# Telektronikk 3/4.96

## Tele-education

# Contents

## Feature

Guest editorial, *Tove Kristiansen* ..... 1

Telecommunications in distance education – An introduction, *Tove Kristiansen* ..... 2

Distance education – a response to social needs or technology in search of application? *Erling Ljoså* ..... 9

Field trials – the need for user participation in telecommunications development, *Tove Kristiansen* .. 15

Cultural and educational barriers to tele-education – Experiences from the use of videoconferencing, *Tove Kristiansen* ..... 20

Distance education in the electronic classroom, *Bjørn Hestnes and John Willy Bakke* ..... 22

Something in the air – Norwegian experiences with telelecturing in flexible education, *Gunnar Grepperud* ..... 29

Telecom and Open Learning – a challenge to institutional cooperation, *Harald Haugen and Bodil Ask* ..... 34

From electronic mail to Internet – where does it take us? *Torstein Rekkedal* ..... 38

Design guidelines for WWW-based course environments, *Anke Eekma and Betty Collis* ..... 44

Learning in collaborative virtual environments – Impressions from a trial using the Dovre framework, *Ola Ødegård and Karl Anders Øygard* ..... 51

Distance education in Norwegian manufacturing industry and the education sector – Current situation and future needs, *Tom Erik Julsrud* ..... 59

The globalisation of education, *Robin Mason* ..... 69

The future of learning, *Anthony W. Bates* ..... 82

## Special

Protocols for multimedia multiparty conferencing – a presentation of the ITU-T T.120 series recommendations, *Trond Ulseth* ..... 95

Charging of ATM services, *Ragnar Andreassen, Øyvind Breivik, Einar Edvardsen, Thor Eskedal, Nina Kloster and Olav Østerbø* ..... 105

The frequency assignment algorithm used in the mobile network planning tool MOBINETT, *Ralph Lorentzen* ..... 118

## Status

International research and standardization activities in telecommunication: Introduction, *Endre Skolt* ..... 125

COST 219: Future telecommunications and tele-informatics facilities for disabled people and elderly, *Per Helmersen* ..... 126

COST 235: Radiowave propagation effects on next generation fixed-services telecommunication systems, *Agne Nordbotten* ..... 128

COST 231: Evolution of land mobile radio (including personal) communications, *Per Hjalmar Lehne and Rune Harald Rækken* ..... 131

## Kaleidoscope

50 years of radio links in Norway. The transition from the telecommunication Stone Age, *Knut Endresen* .. 141

A presentation of the authors ..... 168

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# Guest editorial

BY TOVE KRISTIANSEN

Modern information and telecommunications technology is about to revolutionize the field of distance education. Only a few years ago, all distribution of learning material and communication between teacher and students was totally based on postal services. Today, we see a multitude of media and communication technologies being used. Even though mail is still the medium most used in distance education both nationally and internationally, the use of telecommunications is spreading rapidly and is expected to become dominating in our part of the world early in the next century. That is why we have chosen to call this issue of *Telektronikk* "Tele-education" and not distance education.

What we witness in Norway, as in many other countries, is that the differences between distance education and ordinary education are slowly being wiped out. New technology is being brought into the educational settings, opening up for a globalisation of education. Distances do not matter any more. Students may collaborate with students in other countries just as easily as with students next door. Experts may give lectures to all parts of the world without having to travel. Employees may study from home, in their work place or at a local study centre. They may choose whether to study at their own pace using asynchronous media, to follow a fixed schedule being connected to their teacher and fellow students through synchronous media, or using a mixture of the two.

This independence of time and place admits the learner to a much larger degree than before, the freedom to choose a learning model which suits the individual best. We are witnessing the development of a more individualized system of distance education, which we may call learning on demand. This respresents a challenge to all established educational institutions, which will have to become more learner oriented than they are today.

The flexibility of modern communications technologies, is of great importance to the growing demand for continuous and life long learning in the work force. In today's society investment in competence is said to be the major factor for companies to survive in the increasing competition. This need for continuous updating of the employees' competence, can greatly improve in efficiency by means of tele-education.

Tove Kristiansen

# Telecommunications in distance education
## – An introduction

BY TOVE KRISTIANSEN

### 1 What is distance education?

*Distance education is teaching where the teacher and pupil(s)/student(s) are remote in terms of space and/or time. Technical aids are used to disseminate study materials and to provide genuine two-way communication, as a means of supporting the learning process.* (St.meld. (Government White Paper) No. 43, 1988–89, p.88.)

The history of distance education started some one hundred years ago. The purpose was to offer the opportunity to learn to remote regions and groups of the population with limited access to ordinary educational services. For many years correspondence schools were the only ones to offer this kind of courses. During the last ten years, however, other educational environments have shown an increased interest in distance education.[1] This is due in particular to two aspects: societal changes and technological innovation.

Demographic changes, industrial restructuring and the pressure exerted on us throughout our lifetimes to continually update what we know and to acquire new skills means that our need for continuing and refresher education is greater than ever. Improving the skills of employees is an increasingly important investment area for all types of companies. The provision of continuing and refresher education for the work force has to a greater extent become the responsibility of the individual employer. At the same time there is a greater demand for improved efficiency and better exploitation of resources. This includes the savings on travel and course budgets and the value for the company of investments made in its employees' education.

This increased need for learning means the education sector faces new challenges. New groups of students with specific educational needs are emerging. These groups consist primarily of adults in employment, with families and social ties which restrict their mobility. Learning must take place where they are, in the workplace, in the home or at a local study centre.

In this context the development of technology is important. On the one hand, technological developments help speed up the social changes which create the need for continual learning. On the other hand, the technology provides new opportunities for this learning to take place without the student needing to travel to an educational establishment. Via the telecommunication system, teaching sessions can be distributed to the student, no matter where he or she is located. As compared to postal communication, the student is able to enjoy a far more direct form of two-way communication with the tutor, and with other distance students. Depending on what the situation of the students are, what their needs are, and what subject is to be taught, the course may be offered via synchronous or asynchronous media, based on audio, text or video communication. Very often a mixture of media will be used, combined with ordinary classroom instruction and group work. As the technological development goes further, the number of possible combinations will grow and the individual student will to a larger extent have the possibility to choose media and learning models that are best suited to meet his or her needs.

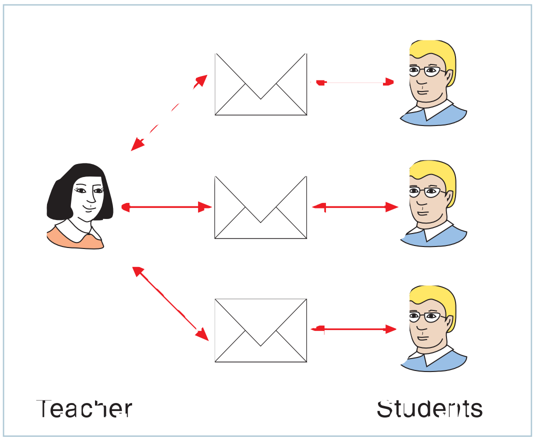


*Figure 1 First generation of distance education*

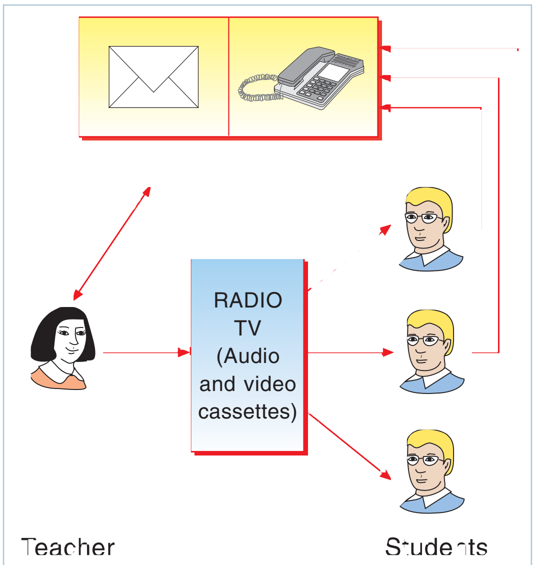


*Figure 2 Second generation of distance education*

### 2 The "generations" of distance education

The development in distance education may historically be divided into various generations, according to what kinds of technological devices that have been used at various times to establish two-way communication between teacher and students.

One way of presenting this development is the following model of three generations:

First generation was characterised by the use of mail only. The contact was based on written communication transported by the postal system and ran between the teacher and the individual student (ref. Figure 1).

Second generation used broadcasting (radio and television) and audio and video cassettes distributed by post to reach the students with teaching material. The two-way interaction was still mainly mail-based, but supplemented by the use of the telephone (ref. Figure 2).

Third generation saw the introduction of tools that opened up for a greater variety and flexibility of interaction. Electronic mail and computer based conferencing represented asynchronous communication that proved to be stimulating and motivating to both teachers and students. An important aspect was that it allowed for students to interact with each other. This generation also saw the introduction of videoconferences and videophones (ref. Figure 3).

[1] *A more thorough presentation of the historical development of distance education is given in the article* "Distance education – response to social needs or technology in search of application?" *in this issue of* Telektronikk.

Following these three generations, a fourth generation is about to take shape. This is the generation where all communication has turned digital, multimedia technology is being introduced into the market, and the interactivity and flexibility of both technology and learning and teaching models are much improved.

## 3 Telenor's engagement in tele-education

Telenor (Norwegian Telecom) has since the mid 1980s been working in the field of distance education and has during a ten year period run a large number of field trials in this area.[2] These trials have had two objectives. The first was to test previously established services to gain better insight into the advantages and disadvantages they offer when used for distance education purposes. The second objective was to devise new telecommunication services which could be used for this purpose, by testing new equipment in conditions specific to distance education. By doing so we have been able to gather information from users which is of great value to us when developing these services, material which not only helps technological development but which also sheds considerable light on the educational and communicational aspects of tele-based distance education.

The field trials have partly been initiated by Telenor, partly by other establishments. Some of the trials have been joint projects. Others have been carried out without Telenor's direct involvement, though Telenor has been responsible for the assessment of these. Telenor has emphasised the need for a thorough evaluation of all the trials the company has been involved in, and the reports produced contain a considerable amount of user findings.

There are many circumstances that can affect the outcome of a trial. Key aspects in every distance teaching situation are economic, educational and organisational considerations. The extent to which a given medium is suited to a specific distance education context will therefore depend on a number of factors and the way these factors interact. The technology will, in other words, be only one of many aspects that must be evaluated when selecting a suitable communication aid for distance education purposes. However, the technology is important in itself, because it will to a great extent determine the form of communication. It opens the way for certain possibilities while simultaneously setting limitations. In the following we will present some of the experiments Telenor R&D has been involved in and experiences gained from them.

[2] *There is a separate article in this issue of* Telektronikk *on* "Field trials".

## 4 Audio-based communication

The telephone is internationally a much used communication aid in distance education. A number of countries have many years of experience in utilising telephone conferences as a way of teaching and gathering groups of students for discussion purposes. In Norway the telephone has primarily been used by correspondence schools as a means of direct contact between the tutor and individual students. Open arrangements allowing students to call the tutor/school when the need arises have shown that it is difficult to get the student to call on his or her own initiative. However, there is plenty of evidence indicating that direct contact over the telephone is an important means of motivating and supporting the student in a period of private study. The correspondence schools have therefore gradually incorporated telephone contact with the students as part of the work-load of correspondence school tutors.

### Telephone conferences

In telephone conferencing it is possible to link up several locations simultaneously to form a group "meeting-place" over the telephone. In this way contact can easily be made between tutors and students who live a long way from one another. Telephone conferencing can be used to spread information, to maintain social contact and for professional activities.

One of the first trials Telenor R&D took part in, during the winter of 1988–89, was testing telephone conferencing as a supplementary service in adult education. The trial formed part of a project at a high school in the northern part of Norway, where an adult education course in history was started in the autumn of 1988. A total of 30 people applied to take part in the course, which was based on a correspondence course. Since they lived far apart, there was no point in arranging *combined teaching*, as is often used in Norway, i.e. local classes are held once every week or fortnight as a supplement to the correspondence course. In this project, as an alternative, weekly classes of one hour duration were broadcast on local radio.

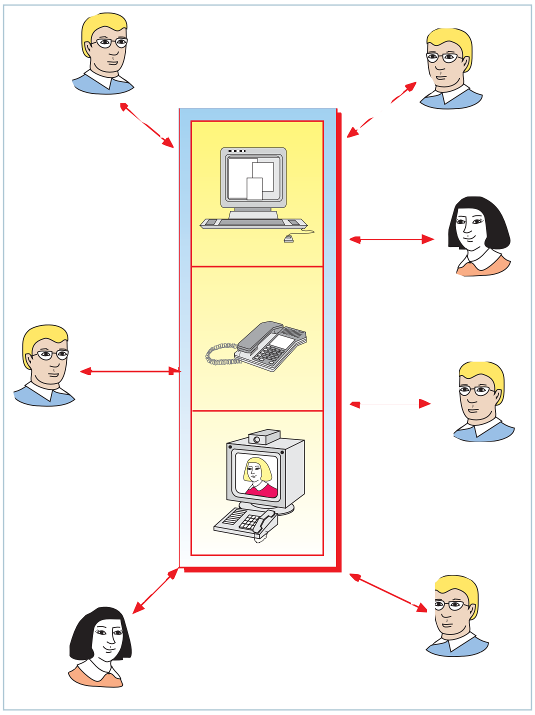

*Figure 3 Third generation of distance education*

In addition, telephone conferences were used to bring the course participants closer to one another and to create a "classroom environment" despite the great distances involved. This worked very well. Most of the participants had never heard of telephone conferencing before the trial commenced, and there was little enthusiasm among the participants for testing this facility. After trying telephone conferencing a couple of times, however, the participants were so pleased with the benefits gained that they wished to continue using it.

Interviews with the participants showed that telephone conferencing was important both from a social and an educational point of view. Seen in terms of social benefits, it would appear that telephone

*Figure 4  The Tandberg Vision videophone*

conferencing motivated the students to "meet" others similarly situated with whom they could discuss problems they had in common. In educational terms, telephone conferencing gave the students the opportunity to discuss those parts of the syllabus that had not been covered sufficiently in the radio broadcasts and to talk about topics which they found difficult.

The course participants achieved very good examination results, and the course drop-out rate was low. Although this tells us nothing about the significance of telephone conferences in isolation, it does indicate that the tested combination of media worked well for the participants.

The model chosen in this project is considered to be of great interest for distance education, because it is based on simple, inexpensive and easily accessible forms of media with which the users were already familiar. Both radio and telephones are media we may assume can be found in every Norwegian household. Radio broadcasts also have the advantage that they can be recorded and listened to at a later juncture for revision purposes. Although telephone conferences demand a certain amount of conversation discipline which will be unfamiliar to most people who are only used to normal telephone conversations, this is something that the majority of individuals quickly become accustomed to.

Another important advantage of telephone conferences is their flexibility. They can be established between individual students or groups of students, and the location of the participants is of no consequence. Within the field of distance education, telephone conferencing is considered to have great growth potential, considering the widespread distribution of the telephone, its user-friendliness and low level of cost.

## 5 Visual communications

Visual media used for distance education purposes can be divided into two main categories: *one-way* and *two-way* communicating. Television is a one-way communicating visual medium, which has played an important role as a medium for distributing educational programs to the population both in Norway and other countries. It may be transferred via the national or private broadcasting networks, local cable or satellite. One-way communicating media provide few opportunities for feedback from student to tutor. Two-way communication can be provided, however, by combining television teaching with other media, e.g. telephones, fax machines, and/or computers. In Norway, we have made some experiences with satellite distribution of lectures combined with telephone conferences.[3] We have also made som experiments with videotelephony in this connection. They have so far been limited, but very promising. Most of the students reported the use of videotelephones to be an improvement as compared to telephone conferences, mainly because they experienced a closer contact with their teacher.

At Telenor R&D we have to a large extent been engaged in experimenting with two-way visual communication in the telecommunication networks, i.e. videoconferencing and videotelephony. This is due to the fact that videoconferencing was introduced as a public service in the Norwegian telecommunications network in 1983, and that Telenor R&D at an even earlier stage, in the late 1970s, initiated studies in the field of image compression techniques which eventually, in 1991, resulted in a Norwegian made videotelephone (produced by the Norwegian company Tandberg A/S) (ref. Figure 4).

The transfer of broadcast quality real-time images requires a great deal of telecommunication network capacity. By using coding techniques to digitise and compress the information contained in the image, the transfer capacity required can be reduced. While the transfer of an image of broadcast quality requires a capacity equivalent to approximately 1000 analogue telephone lines, videotelephony can be transmitted on only one single digital telephone line (64 kbit/s) (ref. Figure 5).

Reducing the transfer rate does result in a loss of quality. In distance education, *videoconferences* and *videotelephony* are nonetheless interesting services. By utilising two-way visual communicating media it is possible to produce a teaching situation which in many ways resembles that found in traditional classrooms:

- The teacher and students can see one other. This gives them a feeling of proximity and direct contact, which has a motivating effect.
- It is possible to visualise the teaching by
  - showing text, illustrations and objects with the aid of a document camera
  - producing text and figures on a blackboard, on paper or a personal computer
- It is possible to show movement which can be of benefit when
  - giving instruction in subjects that involve motion, e.g. drama, music and physiotherapy
  - demonstrating work operations and laboratory exercises.

