach normality.

During the process of adoption, adopters in a social system can be placed in five major categories based on their innovativeness, which in time order are named innovators (who sometimes fulfill the role och change agents), early adopters,early majority, late majority and laggards. Individuals in the categories differ in innovativeness, but it is also known that other important differences can be found between categories in patterns of communication, search for information, and the degree of homophily (to what extent a persons that interact are similar in background, values, patterns of communication, etc.). These differences are important for the development of the process of adoption. When it comes to an innovation with a high technological content information on software aspects embodied in the technology and innovation-evaluation information are regarded as of central importance. It has been found that interpersonal communication is very important for information on an innovation and that a higher degree of homophily between members of a social system is important for the diffusion process. Information from a peer is given higher credibilty than information from someone whith a lower degree of homophily. Thus, results form research in the duffusion of innovations show that early adopters are generally more important for the development of the diffusion process than innovators or change agents.

In the project Utbildning Direct where 17 upper secondary schools from 13 municipalities in the county of Norrbotten participate, we can find a hard kernel of roughly 10 indiviuals that we can call innovators or change agents. These individuals have been more actively involved in the project and combine a relatively high competence in using the mStar system with an interest in educational development. Outside this hard kernel we can find a larger number of what can be characterized as belonging to the early adopters. This indicates that the process of adoption of the mStar system is still in an early stage, though the process of diffusion has lead to a spread of the technology to all municipalities in the county.

The adoption of an innovation is dependent on previous practice, experienced neeeds and problems, the degree of innovativeness and the norms of the unit of adoption. Inside the project Education Direct, there is a tendency that sparsely populated inland municipalities regard the mStar system as a solution for needs to keep schools in villages with a diminishing population, and as a means to offer courses to these schools in subjects, that would otherwise be impossible to offer.

Reinvention is the degree to which an innovation is changed or modified by a user in the process of adoption or implementation. While mStar is starting from the lecturing metaphor, t has however been observed that a secondary school teacher has used the system in a way characterized by a much richer interaction between teacher and students, than is normally the case in a lecture. This and other cases indicates that although the system is based on the lecture metaphor, it is flexible enough to allow for other forms of interactions. At the same time it is important for the further development of the mStar system to note and evaluate occuring tendences of reinvention among educational users.

7.0 Related Work

The MBone [MBone] has been used for distributed presentations for several years, and is rather well described in many references. What distinguishes this project is however the broad use in less specialized education environments together with the novel tool-suite of mStar. Reference [Parnes 1997] describes the mStar environment in more detail, and its usage from the distributed project scenario. Concerning the use of WWW as a distributed and synchronized presentation medium, there have been at least two earlier attempts:

In 1995, Ed Burns presented his work on Web-Cast [WebCast], a platform for sharing WWW documents over the MBone by either multicasting URLs or HTML-documents. It interfaced the WWW browser XMosaic [Mosaic] through the Common Client Interface (CCI) and distributed WWW pages and corresponding inline images using the Reliable Multicast Protocol [RMP]. Tests were conducted during the spring of 1995 which showed that the multicast distribution model used by that version of RMP was not suitable for wide-area-networks, because only the original sender of the data could do a repair of lost packets. In more recent versions of RMP the distribution problems have been solved.

mMosaic [mMosaic] is another tool for sharing WWW-documents over the MBone and is an extended version of the WWW browser XMosaic. Initial tests show that mMosaic works well with HTML-pages and smaller images, but the distribution delay gets too large with bigger images. A drawback is that it is very tightly coupled to XMosaic. Both these tools and other earlier Web-distribution tools are all tightly connected to the XMosaic browser. One of the main design-constraints on the mWeb application is that it should be browser independent.

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