The similarity to classroom teaching makes many teachers feel comfortable using this technology because it allows them to act in much the same way as they are used to.

It should be recognised, however, that distance education no matter what technology is being used, is a totally different method for both teaching and learning. Using this medium therefore needs careful preparations from both teacher and student.

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[3] *Some Norwegian experiences from satellite distribution are presented in the article* "Something in the air – Norwegian experiences with telelecturing in flexible education" *in this issue of* Telektronikk.

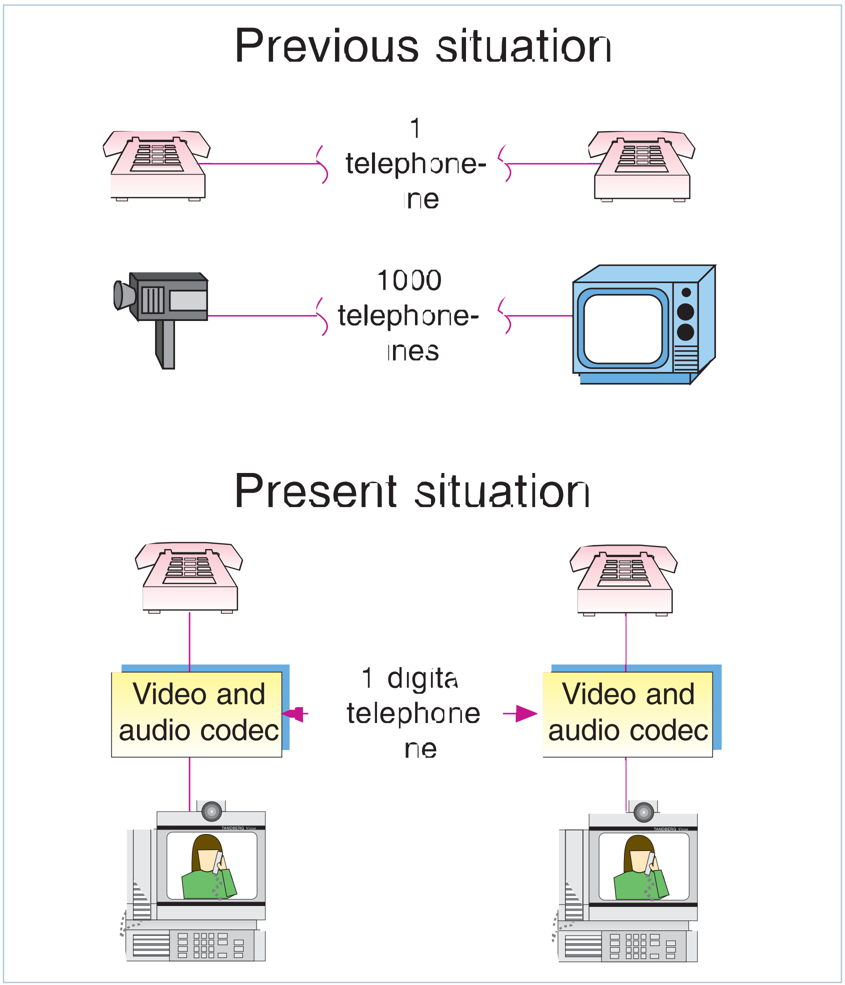


*Figure 5*

Telenor R&D has been engaged in a number of field trials using videoconferencing and videotelephony in distance education. It all started with a project called "Telematics in the North" launched in 1988, in which videoconferencing was defined as an area of investment. Telenor R&D played an active part in this, in two areas in particular: telemedicine and distance education. Within a short period of time, a number of locations had installed videoconferencing equipment. There was an especially large amount of activity in Finnmark (the most northerly part of the country), where the great distances between participants and lack of teachers meant that many environments found this form of distance education very interesting. The impact this form of teaching could have on rural areas and small communities was thought to be of great value.

Most distance education trials involving videoconferencing have been between two locations, so-called point-to-point connections, where a teacher in one location has taught students in another. In some cases a group of students have been present in the same location as the teacher, at the same time as the course has been followed by a group of students over the telecommunications network. In the course of time technical developments enabled the simultaneous transmission of a teaching session from one educational establishment to several locations, and this has been utilised in a number of contexts. Eventually, technology moved even one stage further. In the summer of 1991 it became possible to link up several locations in one full multi-point conference, that is, all locations became able to see and hear one another (ref. Figure 6). Telenor R&D has participated in trials involving all these different models.

The very first trial involving videoconferences took place in a fishing village on the northern coast. A newly started elementary course in fishery studies at the high school lacked qualified teachers in a range of subjects. This was compensated for by organising for the transmission of direct teaching over the telecommunications network. In addition, employees in the local fish processing industry got the opportunity of further education through lectures given to them on the screen.

Soon other examples followed. Regional college centres saw videoconferencing as a tool for reaching new categories of students and students unable to attend courses at campus. The Norwegian military service used videoconferences for distributing courses to locations spread all over the country. Telenor used it for internal training of employees. Hospitals used it for further education of doctors and nurses.

With the introduction of videotelephony, two-way visual communication has become interesting to a larger amount of

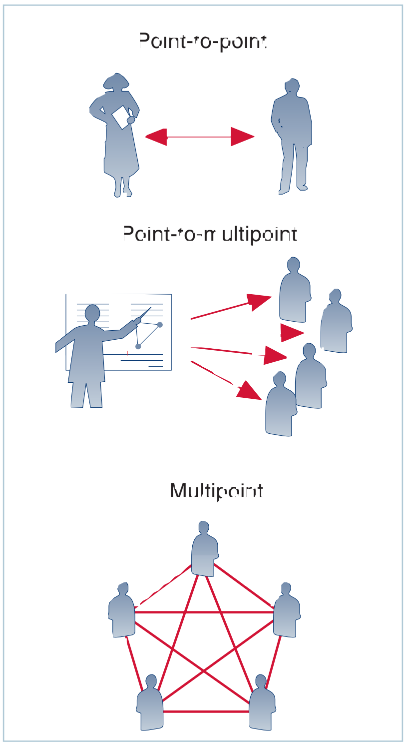


*Figure 6 Models for use of videoconferences*

educational institutions, due to the lower cost and better accessibility as the digital network is being built out – ISDN (Integrated Services Digital Network). Today, there is quite a large number of institutions using videotelephony for educational purposes in Norway.

It is used both for transferring lectures, supervision, consultation, habilitation, and discussion groups. The technical installations differ from case to case, depending on the number of participants and the subject being taught. At Telenor R&D we have made certain efforts to develop solutions to satisfy the needs of both teachers and students as they have been expressed in field trials we have been involved in.[4]

Experiences made from all the projects that have been using videoconferences or videotelephony are very much the same when it comes to the communicative aspects. Both students and teachers think it important to see each other. They find that "meeting on the screen" makes them feel close. Especially the students report that they feel they get to know the teacher quite well. Nevertheless, as with all kinds of distance education courses, it is recommended that teacher and students meet each other before a course starts.

All the Norwegian trials indicate that both teacher and students quickly become accustomed to the technology and that they easily learn how to operate it. It is worth noting that the quality of the sound is felt to be far more crucial to successful communication than the quality of the images.

As all the teaching takes place on a screen, it becomes more structured than in the classroom. It demands a high degree of concentration from both teacher and students, and even though it allows for continuous interaction, experiences show that spontaneous interaction is hard to achieve. The dialogue has to be planned by the teacher, and he or she must to a large extent invite the students to interact. Pedagogically, this is where the greatest challenge lies in further developing the use of videoconferencing and videotelephony in distance education, to find good methods for utilising the possibility for two-way communication.

## 6 Text-based communication

The most commonly used form of text communication in distance education, besides hand-written letters, is computer-based communication which allows for electronic messages, letters and contributions to be transferred at high speed. There are also systems which enable the transferral of hand-written messages via the telecommunications network, *electronic digitising pads and electronic boards*. At Telenor we have in co-operation with the university of Oslo developed an electronic classroom, combining the use of electronic boards with audio and live video communication.[5] Also the *fax machine* has a great potential in distance education. Telenor has tested all these forms of text-based communication. Here we would like to focus on computer mediated communication, which is expected to grow rapidly in the years to come.

### Computer mediated communication

The use of computer mediated communication in distance education provides the opportunity for two-way communication regardless of time (asynchronous communication) and place. Tutors and students are able to work whenever and wherever they feel like it. Since it is a flexible and readily available form of communication, computer mediated communication meets many of the requirements of the traditional distance education institutions. People's access to a computer is nonetheless still limited, although the rapid rise in the number of computer terminals both in the workplace and at home makes computer mediated communication an increasingly interesting alternative in distance education.

During the last couple of years, we have seen a dramatic growth in the use of the Internet, and this is thought to become the dominating medium for computer mediated communication in distance education in the years to come. Many distance education institutions do, however, already have long and valuable experience in the use of various computer conferencing systems. The various systems may differ in terms of user interface, menu system and organisation of conferences. Common to all of them is the fact that they include three principally different forms of communication:

- **Electronic mail.** *One-to-one communication:* messages, comments, questions, information and answers can be sent as electronic mail from one person to one or more addressed recipients.
- **Electronic bulletin boards.** *One-to-many communication:* information is sent electronically from one sender as an open message to a larger number of unaddressed recipients.
- **Electronic conferences.** *Many-to-many communication:* messages, questions and comments are sent electronically from one conference participant to a common conference, a forum established for a limited number of participants. The message can be answered by one or more of the other participants. The conference thus resembles a meeting place for students and tutors where communication occurs freely among all the participants.

The metaphor often used for computer conferences is the school building itself. As a student/participant you have to be admitted. When you are "inside", you may choose whether to read your mail, to read a notice on the board, to be social and chat with others in the "café", take part in a thematic discussion that is open to everybody or, if you are a "member", discuss with a smaller circuit of people "behind closed doors".

Experiences drawn from the use of computer conferences so far clearly show that the number of students who access the conference merely to read messages far exceed those who log on to the system to send comments. The degree of activity among students also seem to be strongly related to the activity of the individual tutor, i.e. the more active the tutor, the more active his or her students.

In Norway it was the largest of the traditional correspondence schools that first began to utilise computer conferences as an integral part of distance education. Computer conferences proved well-suit-

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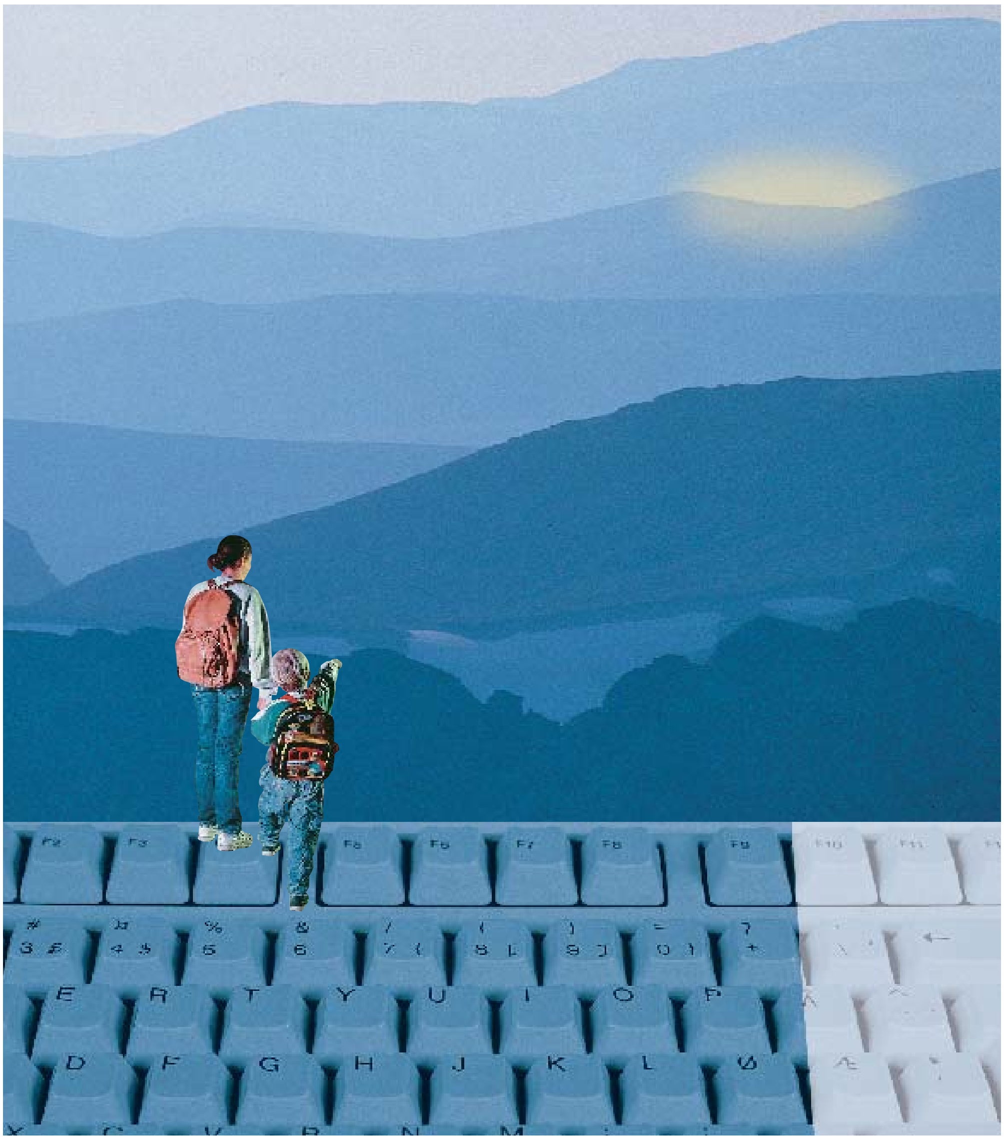
[4] *Examples of this is given in the article* "Field trials – the need for user participation in telecommunications development" *in this issue of* Telektronikk.

[5] *This is presented in the article* "Distance education in the distant classroom" *in this issue of* Telektronikk.

ed to their established structure and the service could be offered to students throughout the country. Telenor R&D supported in the late 1980s trials involving computer conferences at two of our largest distance education institutions (NKS and NKI). We also tested the use of computer conferences as part of a joint Nordic education programme for researchers, in co-operation with the University of Oslo.

There is now a large number of educational institutions in Norway which are using computer mediated communication as an integral part of their courses. Some have courses that are based completely on electronic distribution and communication, and the use of Internet is rapidly growing.[6] The introduction of electronic networks has also led to the collaboration between institutions and we see new ways of organising studies that offer greater openness and flexibility to the students.[7]

As the penetration of computers into homes gets higher, and the demand for more flexible ways of learning grows in conjunction with a greater need for updating the competence level of the work force, the use of electronic based courses is expected to "explode".



## 7 The Internet

As mentioned above, the use of the Internet for distribution and communication in distance education is growing rapidly. This is a challenge to course designers who need to learn new methods for presenting a course in a new context. Some environments have started working on guidelines for designing WWW-based courses.[8]

The fascinating thing about the Internet is that it combines all the previously separate modes of communication; text, sound, images, graphics and live video (although still of some limited quality). It gives you direct access to all the digitally stored information in the world. You may communicate as easy with persons in your own neighbourhood as with persons living at the other side of the earth. You may also make your own presentations that can be read and responded to by anybody anywhere. This is obviously a challenging technology to all kinds of educational institutions.

At Telenor R&D we have so far little experience ourselves with the Internet in distance education. We have, however, since the summer of 1996, been engaged in the utilisation of the Internet in schools. In conjunction with that, we have developed learning material for teachers and IT-co-ordinators at schools. This has been offered as free videos to all schools, and as courses given locally in twenty regions of the country. The course "Internet in education" is about to be transformed into a WWW-based course, which is economically supported by the Norwegian Ministry of Education.

Our engagement in schools is part of Telenor's initiative to provide teachers and pupils with limitless communication, a project called "The electronic school

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[6] *One example is NKI, see the article* "From electronic mail to Internet – where does it take us?" *in this issue of* Telektronikk.

[7] *See the article* "Telecom and Open Learning – a challenge to institutional cooperation" *in this issue of* Telektronikk.

[8] *See the article* "Design guidelines for WWW-based course environments" *in this issue of* Telektronikk.

path" containing the delivery of communication lines and equipment, a Web-site for schools[9], the above mentioned educational offering and research.

In the field of research we have signed a treaty of agreement with the Ministry of Education on collaboration from 1996 to 1999. The treaty is meant to support the Ministry's plan for implementing information technology into Norwegian schools, the aim being to make all teachers and pupils into personal users of IT.

We have, as part of our research in this field, started a joint project with British Telecom Labs, connecting two schools in Norway with two schools in England. The intention is to let pupils from both countries communicate and collaborate by using videotelephones and the Internet.

This project is an example of two important trends in today's education:

- The internationalisation of teaching and learning[10]
- The merging of distance education with classroom teaching.

## 8 The future

As new technology is brought into the classrooms from primary schools upwards, there will no longer be a clear distinction between ordinary and distance education. Collaborative work may take place between pupils and teachers across national borders. Experts from all over the world may be brought into the classroom for consultation, and guest lectures may be given from wherever the lecturer is situated. Thus, we will see a merging of distance and classroom teaching.

We will also see a great variety of technologies being used. Telecommunications will become more and more dominant, although they will still be used in conjunction with local gatherings and physically distributed media (books, letters, cassettes, CD-ROMs). The merging of various forms of communication as we have seen in the Internet, will also appear in other media. We already have mobile telephones that at the same time are tiny personal computers. WEB-TV is about to be introduced, giving you access to the Internet from your ordinary TV set.

Within a few years we will also have the possibility of meeting in virtual space, trespassing the screen and entering the artificially created world itself. There, we will interact with the representations of other humans. At Telenor R&D we are developing VR solutions that may prove to be of great interest to distance education in the future.[11]

Whether we like it or not, the technological development is a major driving force in the development of education and must be taken seriously. Technology itself cannot, however, solve the need for lifelong learning in tomorrow's society. Much work has to be done at the educational institutions in terms of pedagogical and organisational development. Only when technology, pedagogics and organisation are developed in conjunction can our educational institutions manage to meet the challenges of tomorrow's demand for flexible and open learning.

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9 *The address to our Web-site is: http://www.skoleveien.telenor.no.*

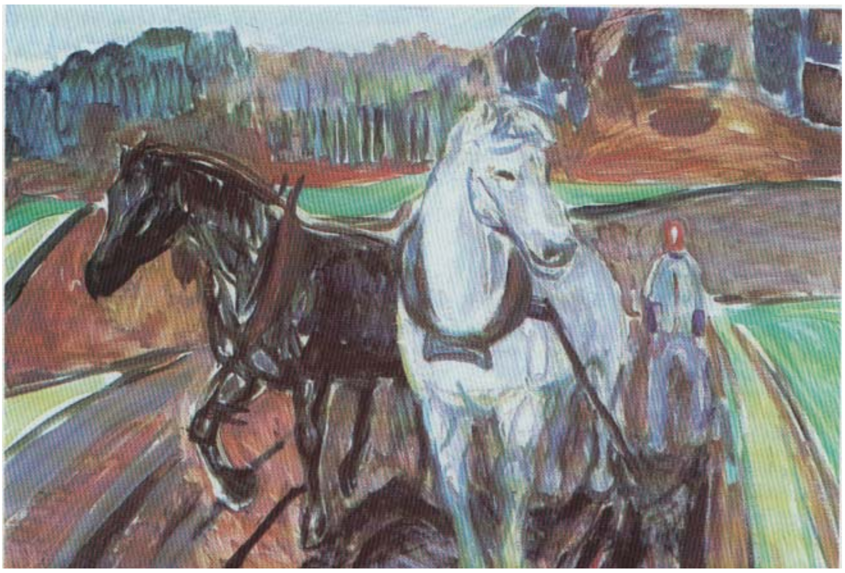
10 *Further reflections on this are given in the article* "The globalisation of education" *in this issue of* Telektronikk.

11 *An example of this is given in the article* "Learning in collaborative virtual environments – impressions from a trial using the Dovre framework" *in this issue of* Telektronikk.

# Distance education – a response to social needs or technology in search of application?

BY ERLING LJOSÅ

One of the Norwegian painter Edvard Munch's pictures, 'The Plough Team', shows a man who is out ploughing. He has two sturdy horses drawing his plough, one is black, the other white. They are harnessed together, but in the picture it appears as though each is pulling in slightly different directions.



The development of technology is indeed a part of the development of a society, but even so we can sometimes feel that technology is an uncontrollable member of our 'ploughing team'. It is therefore a relevant question to ask: is it society's real need which is decisive in the type of distance learning that is on offer? Or is distance learning to some extent a technology driven invention in search of relevant application?

This question of the relationship between technological and general social development in connection with distance learning is indeed tightly knitted. There are few, if any, social researchers who have been interested in this subject, so there are few research or literary sources available to lean on. I shall try to open up the topic in a few different ways – by looking at historical trends, some typical examples and a few personal reflections.

## The first technological stage – education by post

> Bernhard R. Tynes *started a furniture factory in 1927 in Sykkylven in Sunnmøre, when he was 20 years old. In 1930 he expanded and built a new factory. When he was only 13 he had begun to make wooden buttons, and at 16, ski poles. He was one of the founders of the 'industrial fairytale' in Sunnmøre.*
>
> *In 1934 Tynes took a correspondence course in technical drawing, freehand design and business accounting. His first technical education was from a carpentry college in Molde, but he gradually became aware of a need for further education in design as part of his job as manager of an expanding furniture factory ... Tynes himself designed the furniture which was to be put into production, and the factory in Sykkylven became a model company.* [2]

More than sixty years ago we can already see that correspondence courses were used to increase competitivity in small Norwegian companies. Indeed, correspondence courses have been in use in such connection for over eighty years now, in Norway. Distance education, in other words, is not a recent phenomenon based on new technology. It has been in widespread use over large parts of the globe for the last century or more. Even so, from the very beginning, distance education has been affected by general technological developments. Pitman, the oldest correspondence college in Europe, was started in England as soon as the national postal system had been established. Indeed, the Post Office communication system was a prerequisite for the growth of correspondence colleges. This system still works extremely well, at any rate in Norway. It is cheap, effective and reasonably fast, and covers as near 100 % of the population as possible.

When Ernst G. Mortensen ventured to start NKS (the Norwegian Correspondence College) in 1914, the basis for his success was not new technology. He himself had no more education than a 6 months business course after a basic education, but he was desperate to start his own business. He took the initiative in a previously neglected area in Norwegian education, namely business education. The two first courses – 'Double entry bookkeeping' and 'Business correspondence' – filled a need for practical skills in a rich variety of establishments in many small local communities. He was lucky with his timing, for work was plentiful during the First World War. Mortensen wrote in his advertisements and school timetable, "We live in restless times. Never before has work pressure been so intense as now, and never before has demand for skills been so high", and indeed he was correct. The need for working skills and education was acknowledged to an increasing degree, and the public at large was thirsty for knowledge.

The Norwegian school system was in no position to meet this need. Certainly, there were public schools and business schools in the larger cities, but very few people had either the resources or possibility of travelling from home to attend these courses. Loss of earnings, dear maintenance and school fees made it difficult for most. At the same time knowledge was an important prerequisite for higher paid work and social advancement. The two course offerings from NKS cost the dizzy sum of 40 kroner, at a time when a normal skilled workman's wage was about 0.50 kroner per hour. Even if that was expensive, school support costs were much higher.

At that time business education was the poor relation in the Norwegian school system. The industrialisation and development of business at the turn of the century created a large demand for training. Business education gradually came to consist of a range of short courses, from three months and upwards. At first it was mainly private, without state or local authority support. In 1907, for the first time, there was a demand for some level of education or experience to gain a business certificate, and gradually there also developed a public demand for specific course contents. The Central Bureau for Statistics wrote, after reviewing the statistics for 1909:

> "The available information shows that the overwhelming majority of businessmen have no specialist education, and that on the whole they are recruited from the lower ranks of society."

Ernst G. Mortensen was successful with business correspondence courses, and from 1917 the range of courses offered was greatly increased, including technical and agricultural courses. In 1920 the college offered different courses and combinations for businessmen, shop assistants, bookkeepers, secretaries, council treasurers, bricklayers, carpenters, electricians, machinists and civil servants in the customs, postal and telegraph services. In addition, a course was developed to help in preparation for the Lower Secondary School examination, for those interested in raising their general standard of education. These courses were very popular with teachers – so-called seminarists – who wished to gain qualifications to teach at a higher level in the school system.

Obviously, the correspondence courses Ernst G. Mortensen established in Norway were not technology inspired. They had their origin in a social need for education and knowledge development, closely connected to practical work and industry. The geographical aspect, which is often stressed, was only one aspect of this social adaptation.

Correspondence courses built on a well understood technology, but even so, represented a pedagogic development that was truly radical. They were received on the one hand with praise, but on the other in the educational establishment, with scepticism, even though the 'seminarists' seized the opportunity for further education. It took eight years from the foundation of NKS before this style of education was even mentioned in the current education press.

## Technology and distance education

The postage stamp and a coherent price mechanism for *post* was one of the historical prerequisites for the growth of modern distance education. Another technological connection was the *printing and book trades*. Rightly so, there were a number of correspondence colleges which grew from normal schools, and individual creative operations with stencil machines and similar apparatus. But very often we find a connection with a publishing house. In Germany, Gustav Langenscheidt (later a well-known publishing name!) worked on a self-study course with a Frenchman, Toussaint, as early as 1856, and a book dealer called Hachfeld produced a course in technical skills from 1895 [7]. One of the largest and best known American correspondence colleges, International Correspondence Schools, was founded around 1890 by a newspaper editor in Scranton, Pennsylvania, as a result of a series of articles on worker protection in the mine industry.

Newspapers have had only sporadic impact on distance education, but on the other hand, connection to a publishing house has been common and lasting. Development and production of correspondence training material has a technological relation to both book and magazine production. Ernst G. Mortensen is a good example of this. He was engaged in book publishing and printing, and established himself as one of the major magazine publishers in Norway in the 1930s.

New media and technologies gradually created new opportunities for offering education. *The gramophone record* made inroads in language courses at Langenscheidt at least as early as 1906 [7], and obviously was a great stride forward in improving the practising of correct pronunciation. Later, the record was naturally replaced by tape and then by cassettes. These are media which integrate easily with correspondence courses.

*Broadcasting* on the other hand is a considerably different medium. The first attempt at schools broadcasting by radio came in the 1920s. The radio lecture was a popular programme format, and was early used to supplement correspondence courses, e.g. in Germany, Canada and Australia. Broadcasting has often been concession controlled and consequently reserved for larger, national players. This is particularly so with television, which began in the mid-1940s. Here again education was an important element. For example, Chicago TV College in around 1960, was an important forerunner of the Open University. Right up to present times, broadcasting has a particular position in distance education, either as schools broadcasting, or in combination with correspondence courses and study circles [4]. In Norway, we experienced the first co-operative project in language education between NRK radio and a correspondence college in 1949, and since 1960, adult education via radio and television has been a continuous offering. NFU, the State Institution of Distance Education, was founded especially to organise this type of co-operative approach, in 1979.

*The telephone* had been in existence long before it was used for distance education. The first attempts were made as early as 1939, but its use became more widespread from around 1960, especially in North America [9]. The most common use today is in telephone conferencing. Even though the telephone has a place in distance education, it has never really taken off in the sense of having a central position. Even though it can obviously function well in telephone conferencing, it has its limitation as an audio based medium.

*Video* was a new wonder-child, much discussed in the early 1970s. Special companies were set up to develop and market educational videos. Today, we find little trace of them. However, video cassettes have acquired a foothold in education. We find both programmes of broadcast quality for a large market, and simple productions with recordings of lectures or a short introduction as a basis for group work. As a rule video is integrated with a more comprehensive educational project. The length of time it has taken for video to take hold has obviously some connection with price levels and how widespread video players have become.

In the mid-1970s experiments began with use of *satellite-carried* distance education in Canada and the USA. In some cases it was combined with a reverse channel over the telephone network, and a new form of distance education had been born. In contrast to the normal television it was possible to ring in during the broadcast, ask questions, or join in discussions. The media was more interactive, and this interactive use of broadcasting has become quite popular, especially in North America [6]. In other countries, including developing countries, satellite is most often used only to carry television programmes, without interaction. In Europe, trans-national educational broadcasting via satellite was initiated around 1990, with programme input from educational institutions and free transmission time. Although funding vanished, transmissions continued at a lower level, and a number of national systems also exist. We also have some commercial, quasi-educational channels. In Norway, NORNET represents an attempt to introduce the more interactive style of distance education.

In parallel with satellite use, the television companies began to send *pictures over the telephone network*. It is possible to send pictures both ways, and multiple sites can be connected in video conferences. For a long time this was fairly expensive, but with steadily improving compression technology this development has led to the video telephone, at the same time as the ISDN network has provided a higher transmission rate. This means that cost is no longer the chief problem with this technology, but even so, there are limits when it comes to organising many participants and many sites simultaneously [10], [11].

*Computers* represent a technology that, so to say, has revolutionised the whole of society since the Second World War. Obviously, it has also been adopted for the administration of distance education. It has taken a longer time before IT made inroads for educational purposes. We may distinguish between two main forms:

- CBL – Computer Based Learning
- CMC – Computer Mediated Communication.

Computer based learning has never had a large application in distance education, for many good reasons. These include cost, lack of standardisation, little flexibility, difficult access to equipment, etc. In the 1970s, NKS developed a programme for correction and commenting of student replies, which can perhaps be considered in this category. It has not been maintained.

Use of computer mediated communication appears to have a larger application. The first conference systems began to be used 10–15 years ago. American institutions again were the first, but there has also been Norwegian activity and considerable development [8], [12]. NKI introduced its own system in 1987, and NKS launched its ‘Electronic College’ two years later. The Ministry of Education had its own ambitious project in this field, and several higher education institutions became involved. The current NITOL project, with the colleges at Trondheim, Stord and Agder as central partners, is in some respects an outcome of the initiative of the Ministry.

Over the last few years it has become clear that the Internet stands out as a sort of common highway for most of what happens in computer mediated communication. The World Wide Web is just a few years old, but today it is the standard domain in the Internet world. In this way, de facto standards make it easier to develop distance education as well. Already today, hundreds of distance courses have found their way onto the international market through Internet. Also Norwegian institutions, among them NKS, prepare new and exciting initiatives in this area.

What we are now seeing is that many of the technologies I have discussed here are in the process of blending together. Databases, telephony, broadcasting, printing technology, etc. – they will all come to be based more and more on the same digital technology. Multimedia replaces the individual media we know today. That will have considerable and important consequences for distance education.

## Which training is suitable for social development?

What do we really mean when we say that education and training should be suited to the development of a society? Can we say that distance education as a form fills this need, and in particular, that distance education in Norway is suited to the social developments we see? It is easier to ask than to answer, but even so, I will try.

Just before Christmas 1995, the EU commission issued a so-called *White book on Education* [5]. That document pointed to many important challenges and aims which are relevant to education in a modern society. Generally, we can say that education and training should serve three main aims: personal development, social integration and enablement for work and social life. How can we relate this to the current social developments?

The White book points to the multiplicity of factors that affect education’s place in social developments, and there are three chief factors that drive more in-depth changes than most. These are:

- Future growth of the information society
- Internationalisation of the economy
- The effects from scientific and technological inventions.

The social changes connected with IT are often compared with the effects of the Industrial Revolution. I am certain this can be disputed, but I am also certain that the effects are considerable. First and foremost, IT has changed work processes and the way we organise production of goods and services. Mass production is giving way to smaller, tailored runs. Work is being organised more flexibly, with teamwork and companies in a network. Job contents are more varied and demanding, at the same time as people become more dependent on each other in a complex system of functions. Much routine work is disappearing, and in its place more skill intensive work and workplaces are growing up.

If we see this in relation to education, it means obviously that the content of education should be re-focused, so that it covers the new skills needs. In addition, a technological convergence is taking place between education and the workplace. That will be meaningless if education continues to use a classroom and blackboard with a teacher at a lectern and students with desks in a row – if education should prepare us for life in a modern society. Computer tools and communications media ought to be natural aids, and training work ought to adopt project work, independent responsibility and cooperation on how to utilise the information resources available in our information society.

The second important factor the White book points to, is the internationalisation of the economy. We saw a clear illustration of that during the recent workshop strike in Norway. When the media talked about the problems of a long strike, it was not the national consequences that were emphasised, but those for the car industry in Germany and Sweden, and the erosion of confidence in Norwegian industry internationally. We are all aware of the increasing difficulties we have in driving a national economic policy in a market which is more and more open to international competition. In addition, we should remember the cultural effects of the globalisation of society.

Again this development has considerable consequences for the education sector. It is not only the contents that are important, even more important is the considerable emphasis now being made – in all countries – that the education sector must contribute to enhance a nation's or region's competitive strength. Most economists believe that one of the most important competitive factors is a population's skill level. It is therefore believed that effort in education can also contribute to reducing employment problems, which has become a bugbear for our society. It is not enough in this connection to strengthen basic education in the normal education system, access to training and skills development must be available to all age groups.

The third factor mentioned, is current scientific and technological inventions. Here we meet a paradox, fifty to a hundred years ago most people regarded scientific progress as positive and promising. Today, we gain new knowledge at an increasing tempo, but at the same time it is increasingly regarded as a threat. Look at the environmental problems and the discussions on genetics. Much points to science and technology being split off from cultural development and basic ethical thinking. If we are to get everything in the right proportions before the next millennium, it is clear that the education sector has an important role to play. Above all, it cannot just offer more and more knowledge. It must contribute more than previously to creation of understanding for relationships, perspective and duties, across the traditional disciplines and cultures.

From these three factors we can formulate some general requirements for an educational and training system which is suitable for social development:

- Adopt available technology and available information resources
- Use workstyles which promote communication and co-operation
- Contribute to the fulfilment of skill needs in working life
- Provide access for all to a system of lifelong learning
- Link knowledge in working life and social conditions
- Give cross-disciplinary and cross-cultural understanding
- Strengthen a whole, social and ethical perspective.

## Does distance education satisfy these demands?

When asking if distance education satisfies these needs, I have to reply, in parts yes, in parts no, and partly that 'it depends ...'. If we start with the last two demands, there is no conclusive answer. I am afraid that distance education has not taken up the challenge, any more than ordinary education, of providing a complete understanding and perspective. What we positively can say, is that distance education is often used by people who wish to gain a greater breadth in their education. An engineer will study management, a secretary marketing, a social worker reads a little law, etc. In this way, we contribute to a strengthening of cross-disciplinary breadth of knowledge among the participants. An effective system for mature and further education must not only provide updating of skills from basic education. It is equally important to develop breadth and combine skills from various skills areas.

The great advantage that distance education has, lies in the middle of the needs list. Distance education was created exactly for the purpose of opening access to knowledge and education for new groups. It is considerably ahead in being an established system for lifelong training and updating and renewal of work related competence. As a system it is flexible, efficient and reasonably low in demands on resources. An example: Since 1989 between five and six thousand nursery assistants have completed a basic training for their work through NKS, without a single classroom being built, or a new full-time teaching position being created. That would obviously not have been possible with a traditional training organisation.

The two needs at the top of the list bring us back again to our main problem: distance education, technology and society. I would like to look at each of them in turn.

### Adopt available technology and available information resources

In my opinion, education that is to be in step with social development, must use available technology and information resources. This does not mean, at any rate in a negative sense, that it should be controlled by technological development. This negative feeling in the expression is connected to two dangers. The first is that people can be tempted to adopt technology too early, i.e. that technology can be available but not to the actual users of an educational offering. This leads to the possibility that choice of technology does not help to provide good education, but can be a new barrier that prevents users from participating in education. You can easily confirm that by looking at the historical progression. Many technologies have been adopted, but it has often taken a long time from the first adoption before they reached widespread use and were useful in connection with education.

NKS has over the last ten to fifteen years had a systematic, running evaluation and testing of new technological possibilities. In the course of this process we have, amongst other things, made a strategic choice – to invest in visual media, primarily television and video. There are many reasons for that choice, but one of the most important is that these two media are available to all Norwegians – and not only available – people also know for the most part how to work the equipment.

The second strategic choice we have made, is to invest in data communication. This is much more problematic as regards availability. Most people have indeed met and used a computer at work, and many also at home. But it is still a minority that has free access to communication. The most recent figures I know for connections to the Internet, are 21 %, of which 7 % are home users [1]. Even so, this is several hundred thousand people, and the numbers are increasing rapidly. We have chosen data communication as an investment area, because we are convinced that shortly, this form of communication will be normal in most workplaces, and it is gradually appearing to be easy and user friendly.

The second danger which causes technology to be viewed with suspicion, is that we use a technology which is inappropriate to our goal, or we use it in an unsatisfactory manner. There is nothing unusual in this, and it is not always the fault of the technology. There are times when the technology can be the prime mover, and sometimes the driving force, because it is easier to get money for a technically sophisticated experiment than for one that is less exciting, so to say. Perhaps it is technologists and people who are especially fascinated by technology who both develop and evaluate projects. It is unfortunately harder to pull in sceptics and the less capable, and projects can therefore easily be biased towards technology.

But even the non-technical and pedagogues can make wrong evaluations of what technology is best for. When it is new, indeed there is no-one who can accurately judge, and so there must be a proportion of trial and error before we reach firm conclusions. There is reason for stronger criticism when we sometimes see that we have not learned from our errors, but continue on the wrong tracks. This can be blamed on being in a rut, the financial position or organisational inertia.

One of the best known experts on technology and distance education, Tony Bates at the University of British Columbia in Vancouver, writes that there are two main patterns in today's distance education. Representatives of one stream maintain that the ideal method of education is group teaching in a classroom or lecture theatre, and that the nearer distance education can come to that ideal the better, and so technology should be used that best imitates that ideal. The other tradition is based on development of a teaching tool, preferably in the shape of printed texts and/or television programmes, which can be supplemented with different forms of communication between pupil and teacher. New technology can often be used as a supplement to this basic model [3].

It is not difficult to recognise these two traditions in Norwegian distance education. Tony Bates says – and I believe he is right – that both these methods of using technology are inappropriate and mis-directed. Technological development has reached a point where we should begin to develop new educational models. The problem is not that we are controlled by technology, but that we let our past experience come in the way of good use of the technology that exists.

### Adopt work styles that build up to communication and co-operation

The second demand in connection with development of the information society, is for workstyles that reflect the way in which we have begun to organise ourselves at the workplace. Organisation of projects, building of networks, co-operation and communication are some of the buzzwords. I believe that it is right to say that distance education has not come so far, it is still largely characterised by one-way communication and communication between teacher and the individual student. The picture has been influenced somewhat by extended use of combined education styles, where groupwork and class teaching are regular elements. Even so, I do not feel we have come far enough.

What is of interest, is that changes in the organisation of work processes are closely connected with technological frameworks and tools of different kinds. This also means that the compulsion to be in the same location falls to pieces. The extent of home working increases, and companies and projects are held together independently of geography. This ought to mean that the same technology and tools that enable a workstyle, should be able to be used in a similar way in distance education. In this way, we will have a style of distance education that mirrors real life, and contributes to building up co-operative skills. In this sense, technology can be a bridge-builder between the training system and the workplace.

This thought pattern has been the basis for NKS investing in data communication since 1989, especially in the use of computer conferencing systems. Even so, we have only been partially successful. This autumn, therefore, we are trying something new, in a different style. Firstly, we begin with the Internet, using standard tools. Secondly, we develop a new series, partly in a new style, of course offerings, which are closely connected to central training needs in the workplace, both public and private. We offer subjects such as practical project management, systematic improvement management and strategic competence planning. Thirdly, we try to build in more real-life examples, exercises and projects, that require participants to co-operate on tasks as a part of learning. As far as we are concerned that will be a new style of distance education, and we will certainly gain much experience in the process that will help us to improve.

## Conclusion

Finally, I want to remind you of the picture of the 'Plough Team' of social and technological development. Distance education should be a plough that opens up for new life and encourages growth in the furrows of development. It is obviously pulled by strong forces. Therefore, it also requires strong hands to steer the plough if it is not to deviate.

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# Field trials
## – the need for user participation in telecommunications development

BY TOVE KRISTIANSEN

**Developing telecommunications for use in distance education is a process of adjusting technical devices to diverse social and pedagogical settings. In this process it is important that scientists and users communicate to make sure that the services are developed to meet the user needs. The field trial is a method that allows for direct interaction between co-operating users, researchers and industrial partners. An example of a development process based on this co-operating triangle is the development of a Norwegian ISDN videotelephone and its adjustment to a specific distance education situation.**

## Technology must be studied in its use

The technological development is no doubt a major driving force in the development of distance education, and must be taken seriously. Knowledge about the various new technologies that are introduced is necessary in order to further develop the potentials of distance education.

Focusing too narrowly on technology, however, may be disastrous. We know that technology is but one of many issues that must be taken into consideration when studying distance education. Technology can only be understood when studied in its use. To some people new technology can be exciting, to others it can be scaring and alienating. It can bring people together, but it can also leave people in isolation. It can be a helpful tool and it can be a strait-jacket. In other words, there is very little we can say about any technology in distance education without considering the social and pedagogical setting it is going to be used in.

There are several aspects which have to be analysed in every particular distance education situation if the use of telecommunications is to be successful.

Attention must be paid to:

- The man-machine interface
- Pedagogical and communicative aspects
- The physical surroundings
- The organisational structure
- The social infrastructure.

## The users and their needs

The most important question to answer when considering what technology to choose and how to use it, is "who are the users and what are their needs?". The problem is that people are often unaware of what their needs or preferences are.

An example to illustrate this, is a project that was run in the northern part of Norway some years ago, where a further education course was offered by the local upper secondary school. The course was based upon a correspondence course, the intention being to give support through lectures given by a local teacher. This model of combined methods is much used in Norway. Typically, the local teaching will be given once a week or once a fortnight. In this case, the students lived scattered over such a large area that it was not possible to gather them on a regular basis to ordinary classroom teaching. As an alternative the teacher decided to broadcast his lectures through the local radio once a week.

The question arose; what about the social aspects of learning, and what about the two-way communication between students and teacher? As an attempt to meet these needs the project leader thought it a good idea to arrange telephone conferences in conjunction with the radio lectures. That would give the students the opportunity to ask questions and comment on today's lecture and at the same time give them the feeling of being part of a larger group of students. Now, this was not needs uttered by the students. As a matter of fact, many of them were not particularly enthusiastic about the idea of meeting each other in a telephone conference. Many of them had no experience with telephone conferences and others thought it to be just a meaningless add-on. Nevertheless, they agreed to try it, and what happened was that they found these telephone conferences to be so useful that they ended up expecting it to be a natural part of later courses they registered for.[1]

What this example illustrates is that people often have to experience the technology to become aware of their own needs, or rather, what needs the technology can fulfil. For instance, none of us had any need for a fax machine twenty years ago, but now that it is there, and we have become used to it, we can hardly manage without it. Thus, it is true to a certain extent, that new technology creates new needs. At the same time it is important that new technical devices and telecommunication services are developed to meet these and already existing needs. To achieve this, it is necessary that scientists and users communicate. Telenor R&D has seen field trials as a convenient method in this aspect.

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[1] *The project is presented in the article* "Telecommunications in distance education" *in this issue of* Telektronikk.

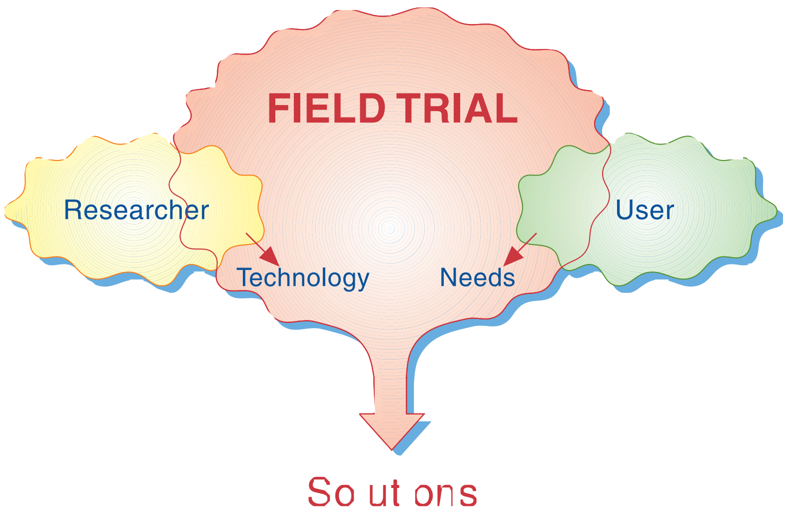


*Figure 1 Field trials*

## Field trials

Field trials as a scientific method acknowledges both the researcher and the users as participants in the development process. The desirable communication between researcher and user is achieved. It is a method which allows the researcher an opportunity to study the introduction of modern technology in a social setting very closely, whereas the users get direct influence upon the shaping of technological and pedagogical solutions.

Telenor R&D has over the past ten years been running a number of field trials in the area of distance education. Through the field trials we have learnt from the users what they have experienced as helpful in the learning process, what were the barriers, what needed improvement and what should be dropped. Through this dialogue with the users we have been able to refine and further develop our services, that is, both the equipment and the rules for use. Where appropriate we have involved our industrial partners in the development process. Much of our development work is based on a co-operating triangle, consisting of our research institute, the industry and the users (ref. Figure 2).

The initiative to new or further development work may come from either of the three partners. The users may express a need for some specific communication tools in a particular distance education situation. Researchers at our institute may predict the need for some telecommunication tool and invite users and industry to explore its potential, or the industry may come up with some new piece of equipment they want to test to see if there is a market for it.

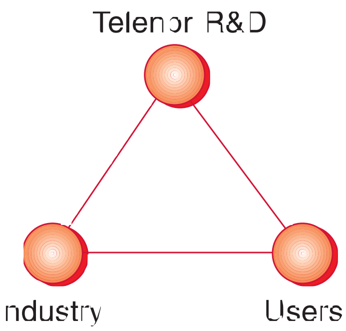


*Figure 2 Co-operating triangle*

In order to highlight the importance of user participation, the story of the development of the ISDN videotelephone will be examined in some detail, including the story of how it was put into use and adjusted to a specific distance education situation in one of our field trials.

## The development of ISDN videotelephone

The development of the Norwegian videotelephone was initiated at Telenor R&D [1]. Some of our scientists started studies in the field of image compression techniques already in the late 1970s. The main objective was to investigate the possibilities for transmitting live colour images with a bit rate of a few hundred kilobits per second. This would highly reduce the requirement for transmission capacity in the telecommunication network. At that time, there was already equipment available on the market for transmitting digital video on 2 Megabit per second channels. Compared to the transmission of ordinary analogue video as we know it from television, much was already achieved. Whereas the transmission of television signals requires a capacity equivalent to 1000 analogue telephone channels, the transmission of digital video on 2 Megabit per second channels requires a capacity equivalent to 30 analogue telephone channels. By 1984 our scientists were convinced that it would be possible to transmit live colour images at 64 kilobit per second. That would make it possible to transmit video on only one digital channel. At that time, very few people really believed that it would be possible to achieve the necessary compression ratio with acceptable image quality.

Nevertheless, in 1986 we signed the first development contract with the Norwegian company Tandberg A/S. During the following two years, a Norwegian low bit rate codec was developed, which made it possible to transmit live colour images over a single 64 kbit/s digital connection. It was first presented at the Telecom '87 in Geneva, Switzerland, and both the cost-performance ratio and the physical size of the equipment were major breakthroughs at that time.

As soon as the codec was ready for presentation we started our first field trials. This was not an ISDN codec. It had to be used on dedicated 64 kbit/s digital connections. It must be admitted that there were certain limitations to the quality of sound and image presentations of this first Norwegian-made video codec. Nevertheless, the quality proved to be sufficiently good for the videotelephone to appear as a useful tool for various categories of users.

Experiments were carried out in the areas of

- Distance education
- Remote supervision
- Sign language
- Remote surveillance.

These experiments gave us some very valuable experiences that were channelled back to the scientist developers at our research institute and at Tandberg. Encouraged by its technical success and several successful field trials, together with the emergence of ISDN, our research institute decided at the end of 1988 to continue work in the field of audio-visual telecommunication, concentrating especially on the videotelephone service. Work that had recently been started in international standardisation bodies also played an important role in this decision. The aim of the ISDN videotelephone project was to establish a public videotelephone service on ISDN on a trial basis from the beginning of 1993, which was achieved.

In the development of this terminal the scientists paid much attention to the experiences that had been made in the field trials. There was a clear need for operating procedures and controls to be as simple and easy to use as possible. From the beginning it was decided to incorporate the human factor aspect as part of the project to ensure a high degree of usability. Much effort was put into designing a terminal that would be just one piece of equipment with a minimum need for connecting cables and wires, that would be user-friendly in terms of installation and use. It should be as easy to use as a normal telephone. The terminal has now been industrialised and is being sold by Tandberg Telecom.

The early field trials proved that in areas like for example distance education, there is a need for connecting external devices to the terminal. When communicating with a group of people you need to connect an extra camera, a larger monitor, and perhaps also extra microphones and loudspeakers. These options are implemented in the terminal. The videotelephone is primarily designed for person-to-person communication. When used in distance education, adjustments have to be made, both technical and organisational ones. One example of that is the field trial that was carried out in one of the largest timber districts in Norway, the Trysil project. This project is a good example of how our co-operating triangle with users and industry works in such a development process.

## The Trysil project

In Trysil the local secondary school aimed to become a competence centre for different target groups in the district. A videotelephone was installed at the school, thus enabling the school to offer distance education courses to adults who would otherwise have had difficulty in attending any kind of further education. Instead of having to travel to a remote school, these adults could attend courses at the local school in the afternoons. There qualified teachers from other parts of the country would appear on the screen and communicate with them. In this project, the videotelephone equipment was used for three different courses [2], [3].

Communicating at a distance, through media, represents a new experience to most teachers. In addition to mastering the technology, there are several factors in such a situation that may place a strain on the teacher. It is important that the teachers be allowed to concentrate on teaching and establishing a dialogue with the students. Effort was therefore made in this project that operation of the technology be as simple as possible. We had in earlier field trials seen this need for integrated, user-friendly solutions.

To avoid a chaos of cables and wires and a multitude of buttons to operate, all the equipment was put into a cabinet, which was designed at our request by a small Norwegian firm called NovaKom. This was an integrated solution, where all the cables were hidden and all the equipment was easily operated with the aid of a few buttons. Feedback given by the teachers at an early stage of the project, led to further refinement of the design and functions of the cabinet until it had become the user-friendly solution we had intended it to be (ref. Figure 3).

In all three courses, the distant teacher was communicating with a group of learners, the size of the group varying from five to twelve persons. This made it necessary to enable the students to see the teacher and the presented material clearly by installing a large screen. A 46-inch screen was erected, featuring the ability to display a small picture within the larger picture. This gave the students the opportunity to see their teacher in a small video window while the rest of the screen displayed a written presentation made on the computer. It may be argued that seeing the teacher's face is of minor importance in the learning process. The psychological value of this "face in the window" should not be underestimated, however. Experiences show that it gives a feeling of "human touch" which proves to be motivating to the students.

A large screen is in itself no guarantee for clear presentations. Earlier experiences had taught us that much attention must be paid to how the material is presented. Due to the reduced quality of the coded video signal, it is crucial that the teachers do not put too much information into their presentations. It takes some practising to prepare good presentations. The teachers in this project were advised to spend some time practising on their own before starting their teaching, thus ensuring that the presentations would be readable to the students.

To establish a dialogue between teacher and students, earlier field trials had proved the audio connection to be more important than the video connection. Having to use a microphone to address the teacher turned out to be felt as a barrier by some students. In other field trials we had seen the interaction be hampered because too many students were sharing one microphone or because the students would have to move to reach a microphone. Based on these experiences, special effort was made in the Trysil project to give the students easy access to the microphones by installing one microphone for every two persons. By placing the microphones immediately in front of the learners, the physical barrier of addressing the teacher was reduced to a minimum (ref. Figure 4).

An attempt was also made to minimise the psychological barrier by allowing the students to meet their teacher in person before the course started. This has proven to be of vital importance for achieving a good dialogue in all kinds of distance education, and is highly recommended irrespective of the type of technology being used.

At the teacher's end an image of the whole group of students was displayed on a small monitor. Due to the quality of

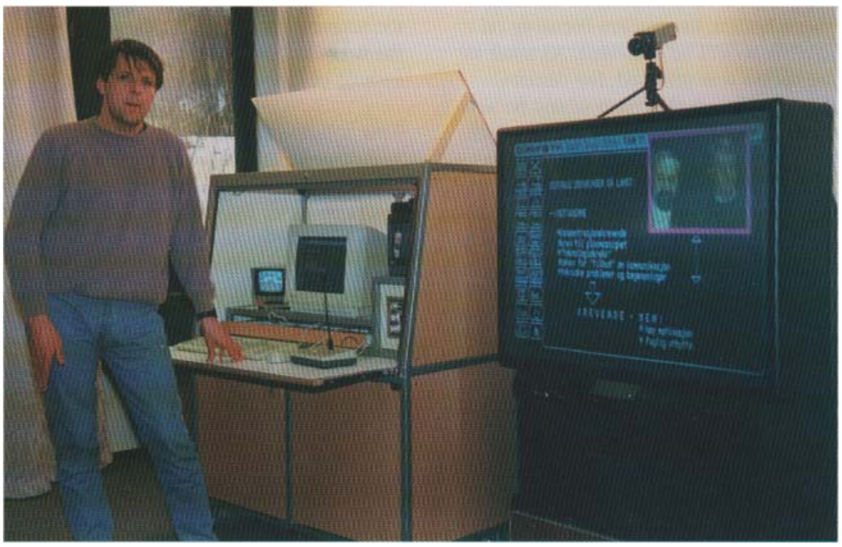

*Figure 3*

*Figure 4*

ual basis with every student. To make this possible, the teacher was given a control panel of the class on his/her screen. The students were equipped with "press-the-button-to-speak" microphones. When a student pressed the button, a cross would appear on the teacher's control panel at the computer screen. By clicking at that cross, the teacher would open up that student's microphone. At the same time, this student's mouse and keyboard would be activated, to allow the teacher and student to communicate person-to-person. Headsets were used in order to avoid disturbing the other students.

This cabinet, the "Teleproff" (Figure 5), has been used for distance education given by the engineering high school at Gjøvik to engineers and building constructors in Trysil [4]. Again we can see how participation from the users has been instrumental in the development of technical devices especially designed for distance education.

this first generation codec, it was impossible for the teachers to recognise individual faces on the screen. This was felt unsatisfactory to the teachers. They soon expressed a need for recognising the individual students with whom they were communicating. At the same time they found it important to be able to see the whole group in order to have a feeling of reaching them all and to know that they were all actually present. To fulfil this dual wish, extra cameras were installed and connected to the microphones so that every time a student pressed the microphone button, the camera focusing on him/her would be activated. As soon as the button was released, the camera showing the whole group would be activated. This solution proved to be much more satisfactory to the teachers. They found it easier to communicate with the students than before. The equipment was implemented by the same company that had designed the cabinet, NovaKom, and is another example of how the users' needs were identified by our researchers, who in co-operation with an industrial partner found a technical solution to meet those needs.

## Developing a "multimedia cabinet"

While running the Trysil project, an engineering high school that planned to offer a distance education course to Trysil, announced a need for simultaneous computer communication alongside the video and audio communication. This gave the impetus to a further development of the technical set up used in Trysil. Again, NovaKom was engaged by our research institute to come up with a solution that would satisfy this need.

NovaKom had already designed a cabinet for use in telemedicine, where this idea of integration was realised. Both sent and received video images were displayed at the screen of a computer, thus enabling the users to operate from one screen instead of three as it was before.

This solution fulfilled the wish for simultaneous audio, video and computer communication and was adapted to our new version of the cabinet tailored for distance education. Our aim was once again to make operation of the equipment as simple as possible. A short menu was designed with only a few functions to choose from. The applications were placed under Windows and easily operated by a mouse. To simplify operation of the equipment to the students, the control of local and remote cameras was given the teacher.

The engineering high school expressed a need for the teachers of computer programming to communicate on an individual basis with every student.

## The need for co-operation

The field trial in Trysil was based on a situation where a teacher at one location met with his "class" at a distance. The "class" was rather small, and the dialogue played a central part in the teaching/learning process. The equipment developed was especially designed for this and resembling situations.

Other situations may call for different technical and organisational solutions. In some cases, the transmission of lectures may be offered as a supplement to self-study courses where a large number of individual students spread all over the country are mainly working on their own. In other cases, the transmission of lectures held by highly qualified specialists may be the main issue. The lecture may be given to students at the same location as the lecturer at the same time as it is transmitted to other locations, or it may be transmitted to distant students only. Interaction may be part of the session or it may not.

Various situations call for various solutions, both technically, communicatively, pedagogically and organisationally. It has been argued in this article that it may be difficult to predict what will be a good solution. To find that out, different models must be tried out in real social settings. Users must be invited to make their experiences and come forward with their judgements. New technology is not synonymous with new technical devices. New technology is defined by how the technical devices be used. Thus, the development of new technology cannot be considered finished before the rules for how it is to be used are developed. This is a process that takes time, and it is important that the users are involved in it.

To sum up, the development of technically functional solutions is not sufficient to make good models for distance education. In addition, effort must be put into developing the pedagogical, communicative and organisational aspects of distance education. To succeed in this, technicians, researchers, pedagogues and organisers of distance education must cooperate. Only in this way can we develop telecommunication solutions and distance education models to meet the needs of the users.


Photo: Rune Lislerud/SAMFOTO

*Figure 5*

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# Cultural and educational barriers to tele-education
## – Experiences from the use of videoconferencing

BY TOVE KRISTIANSEN

**In this article I will give some examples on how cultural heritage and educational attitudes can become barriers to exploratory use of new technology in distance education and thereby also possible barriers to efficient learning. My examples are drawn from experiences made in experiments with videoconferencing.**

## Videoconferencing

In Norway we have during the last ten years run a number of experiments with videoconferencing in distance education, at first using 2 Mbit/s connections and later 64 – 128 kbit/s (videotelephony). The experiments have been run at various educational levels from upper secondary schools to colleges and universities. Telenor R&D has been engaged in many of these experiments.

There are two aspects to videoconferencing which I would like to point out:

1 *The resemblance between videoconferencing technology and television technology.*

2 *The similarity between educational situations established through this technology and ordinary classroom teaching.*

Teachers and students alike tend to get associations partly to television and partly to the classroom situation when first confronted with this technology. These associations make videoconferencing a technology easy to adapt to. At the same time, they tend to set the standard for how this technology is used, and to a certain extent that proves to be a barrier to an exploratory and potentially excitingly new way of utilising this technology in distance education.

## Resemblance to television

The associations to television tend to make teachers act as though they were television newsreaders, whereas the students lean themselves comfortably to the back, expecting to be entertained. In other words, both teachers and students get the idea of a medium where information is given one way from a sender to a passive receiver. And indeed, this is television technology, using cameras, monitors, microphones and loudspeakers for the distribution of a message. *But videoconferencing is by no means television.*

### Videoconferencing is two-way communication

Contrary to television, videoconferencing allows the receivers to respond to the message transferred. Videoconferencing is not a one-way medium, but a two-way medium. Only when this is understood, can its potential be fully explored in distance education.

Whether a teacher has the conception of videoconferencing as a medium for one-way or two-way communication makes the whole difference when it comes to taking on a teacher-oriented or a student-oriented approach. In order to achieve a student-oriented educational situation it is necessary to establish a dialogue between teacher and students at the very beginning. When communication is first established, both parts tend to forget their associations to television. The dialogue is not established by itself, though. It must be initiated by the teacher and needs careful planning to be successful.

As the students' association to television may become a psychological barrier to learning, it must be attacked by the teacher at once, inviting them to a dialogue, letting them immediately experience that this is actually very different from television and that they are expected to be active in class.

## Similarity to classroom education

The other aspect referred to, the similarity to classroom education, is positive in the sense that both students and teachers easily adapt to the situation. Nevertheless, this similarity too, can in some respects prove to become a barrier to an efficient use of the medium and the learning potential. I will give some examples.

In most cases, videoconferencing has been used for ordinary lecturing, in other words, for one-way communication. The students are invited to pose questions much the same way as in a lecture at the university, i.e. at the end of a 45 minutes long one-way delivery of information. Thus, the lecturer's association to ordinary lecturing, sets the standard for how to teach at a distance.

This is NOT utilising the medium's potential for two-way communication. Used in this manner, it could be argued that the lecture might just as well have been video-taped and sent the remote students by post. This would allow them to look at the tape at their own pace, stop and rewind, have discussions where appropriate, and pose questions and comments to the lecturer afterwards, on the telephone, by fax or electronic mail.

Using videoconferencing for one-way lecturing can of course be justified. The

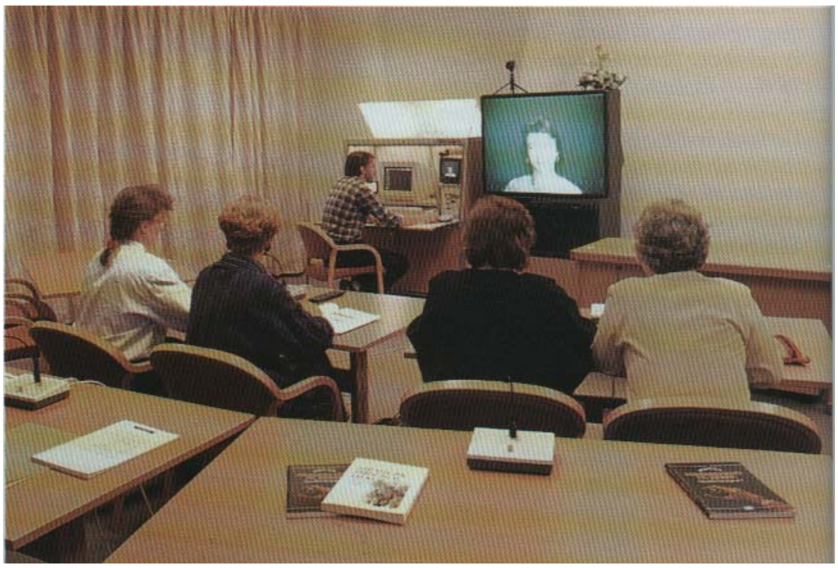

*Figure 1 Similarity to watching television (The Trysil Project)*

point I want to make here is that our cultural and educational heritage tends to make us copy our traditional way of teaching when starting distance education, thus preventing us from exploring its potentials and thereby representing a barrier to development.

### Potential for activating the students

Distance education through videoconferencing could be run quite differently. Instead of the teacher lecturing all the time, the remote students could make presentations from their site. They ordinarily have the same facilities for presenting visuals as the teacher and can easily draw and write or show preproduced figures and illustrations. Few teachers seem to have the fantasy to let the students do this, or rather, it does not fit into their teacher-oriented pedagogical view, so they do not even consider it a possibility.

This medium does allow a more student-oriented focus, though. Not only can the students make presentations for the teacher, but also for fellow students placed at various sites around the country. Some adult students are content with getting one-way lecturing on the screen, but some are by no means satisfied with that. I have met many adult distant students who were frustrated because the lectures had been given in a traditional manner, with very little room for dialogue. Many adult students also get annoyed when teachers fail to make references to their job experiences and help them relate new-gained theoretical knowledge to their daily job situation. They want that to a much larger extent than most teachers seem to be aware of.

Videoconferencing/videotelephony may also be used for direct interaction between students. This has been done in a rather untraditional experiment in Norway with great success. At two of our teachers' colleges located in the western and northern parts of Norway the leaders of the drama sections decided to use videoconferencing as a tool for co-operation. As part of the training they let their students at each college meet on screen, acting various roles in the same screenplay. This worked out very well. Teachers and students were all very excited about it, and found it stimulating to meet colleagues and students at another college in this way.

## A tool for developing new pedagogical methods

The resemblance to television technology and the similarity to classroom teaching makes videoconferencing easy to adapt to for both teachers and students. These two aspects may, however, also become barriers to an exploratory use of this technology. It should be recognised that teaching and learning through videoconferencing differs from any other kind of teaching and learning, and has to be explored on its own premises.

As argued in this article, videoconferencing may be implemented in distance education, not just for copying traditional teacher-oriented lecturing, but as a tool for developing new pedagogical methods. To achieve this, the medium's potential for two-way communication must be utilised to a much larger extent than what has been done so far, and teachers must take on a more student-oriented pedagogical approach.

# Distance education in the electronic classroom

BY BJØRN HESTNES AND JOHN WILLY BAKKE

**The electronic classroom was developed for distance education purposes. A research team called MultiTeam/Munin was established to find out how an ordinary classroom could be extended to reach students at other locations. One of the main issues for the project team was to build a classroom which was easy to use for lecturers experienced with regular classroom situations but not with distance education. They should be able to start using the electronic classroom without having to revise their teaching material or change their teaching style. When lec-**

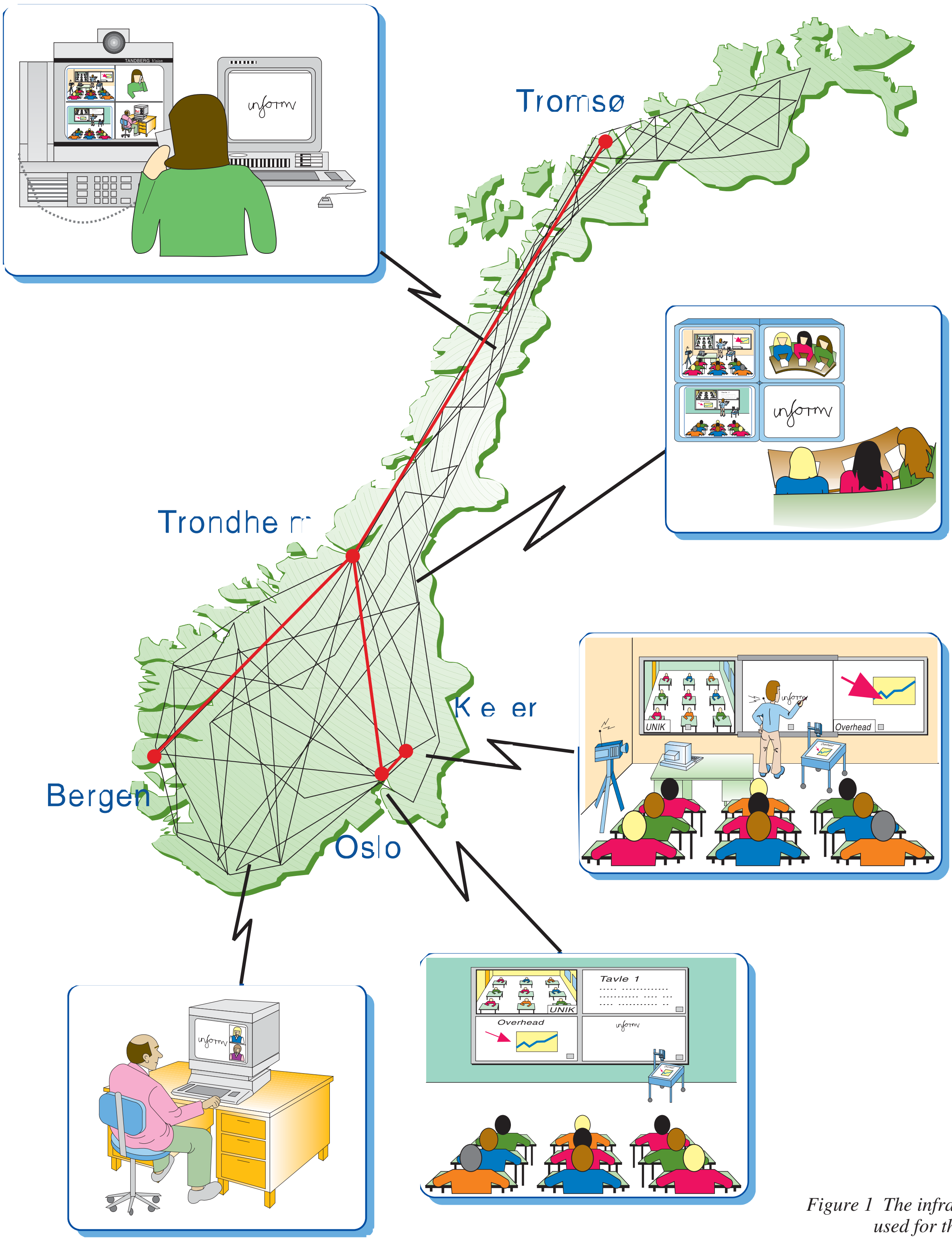


*Figure 1 The infrastructure used for the project*

**turers became familiar with the classroom technology, they were invited to try out new pedagogical principles and more advanced presentation techniques step by step. To gain relevant evaluation results from regular use, the classrooms were placed at two different locations at the University of Oslo. Description of the classroom concept and the evaluation results are described in this paper.**

## 1 Introduction

As the first organisation in Norway, Telenor R&D started in 1977 experiments with LM Ericsson's picturephone [1]. Many research projects continued which resulted in the first public trial video conference service in 1983 [2]. Later on, this service grew to sixty video conference rooms all over Norway. Distance education was one of the main uses for the service and started in 1987 between Båtsfjord, Vardø and Tromsø [3]. There were also connections to the world-wide video conference service. The amount of use was not as high as anticipated, which led to a market analysis carried out in Norway in 1991 [4].

The market analysis was the biggest ever in Norway concerning video conferencing and its conclusions were:

- Every year 10 million meetings are performed in Norway where participants travel to the meeting.
- In 2.2 millions of these meetings, the participants themselves were of the opinion that the meetings could have been substituted by a video conference. This potential correlates with other analysis outside Norway, [5] and [6].
- In 1.5 millions of the meetings, it was also a requirement to see "what is talked about", in addition to see "who is talking". "What is talked about" is either presented on a blackboard or an overhead projector.
- A large part of these meetings dealt with education in one way or another.

This new knowledge of the use led to the start of the MultiTeam project in 1991. Later on, a joint project was initiated with participants from UNIK (Centre for Technology at Kjeller, University of Oslo), USIT (Centre for Information Technology Services, University of Oslo) and T R&D (Telenor Research and Development). The project was called MultiTeam at UNIK and T R&D, and Munin at USIT. The joint project was managed from T R&D. Some of the project members also participated in a European project called ESPRIT MICE (European Strategic Programme for Research on Information Technology, Multimedia Integrated Conferencing for Europe) [7].

The main infrastructure used in this project was the Supernet, which was a Norwegian packet switched 34 Mbit/s network connecting the four universities in Norway and T TR&D. In addition, the more narrowbanded IP-network was used (Figure 1).

## 2 The objective

The objective of the project was to provide lecturing at one of the University sites in Norway available for students at other sites, both inside and outside Norway. Therefore, a concept called "Electronic classroom" was developed. One of the main concerns of the project group was to make it as easy as possible for the lecturers to start using this new form of education. They should be able to bring with them their regular teaching material into the classroom without having to change and adapt it. In addition, they should be able to use their usual teaching style, for example moving around and being "on the air" all the time. There should be no need for helpers to operate the classroom, so a high level of automation was built in. Therefore, there were no camera people there, no script girls and no producer. The only people were the lecturer and the students.

## 3 The development of the classroom

The idea was to design a classroom which incorporated video, audio and whiteboard information. Previous experiences from distance education and video conferencing clearly indicated the importance of having a shared educational material. It was also considered important to design a classroom not radically different from an ordinary classroom; one that could be used for regular classroom teaching, group work and distance guidance.

The three main media used in the electronic classroom were:

- Audio – used to hear who is talking
- Video – used to see who is talking
- Data – used to see what is talked about (on the electronic whiteboard).

Figure 2 shows a typical classroom situation. Microphones are mounted in the ceiling, evenly distributed in order to capture the voices of all participants. The lecturer used a cordless microphone so as to be able to move around freely. One camera had focus on the lecturer and was placed at the back of the room. This camera could handle the flickering of a whiteboard which for most of the time would be behind the teacher. Two cameras were also placed at the front of the classroom with focus on the students. A video-switch selected the camera corresponding to the microphone with the loudest input-signal. A trolley with two TV-monitors was placed at the front of the classroom and one at the back of the room. The two cameras at the front were for the students, so they could be seen by the remote students. The one at the back was for the lecturer. When he was looking at the local participants, he would also see the remote students on the monitor at the back. Each trolley had one monitor for incoming video (covering the remote site) and one for outgoing video. A whiteboard was available for the lecturer for writing and displaying his teaching material. To operate the whiteboard, a light-pen was used as a writing, pointing and erasing device.

At the remote site, there was another classroom with audio, video and whiteboard information. Thereby, the remote students could hear the lecturer and the students and see the lecturer's movements and body language. Behind the lecturer they could see where he was about to operate on the whiteboard, but the video channel had too low resolution to provide full whiteboard information. To see the whiteboard information, they had to look at the electronic whiteboard.

## 4 The audio

Audio was the most important part of a multimedia conference. If the audio was poor or lost, it could not be compensated by good quality on both video and data. Without acceptable audio, the conference may as well be terminated. Our experience shows clearly that the importance of the audio hardly can be overestimated.

Minimal requirements to the audio system was that audio signals from the lec-

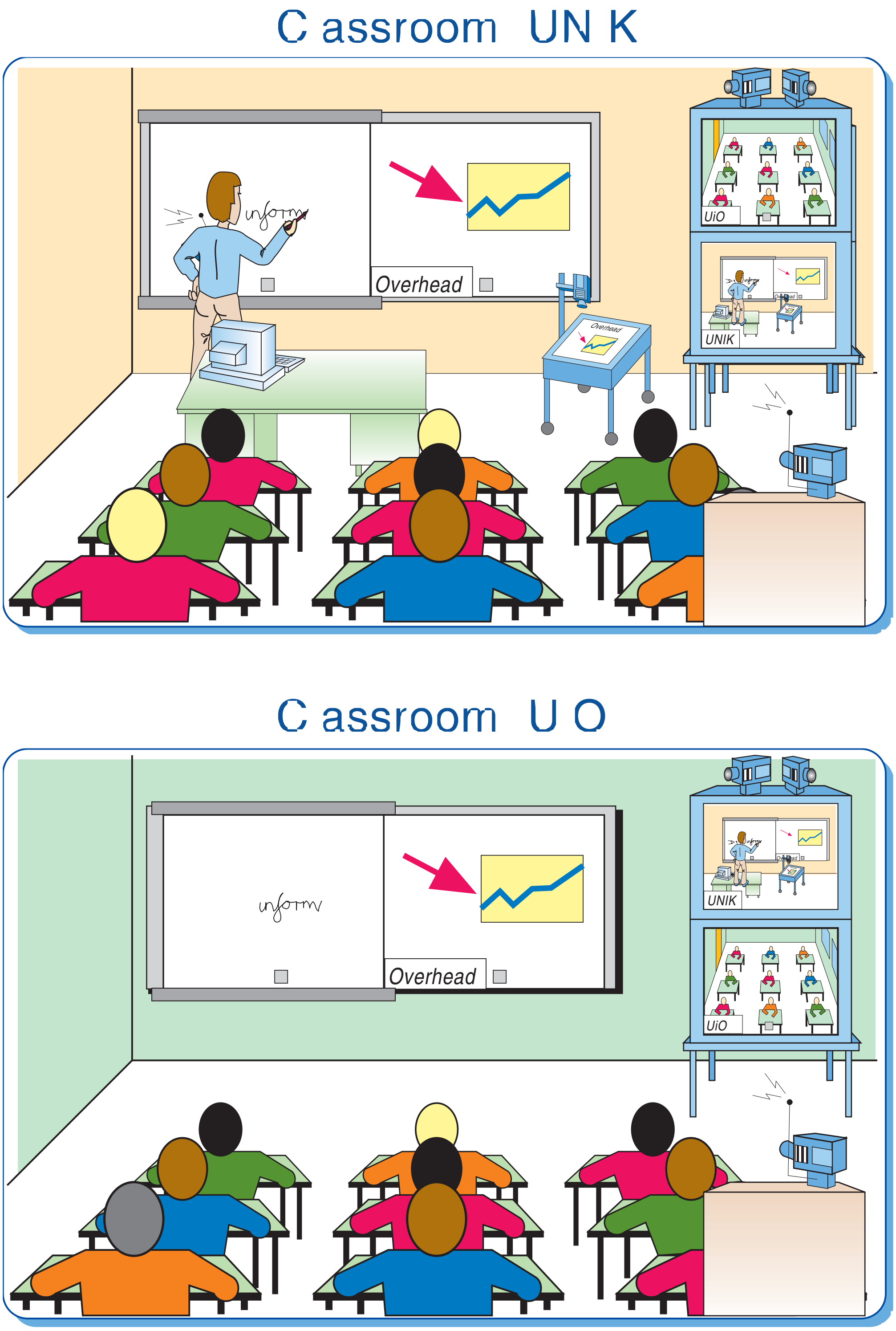


*Figure 2 A typical electronic classroom situation*

turer should be heard by everyone, and that all the other participants should also be heard when they took the floor – similar to a regular classroom situation.

The microphones were mounted in a matrix formation in the ceiling of the classroom in order to minimise noise from tables, chairs, etc.

The audio in the classrooms had a bandwidth of 7 kHz, which was sufficient for speech.

The ideal solution for audio connection was to have an open, two-way communication channel. To overcome the problems of reverberation and echo, a system for echo cancelling was implemented. Audio from one site was transmitted to the loudspeaker(s) on the remote site, where it was picked up by the microphone(s) and transmitted back again. By subtracting the incoming signal from the outgoing signal, this undesired echo was attenuated. A problem, however, was that the signal from the loudspeakers was changed by the acoustic properties of the room. Available technology claimed to be able to "subtract" up to 40 dB (decibel) of the echo. This implied that the cancelling capacity was not sufficient in all situations. To eliminate the echo completely, the loudspeaker volume was reduced when 40 dB was not enough.

*Figure 3 A lecturing situation*

## 5 The video

The video system provided moving picture from the remote site. The students could see the lecturer, where he was writing on the whiteboard, as well as his gestures and body language. One camera placed on top of the trolley at the back of the classroom covered the lecturer, and two cameras placed at the front of the room covered the students.

The video system turned out to be quite complicated in the wish to meet the requirements of a high degree of automation as there was no "production team" available for the lectures. Since there were several cameras, a switching system activated the most appropriate camera. This was accomplished by a video switch which monitored the microphone levels and selected the camera corresponding to the microphone with the loudest audio signal. The camera in use had autofocus, was tuned for the best zooming angle and had auto-iris. The camera at the back of the classroom, which covered the lecturing stage, had a specific tripod. A motor controlled the pan and tilt function. The cordless microphone transmitted, in addition to the audio signal, also control signals to the camera tripod. This was the reason the camera followed the speaker so he was in the picture all the time.

## 6 The data (whiteboard information)

At each site, there was at least one whiteboard displaying the written content of the lecture. The lecturer might use the electronic whiteboard for writing and displaying his presentation material. From the literature we know these applications as "shared workspace", "global window", "electronic whiteboard" or "shared window". In this project, the whiteboard medium was considered the second most important medium (the most important was the audio).

The lecturer could load his transparencies into the system before the lecture, and select transparencies by pointing and clicking on a scrollbar. When a transparency was displayed, the lecturer could write and draw comments on it, using the light-pen. There was also an eraser function that allowed him to erase parts of the content.

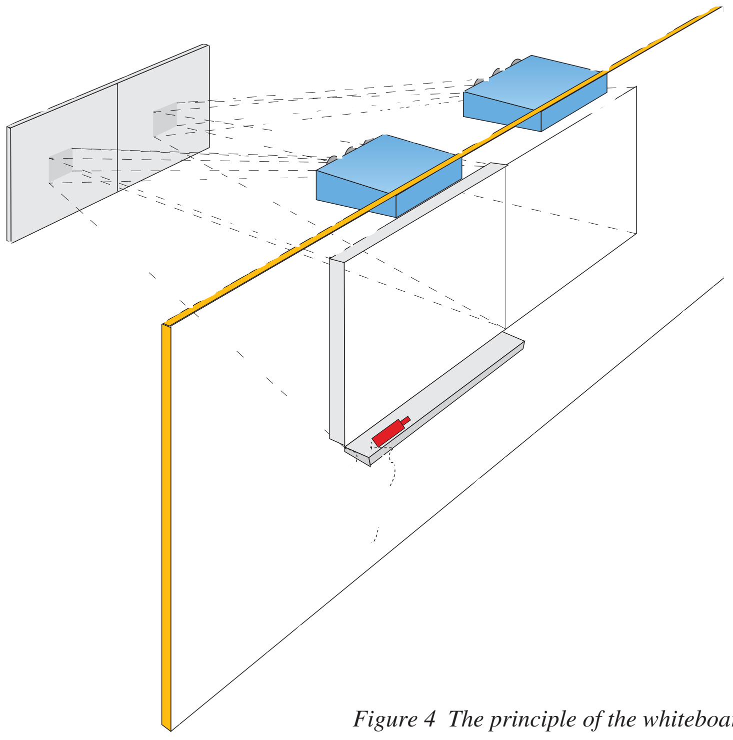

*Figure 4 The principle of the whiteboard*

The whiteboard was in principle an ordinary computer screen. Since CRT-technology did not permit monitors larger than 21” without a big increase in cost, a video cannon was used, allowing a 100” whiteboard (2 metres wide and 1.5 metres high).

The working area of the whiteboard could contain the same amount of information as an A4-document or transparency (950 x 950 pixels). (An overloaded text document or a drawing with many details was usually not a good solution, seen from a pedagogical point of view.) With the high resolution whiteboard, it was possible for the lecturer to use existing educational material prepared for the regular courses. This maid it easier for the lecturer to commence using the whiteboard.

For writing on the whiteboard, a light-pen was introduced. At one site, the position of the pen was determined by its iteration with the scanning mechanism of the video cannon. At the other site, the whiteboard was in principle a large pen-pad or digitising board.

The light-pen had three buttons, like a three button mouse. The write-function was activated when the pen was pushed towards the surface of the screen, whereupon pixels were echoed to the whiteboard(s). Pressing one of the buttons on the side of the pen would produce a cursor on all the whiteboards. Each site had their own colour on the cursor so the participants could see which site was pointing at a given time. Pressing the other button activated an eraser function. The basic functions of the pen were therefore similar to the standard equipment of a blackboard: Chalk, pointer, and sponge.

As Figure 3 shows, the whiteboard was based on a back projected video cannon. The input to the cannon was a computer signal meant for a data screen. To reduce the depth requirements in the room behind the whiteboard, a mirror was used. The screen of the whiteboard was semi-transparent, for projection and writing.

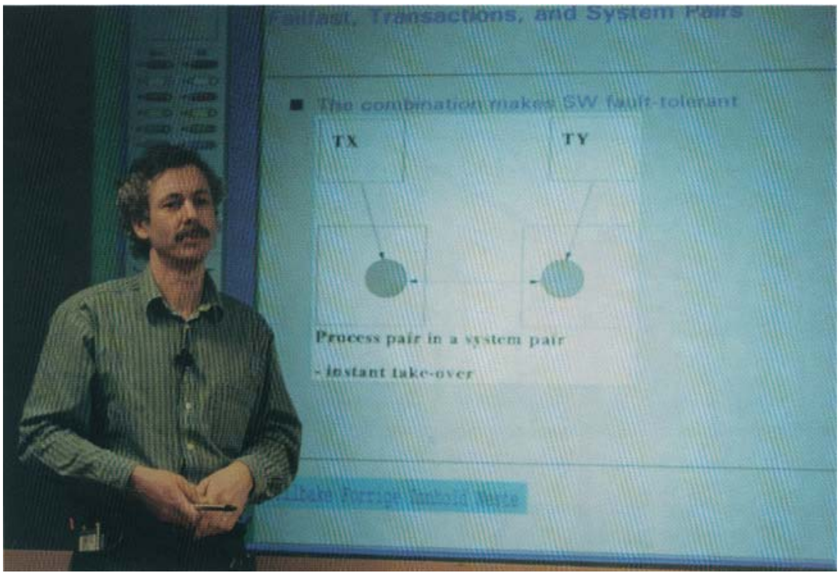


*Figure 5 Lecturer with the light-pen at the electronic whiteboard*

## 7 Experiences from the users

In any project, the verdict of the end-users is the ultimate measure of success. Therefore, great effort was taken in order to evaluate the experiences of lecturer and students. Being used for a series of lectures at the University, the appropriateness of the classroom for educational purposes was evaluated.

### 7.1 Experiences from the students

Two group interviews were undertaken with the students. In addition, they answered a questionnaire after each class. Members of the project team also attended most of the lectures, thereby being able to observe the reactions of the students.

The attendance of the students was motivated by the content of the course only, not by the fact that the course was given in the electronic classroom (an exercise in new technology might be a motivation for students in informatics). The students also had to pass an examination, another fact making them attentive critics of the classroom.

The overall evaluation from the students was positive, referring to the classroom as an environment for learning. There were also several critical responses, serving as inspiration for further development of both the pedagogical approach and the classroom. One reaction was that the lecturer should have had more experience with the classroom before the course started, reflecting the fact that the classroom was completed just before the start of the course.

Regarding the technology in the classroom, the students seemed to be impressed by the quality of the whiteboard, whereas the quality of the sound was the source of several critical remarks, confirming the experiences of the project team.

There were some mixed remarks regarding the video channel. The students at the remote site appreciated the video signal of the teacher, whereas members of both groups of students seemed to be distracted by the self-view function, making them uncomfortable with taking the floor. Sometimes the self-view monitors were even turned off.

One important issue in distance education and conferencing was the feeling of presence of the other party or parties. At first, the students at the remote site found the lecturer distant, not just in the literal sense. A great improvement for the remote students was accomplished when he visited their site, thereby becoming a real person, not just a small figure on the screen. This was in accordance with common knowledge from video conferencing, that meeting in person was valuable for the quality of later interaction via electronic media. Contrary to our initial hypothesis, the local students were the more critical of the classroom. Halfway in the course, all the students at the remote site voted for the experiment to continue, whereas a large minority of the local students voted for a termination of the project.

Explanations provided by the students were partly that they felt pity for the remote students, partly that the operation of the electronic classroom introduced an element of distraction in the lecture.

A further substantiation of their argument may be developed, considering the alternatives of the two groups of students. The alternative for the students at the remote site was either to commute to the other branch of the university, or not to attend the course at all, whereas the alternative for the local students was a series of lectures without experiments, interruptions or distractions.

### 7.2 Experience from the lecturer

The overall evaluation from the lecturer was also positive, and his several critical remarks were very constructive, and an important input to the development process. One obvious reaction was to the fact that the classroom was completed just a few days before the course started, making it impossible to get familiar with the classroom.

The lecturer found the whiteboard easy to operate, and the functions available fairly well implemented. There were several additional features he would have implemented in the whiteboard, like the possibility to zoom in on certain areas of the whiteboard, or to display animation.

It was a disadvantage, according to the lecturer, that the system appeared somewhat rigid, because it worked best when the set of transparencies was loaded before the lecture. He found that this property of the whiteboard made it difficult to improvise during the lectures.

He also had some critical remarks to the audio system and the light-pen, while emphasising the overall positive impression of the classroom.

The lecturer complained about a lack of contact with the students in the remote classroom, and he found it difficult to feel their presence. He also had to invite them directly to raise questions and participate in the discussions.

## 8 Experiences from the operation of the classrooms

The development of the classrooms was an on-going process, also being based upon experiences gathered during the project. In the development process, several lecturers from the University of Oslo gave valuable advice.

### 8.1 The electronic whiteboard

There were several problems with the operation of the pen, partly due to driver and hardware problems, partly because the pen-technology at one of the sites required that the pen was held orthogonally to the whiteboard, causing some problems for writing and drawing on the whiteboard. Another problem with this light-pen was that it was activated about 2 feet from the whiteboard, often producing some unintended results. The conclusion from the project team and the lecturers was that this pen was suitable as a pointing and clicking device (similar to a mouse), but not as a device for freehand writing and drawing. The pen-technology deployed at the other site proved to be a better solution for writing and drawing.

#### 8.1.1 Changes and improvements

The first version of the whiteboard had the menu system on the right hand side of the whiteboard. After a few lessons, the lecturer found that it would be more convenient to have the functions on the left hand side, where he was usually standing during the lectures. A new layout was implemented with the buttons placed on the left hand side, making the lecturer feel more comfortable.

#### 8.1.2 Scanner

To provide better flexibility and allow a larger room for improvisation, the lecturer wanted some kind of overhead function so that he could show new transparencies not previously stored in the system. One alternative was to use a fast scanner, but after searching the market no satisfactory product was found.

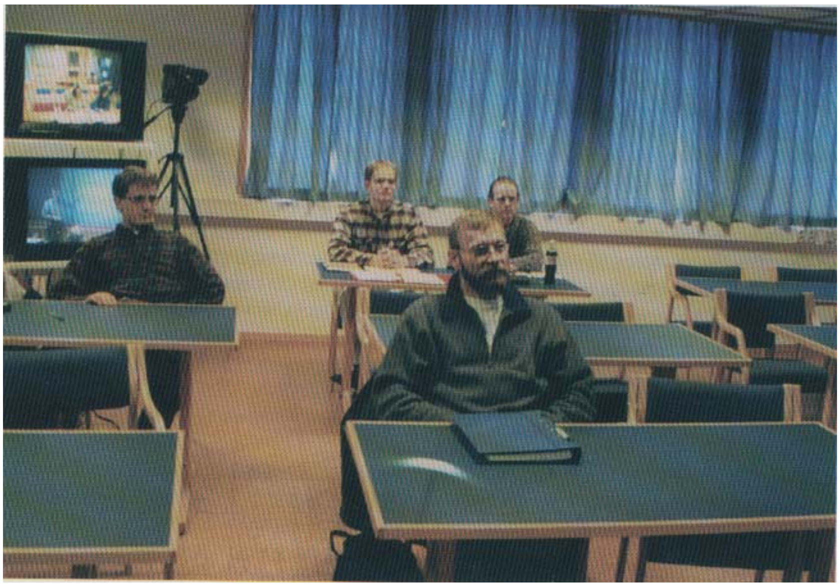

*Figure 6 Seen from the lecturer. Remote students on the upper monitor, self-view on the lower*

### 8.1.3 Document camera

A document camera presenting images on the whiteboard was another alternative proposed by the lecturer. As experienced from the video conference service in Norway these cameras did not have a sufficiently high resolution for the classroom. The document camera was installed, however, as a backup facility.

## 8.2 Audio

The quality of the audio represented one of the major problems during the first months of the project. The packet switched network could rearrange packets received in the wrong sequence, but there were no mechanisms to compensate for packet losses or damaged packages. This latter aspect made some seminars on the narrowbanded parts of Internet very hard to follow.

The quality of the audio was continuously improved during the project period by increasing available bandwidth in the audio channel. Further steps have to be taken in order to obtain an even better quality.

### 8.2.1 Backup facility

In addition to the audio channel, a telephone conferencing unit was installed in the classrooms as a backup system. Then it would still be possible to carry on with the education in case the audio channel should fail.

## 8.3 Video

The whiteboard being back-lit was the source of some problems with the lighting. With no extra light, the lecturer appeared as a silhouette for the students at the remote site, whereas lamps directed towards the whiteboard resulted in reduced readability at the local site. Lighting from various angles was tried out, the solution being that the lecturer was illuminated from a lamp mounted from the ceiling, about 1 metre in front of the whiteboard.

Automatic camera control in the form of an inexpensive "follow me" camera was also tested, with little success. A more expensive equipment was tried out a little later with good results.

The camera on the lecturer provided an overview of the whiteboard and the lecturer, making it somewhat difficult for the remote students to observe the gestures of the lecturer, let alone catch his eye. This in turn caused the lecturer to seem somewhat distant. In addition to the hardware codec, there was a software codec as a backup system.

Each lecture was videotaped, which opened the possibility for a later review of the session for both students and lecturer.

## 8.4 Operation of the classroom

It was considered very important to maintain a high stability during the lectures since this was a regular university course. This in turn called for a support service for the lecturer. Fortunately, one of the students attending the course was also a participant in the MultiTeam project. He assisted the lecturer in setting up the equipment, and took care of problems occurring during the sessions. Similarly, at the other site, there was a member from the MultiTeam/Munin project present, to ensure the proper functioning of the classroom.

The Supernet performed well during the course. There have been some minor problems with routers at two occasions.

# 9 Implications for further studies

The development process and the operational phase provided valuable insights regarding user aspects and technological aspects of the electronic classroom, while also pointing out several areas for further research and development.

One set of questions refer to the way the users experienced their participation in a distributed classroom. The results from this project shows clearly that perceived distance is a very important topic.

The students at the two sites perceived the series of lectures in quite different ways. (It is here interesting to note that the students at the remote site were more positive towards the project, even though they were complaining about how remote the lecturer was.) The lecturer also made comments about the distance to the remote students, and that he had to take special measures in order to integrate them into the discussions. There were important challenges in overcoming this feeling of distance.

Two hardly surprising results from the project was the importance of the audio, and that the whiteboard never could get large enough – both important topics for further development.

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# Something in the air
## – Norwegian experiences with telelecturing in flexible education

BY GUNNAR GREPPERUD

### 1 Telelecturing in Norway – the NORNET-project

In a collection of articles, "Open and Distanced Learning Today" (edited by F. Lockwood, 1995), D. Keegan presents an evaluation of an Irish satellite-based project from 1993–94. Keegan assumes that this is one of the first, if not the first, university-accredited virtual classroom course by satellite in Europe besides projects like Europace and Eurostep which he characterises as mainly technological experiments [1].

Without putting too much of an emphasis on this, Keegan has in fact made a mistake in his assumption about "who is first in Europe". Already in the autumn of 1985, Telenor in Norway, started its first experiment with satellite broadcasting as part of an educational course. A small group of students were able to follow part of a French course in their own home, in front of their own television [2]. Since 1990, we have in Norway been able to achieve a relatively extensive experience with satellite-based distance education, mainly through the so-called NORNET-project. During the period from January 1990 to January 1996 more than 10,000 adult students have been given an educational opportunity. Through the utilization of 360 receiving stations (consisting of 85 study centres, and upper secondary schools that have been equipped to receive satellite broadcasts (transmissions)), 24 different educational courses have been given, and one has cooperated with educational establishments at upper secondary level, university and college level and private centres of competence. The number of participating county councils in NORNET has increased from 3 to 11, and the councils have also appointed coordinators to work with this enterprise. The University of Bergen's Media Centre (UMS), which has had the main responsibility for producing and sending the telelectures, has up until today produced 400 hours of telelectures.

NORNET (The Norwegian Network for Distance Education) was established as a project in 1989. The aim was threefold:

- Distribute further education to the population or vocational groups that otherwise would have difficulty in taking part in the normal courses given by educational establishments
- Offer industry, commerce and management a distribution 'channel' to give information and labour-market training to its users
- Develop an infrastructure to promote knowledge.

Teaching by satellite is (and will be) mainly given as telelecturing, based on traditional methods. Lectures are sent directly from the studio, and coded through Telenor's satellite to each recipient mainly at a local study centre. The form of presentation used, especially the lecture part, is very similar to plenary lectures that are given at universities and colleges. Most of the time is "one-way-lecturing" with a certain amount of time given to enable students to ask questions and give comments.

The oral presentation is supported by written presentations in the form of preprepared texts, computer-designed posters, flip-over material and prepared papers. Most telelectures sent from the studios are supplemented by conversations, guest lecturers and are sometimes illustrated by video sequences.

To give participants the opportunity of talking to the lecturer, either by asking questions or giving comments, time has been reserved during each transmission for tele(phone)conferencing at previously chosen study centres. The students are informed about this and prepare their role as "public askers of questions or comment makers" and in this way represent the rest of the participants. The other groups have the possibility of sending questions and comments to the lecturer via fax and/or telephone.

The students are organised in subject groups and work together in a variety of ways between broadcasts. The subject is worked with in local groups, individual study and written correspondence. The group work is partly followed up by the central course supplier / educational institution.

NORNET is based on both direct transmission and full television quality. Through the use of satellite technology it is possible to reach all parts of the country at the same time, and this gives the possibility of having an unlimited number of participants. NORNET's transmissions are transferred through the broadcasting standard MAC. This means that the broadcasts are coded and can only be received by registered addresses with the correct receiving equipment.

The actual instruction takes place in the TV studio at the University of Bergen or at the University of Oslo and is transmitted through the radio link system to Telenor's earth station at Nittedal, where the programme is coded and transmitted up to the satellite 'Intelsat 5'. Every receiving station is equipped with a satellite dish, a decoder and a coding card in their television.

It is necessary to build up a close cooperation with the individual local authorities, as each authority is responsible for the local coordination of the enterprise. In each of the participants' local community a coordinator or facilitator has been appointed. This person is responsible for giving information, registering course participants, preparing the local study centre so that it can receive the broadcast and is also the point of contact with the project leader in Bergen. The coordinator function plays a key role in the project.

### 2 The challenge of increased knowledge – the NORNET-evaluation

It is often said of distance education that it is an education without any limits or boundaries. This statement can be interpreted in many different ways. In the first instance it gives a picture of an educational form which can give possibilities that exceed geographical and time boundaries. In its formulation it also implies that education will become a more and more international phenomenon. The traditional frontiers are no longer a barrier for educational suppliers. Parallel with the development of education as a market product, Norway will also more frequently experience offers of educational supplies from different countries.

If we reverse the order of the statement, "education without any limits", we can also see that distance education is a *boundary breaker*, meaning that it challenges our accustomed conception about teaching and learning. Through a flexible educational programme one can see outlines of a qualitatively different form of educational organisation, where the traditional mass production paradigm is replaced by a more flexible and much more individualized approach. "There's something in the air", something new and radically different, which is about to push itself forward into the traditional education system. It points towards solutions which are way ahead of the present-day's education system. It is with this perspective in mind that one should analyse and discuss distance education.

Within the NORNET-project a number of minor evaluations have been executed in connection with individual course offers [3]. These evaluations have brought to light the fact that satellite-based distance education is in fact many things. Even though telelecturing, distributed via satellite, has been a common denominator, the evaluations have shown that there is a diversity within the basic organisation, as well as in the preparation of the actual teaching.

The evaluation reports which are now available (only in Norwegian), vary in size, quality and also have different levels of ambition. They differ from simple course evaluation to results given by appointed external evaluators. A common feature is that they have been written within a somewhat short period of time. Because of that one has neither had the time nor the possibility to go in depth theoretically or empirically. The methodological approach has mainly been the use of rather limited questionnaires. It is also interesting to note that the Norwegian reports and evaluation have rarely built upon each others' experiences, which makes it difficult to develop specific knowledge in this complicated field of study.

The most comprehensive evaluation of NORNET was made in 1993. 580 students, out of a total of 881, were interviewed via telephone about their experiences with television-based education. For three of the four educational offers that were involved, 90 % of the total number of participating students were interviewed. The majority of local coordinators (45 of 60) and teachers (30 of 45) were also interviewed, partly through the use of questionnaires, partly by telephone and partly in private meetings. Also representatives from the educational institutions that had given the courses via NORNET were interviewed.

The evaluation and points of view given by the three involved groups have been summarized, commented upon and analysed in a preliminary report with the working title, "Increased Knowledge is also a Challenge" (from now on referred to as 'the NORNET-study') [4]. Experiences from NORNET are also compared with national and international evaluation and research in the field of satellite-based distance education.

The main conclusions in the NORNET study coincides with the research which has been done on satellite-based distance education in several countries so far:

- It is technically possible, also in Norway, with its fjords, mountains and scattered population, to give an educational offer where lectures and teaching are distributed via satellite.
- Nothing indicates that the academic quality or/and the educational level are in any way damaged by this kind of lecturing.
- Local study centres are important in many ways; as receiver stations, as common ground both socially and educationally, as marketing operators and as a "listening post" to register any necessary requirements.
- The satellite model contributes to "additional knowledge for more people".

The NORNET-study focuses on a number of situations connected to organisation and teaching. We will present the participants' and teachers' points of view in some of these areas.

## 3 What do the students experience?

The NORNET-study focuses on four different courses, a smaller course about EC economy, a further education course at upper secondary level about Welfare Services for the Elderly, two qualifying educational courses at university and college level covering Public Administration (5 credits) and Working Life Psychology (10 credits). The largest group of students (42.5 %) were between the ages of 41 and 50. The average age of the students following the NORNET-courses was higher than of those following normal distance education courses that are otherwise offered in Norway. In three out of four courses there was a majority of women. In the course covering Welfare Services for the Elderly the dominance of women students was a natural phenomenon, because the course was directed at the occupational group, which is predominately made up of women. The courses were primarily taken as further education, except for one offer, that of Public Administration, which was taken (especially by women) as a first university subject.

Two-thirds of the students maintained that satellite teaching was their only chance of being able to study. Incorporate in the answer and a decisive factor, quite naturally, was that they didn't need to travel a long way, leave home or take leave of absence from work, in order to study. In Norwegian and Scandinavian context, it is interesting to notice a development which points out that geographical distance is only *one* of many reasons for developing studies outside educational institutions. In the NORNET-study we find that people living right next to an educational institution, prefer to study through distance education. Without opening up old debates about the concept of distance education, it should be pointed out that it is about time we demanded a new term to cover what we mean by distance education.

The NORNET-study also shows that many students are neither aware of which educational possibilities exist on the market, nor have they done anything to provide themselves with this knowledge. One of the courses offered by NORNET was also, at the same time, available as a correspondence course, produced by NKS Distance Education together with the College of Lillehammer. The course offered was marketed over a longer period and in different ways throughout Norway. Even so, few, if any, students attending the NORNET-project seemed to be aware of it. One of the main conclusions, therefore, is that it is crucial in connection with any future recruiting of students to flexible educational courses, that the information and motivation about the courses take place as closely to the users as possible.

When students are asked to give a full evaluation of the total course package (by giving an estimated value on a scale from 1–7), "the average grade" given is 4.7, that is a little over average. The evaluation varies from subject to subject, mainly due to the quality of the lectures, partly due to the way the course is structured and what is stressed in the study. While students on one course were reasonably satisfied with the lectures, students on another course felt that they had too few. While students of one subject felt that two-way communication by telephone was to a certain extent a waste of time, students studying another subject felt that this form of communication was extremely valuable.

Students were also asked if they would follow another course with a similar structure. The answers were mainly encouraging, 50.9 % said that they would definitely think about repeating the experience, 31.5 % said that they might, and a clear 13 % of the participants were quite definite that they would not be taking a similar kind of course again. There are a number of conditions connected to whether one would take such a course again or not. The NORNET-study shows that the amount of work involved, the extent to which one has been a student before and the distance of time since being a student or pupil, play a decisive role. It appears that women to a lesser degree were interested in taking part in further courses organised in this way.

Other Norwegian evaluations of satellite-based distance education is more positive with regard to the evaluation of the contents and organisation. In Vaagland's evaluation from 1990, 90 % of the students say that they would not mind attending similar courses again, and over 96 % thought that form of distance education was practical [5]. Lorensen, and others, reported that all the students that completed the questionnaire recommended that one should continue teaching in this way [6]. Even in the project that has received the most negative remarks in connection with content and form, it was found that the participants had not been scared away by their more negative experiences. One could quite well continue to work in this way under specific circumstances [7].

Not surprisingly, the use of satellites and telelecturing received great attention both among students and in the communities. Telelectures sent directly via television was something new, and involved the setting up of a large technical and organizational apparatus. Quite a lot of investments were made to supply the necessary equipment and the media focused upon this as it was new and exciting (but also caused problems).

In one of NORNET's minor evaluations it is stated that the focus on satellite and television created an unfortunate situation by taking the attention away from the main intention, which was to try out an "in-service-training model" for teachers in upper secondary schools. Instead of concentrating on their own processes of learning, the teachers were only concerned about how the lectures were dispatched.

## 4 What then are students concerned with in connection with their evaluation of tele-lectures?

Both because satellite transmission played a central role, but also because telelecturing was primarily the basic element in the educational programme, it was of special interest for the NORNET-study that this aspect was evaluated. Both students and teachers were therefore asked to evaluate different aspects of telelecturing.

Even though one finds some variation between the groups of students, subjects and gender, the main conclusion was that the students were satisfied with this form of delivery. Compared with other Norwegian evaluations in this field the evaluation results given in the NORNET-study were very positive. The same can be said if one compares the distance education students' evaluation with evaluations given by students studying on campus at universities and colleges.

The lectures were, as far as the students were concerned, well planned, especially with regard to the contents they presented. Another way of putting it is that participants experienced that the lecturers knew what they were talking about, and the majority felt that the lecturers gave them a better understanding of the contents both by stressing the central points in the study, by presenting new and exciting material and by helping students solve their given tasks.

There is more criticism with regard to presentation, and about a third of the students said that the lecturers could have been better at organising their material more pedagogically. It was pointed out, especially, that the lecturers kept up such a tempo that it was difficult to keep up with writing notes, and that it was difficult to follow everything that was said. This was regarded as somewhat of a dilemma by the lecturers themselves, and one never actually found out how one should compensate for not having students in the studio with them. Many different tricks were tried out. One of the teachers, for example, said that he used the camera-man as if he was a student, and talked to him.

The students were relatively positive to the lecturers' use of supportive material during their lectures, whether it was computer designed posters, flip-overs or use of the document-camera. But a number of students would have liked to have been sent the visual material beforehand.

The fact that telelecturing distributed via satellite has functioned well is confirmed by a number of investigations in a number of countries. Wong, for example, reaches a similar conclusion in her evaluation of satellite-based distance education at the University of Saskatchewan [8]. In his evaluation from 1995 (see above) D. Keegan asked students on two different occasions to evaluate whether these kinds of courses were able to sustain the academic level of excellency. Mid-way evaluation results gave 86 % positive answers, and the final results were the same. Only 1 % felt that it was a disadvantage not to have face-to-face contact [9].

The positive reactions do not totally represent a united front. Collins and Murphy show results where participants are in agreement that the lecture form does not suit satellite distribution. One becomes quite quickly passive and bored. This explanation is primarily based on the fact that the teacher is in control and dominates the situation, as well as seeming to want to present too much material in too short a time [10]. A natural conclusion to this is that bad teaching becomes twice as bad when presented on television!

With regard to the contact between teachers and students the latter are not quite as positive in their evaluation. This is primarily due to the technical problems in connection with tele-conferences, and to problems concerned with audibility. It was the technical problems that caused the students to give a rather negative "grading" here compared with the evaluation given to the lectures.

From a didactical point of view tele-conferencing was not particularly successful either. Three conditions are deciding factors for this conclusion: The situation was perhaps not put to good enough use, neither students nor teachers had been given information about various possibilities as to use, and one had too high ambitions for what actually was possible. Therefore, two-way communication was rather an artificial element, and represented more of an illusion about conversation than a conversation in its own rights. The communication became more like a concept of narrative in the actual programme.

The didactical problem with two-way communication is also a visible concept in other research and evaluation work. Wong, in a similar way as Collins and Murphy, points out that students were obviously rather reluctant about speaking directly over the air. They were clearly influenced by the context in which communication was taking place, and the result of this was that the local assistant teachers had to take responsibility for asking questions on behalf of the students. In line with Vaagland's observations one found that students were concerned about what the other groups saw and did. Partly, one competed to become a visible participant in the studio, and those who didn't manage to get to the fore had a tendency to lose interest [11].

In an evaluation of multi-point video conferencing G. Holden verifies Wong, Collins and Murphy's opinion. Even though a number of students say they want to ask questions, they don't do so. Partly because the teacher dominates, partly because they dare not. G. Holden's overall evaluation is that it is the organisation of teaching and not the medium that is responsible for this passivity. A number of those who didn't participate actively in the interaction sat on the document camera and then left, and very often the teacher did not even notice that they had left the studio [12].

## 5 What do the lecturers experience?

After the first year of satellite-based distance education Wong concludes in her study that much of the success is due to the fact that one had managed to recruit experienced and charismatic lecturers for this role [13]. Even though one should not perhaps be quite so generous with one's praise when mentioning lecturers in the NORNET-project, the students did say that they thought they should be complimented for their work. In spite of the fact that teachers were just left to sink or swim, the students have mainly evaluated their contribution as positive, even though there are some differences to be found from subject to subject.

Nearly all the teachers who participated were new beginners with regard to telelecturing. They were mainly the academic staff who in their normal role use (more or less) traditional lecturing methods. They were placed in quite a different context, in a television studio where they were to be responsible to a camera, and see no students.

When they look back on their experience the teachers are nevertheless very positive.

They do not think that telelecturing is as good as normal lectures on campus. But having the opportunity to give lectures in a new medium was regarded, in itself, as a positive experience. 70 % of them said that it was positive, while only 1 (out of 30) said that it had been a very negative experience.

When asked what they regarded as being most positive about telelecturing the answers were mainly divided into two parts. Firstly, it was pointed out that by using this organisational form, one was able to reach more people (at the same time). Secondly, it was pointed out that by working in this way one also learnt and developed oneself ("It demanded much more thought about what one should present" / "a challenge" / "a new way of teaching" / "learn other forms").

On the negative side the lack of direct contact and possibility of a dialogue with the students were the things mainly remarked upon. Some also mentioned the technical problems and the general uncertainty of teaching via this medium, "I've been worried about the situation for a long time", one of the teachers said.

With regard to this latter remark it is interesting to note that three of the teachers actually said that they didn't experience any difference between satellite lecturing and their normal lecturing situation. This can indicate, without making a point out of it, that some teachers even on campus apparently have little or no contact with their students. But the answers can also be interpreted as meaning that they were not influenced by the situation, even though the surroundings were different.

The teachers are not so equally satisfied with satellite lecturing as the students seem to be. Even so, the majority don't mind giving it another go. 26 said yes, 1 said maybe, and 3 said no. Almost half of the teachers find that form of flexible education very useful, while the other half say that it is "usable".

Why are teachers so positive? When they are asked to give reasons, they give a number of different answers:

- It is part of the future
- The possibility of reaching many
- Become well-known (a star)
- Challenging/exciting
- Technically informative
- Different working methods, new challenges
- Like lecturing
- No reason for not trying
- It must be possible to do better.

This evaluation seems to coincide with other evaluations given by those that teach on flexible education studies.

The following is taken from Dahlén and Lundgren's summary of their evaluation comments [14].

> *Teachers take it for granted that distance education requires another kind of planning and gives less room for improvisation than normal teaching situations. On the whole, distance education demands that teachers give far more of their time.*
>
> *Teachers emphasise distance education and the distance students in a much more positive way. They believe that contact between them and these students functions well, that the distance students are motivated, independent, full of initiative, have critical ideas and take more responsibility for their studies.*

A more or less compulsory question to teachers involved in flexible education is whether the contents attain just as high a level of excellence as normal studies. Of the 10 teachers connected to the NORNET study, who gave an answer to this, eight of them say that compared with the normal course the students' results are much better or better. Only one says that they are somewhat poorer. Even though the number of answers are few, they verify the evaluation from other similar course offers. A summary of 12 qualifying distance educational courses in 1993 shows that in 9 of the projects the results were evaluated as good or very good, 2 were evaluated as average and 1 was evaluated as weak. For 3 of the 12 course offers it was shown that the results were better than those of an ordinary study, and for 6 projects that they were equally as good [15].

There is therefore no specific reason to worry that flexible education course results are qualitatively weaker than those of on-campus studies. Moreover, the examination results show that one is faced with a hard-working and motivated group of students.

Experiences with distance education in Norwegian higher education has shown that teachers themselves profit from working with distance education compared with teaching on the campus-based courses. Did the teachers participating in the NORNET-studies feel the same?

7 of the 30 teachers say that they haven't learnt anything new compared to their normal teaching. Otherwise, the following comments were made:

- The importance of good planning, structure and clarity
- No matter what the setting a need to get away from one speaker/monologue
- Prepare a more complete lecture than is usual in an auditorium
- More aware of one's performance
- Put more stress on details
- Self-assurance, more routine
- Significance of how one looks (!)
- Rely more on the manuscript than on the performance part.

Which advice does one have to those who plan to give telelectures?

- Jump right out into it, it will probably be all right
- Plan well – not too much material
- Try and get some variation
- Take it easy
- Find a relaxed approachable form. Use simple language – not too much subject jargon
- Try to imagine there is an audience – use body language
- Activate the students in their groups / use your imagination
- Divide the teaching into smaller portions.

## 6 The beginning of something new?

The NORNET-project cannot be regarded as standing for new approaches in the field of didactics. One has, mainly, kept to the 'known' and tried to do this as well as possible. In connection with telelecturing one has primarily contributed to improving the traditional lecturing within a television setting.

Even though one would have liked to see greater technical and didactical development than was shown in the project, one must, as a main conclusion to the project as far as it had come in 1994, say that it was positive.

The results show that flexible education based on satellite-based presentation seems to have found a form which functions in relation to different user groups. This conclusion is also supported by other internal and external investigations, besides NORNET, in Norway and abroad.

Perhaps the most important conclusion is that this study conforms with other research and evaluation work in this field, and establishes the fact that educational results and the quality of the studies are in no way behind those which one finds in the ordinary education system. This means that if one continues to develop flexible education courses one also has the opportunity in the future of establishing a qualitatively better education and system of learning. As a clear distinction from the ordinary education system, which has about reached its maximum potential, flexible education is just in its beginner stages. Perhaps we have reached the time when one should begin with more radical changes?

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# Telecom and Open Learning – a challenge to institutional cooperation

BY HARALD HAUGEN AND BODIL ASK

## Introduction

1996 was declared the *European year for life long learning*, stating the fact that there is an increasing demand in all walks of life for updating and refreshing of existing knowledge and skills in order to keep abreast with professional and social requirements. With significant revisions of methods as well as in content of professions, with tight working schedules and continuous challenges by new tasks and requirements, most professionals tend to postpone the extra effort to embark on traditional continued education or in-service training programmes.

New information and communication technology (ICT) has for a couple of decades posed increasing challenges to the working force. A few adventurers and enthusiasts, on their own or by initiative from their employers, threw themselves into the technical whirlpool in the early 1980s. Gradually, they were mastering different operating systems, obscure user interfaces and arbitrary pieces of software available for their purposes. Improved user friendliness as well as escalating capacity/price ratio and popularisation of the technology have all contributed to an increasing application of ICT at all levels.

The combination of life long learning and ICT naturally lead to programmes for provision of in-service training through the use of computers and electronic networks. Both trans-European and different national initiatives have been launched in order to exploit the possibilities incorporated in the new technology. Several projects are in progress, gathering experience and developing new methodologies to suit both course providers and learners. The electronic learning environment may be a challenge to the traditional auditorium, classroom and hotel based seminars.

Cooperation between course providing institutions seems to be a fruitful track for saving efforts and resources. Through different projects in the field of ICT based ODL one has found that partners in production of learning material benefit a lot from exchange of electronic lessons, examples, programmes, etc. They tend to save much on development costs, administrative systems and infrastructure, and at the same time increase the quality of final products and offers to the target groups.

## Future role of professionals

Life in the information and knowledge society puts new demands on professional roles and performances. Not only does the technology itself change the characteristics of traditional work, it also shifts the required skills for certain operations into completely different levels of understanding or detailed knowledge. In one direction the visible results of efficient working in a store is changed from that of manually noting and adding numbers to that of pressing the correct buttons on a calculator or cash register – or moving the bar codes past a photo cell or similar device. On the other hand, the engineer does not need the same drawing skills as before when constructing a house or a ship, but must control the drawing facilities of a computer, requiring a higher level of understanding and insight into practical consequences of certain decisions.

In teaching as well as in company training programmes the role of the presenter or trainer is gradually changing from that of being a knowledge provider and a well of solutions to all problems, into being a guide or adviser for learners to find and choose from the information and instructional material available. In a society where information and our access to it are growing exponentially, it is becoming increasingly important to assist learners in acquiring skills of information handling. An important part of this is to develop a critical and reflective way of sorting, discriminating and interpreting the information provided. They must also be able to turn the acquired information into knowledge and understanding of their immediate surroundings and the challenges facing them.

## IT and telecommunication

Particular requirements are related to new technology as part of new professional roles. ICT is not only a tool and a source of information, it is also in its own right an important part of workmanship and required skills of future citizens. It is well accepted that a clerk expecting to maintain his work in the future must know how to apply word processing, and that an accountant will be obsolete if he does not know how to handle computer based accounting systems. Maybe it is also accepted that a journalist or a history teacher must know how to search in databases for interesting extensions to his lessons on the present situation in the Middle East. But is it realised as equally important for a social science/biology teacher or an environmental adviser to manage system dynamics and simulation models in order to understand or communicate the challenges of local or global pollution?

Telecommunication seems to play an increasingly important role in future society. Capacity, bandwidth and speed of transfer for large amounts of digitised data, including sound and graphics, is covering greater parts of the world every month. From being a separate technology it is now accelerating its integration into computer and other information technologies, changing the PC from a standalone device into a small node in a world-wide network of information. Large databases are included in the same network and professionals of all kinds are meeting in the virtual space to discuss their problems and points of interest.

## Open and Distance Learning (ODL) as a tool to cope with new demands

The ever increasing demand for updated skills and knowledge in different fields makes it impossible to cover it all through traditional education or training systems. Companies and public institutions have long traditions in arrangement of courses in-house or at hotels, etc. when new skills or principles were to be introduced into their activities. No credits or formal qualifications were attached to most of these courses. It was part of the in-service training offered by the employer and a requirement to be updated on the task to be performed.

An alternative for raising the qualifications of the staff was to let a selected few attend formal education programmes, acquiring new degrees or diplomas. Expenses related to such programmes could be borne by the employer, by the professional her-/himself or as a joint agreement between the two parts. Costs could be considerable for study programmes running over several years in order to obtain a degree, even in cases where the education or training was provided outside regular working hours.

Distance education has long been a practical way of taking courses and obtaining qualifications. Specialised institutions like correspondence schools and open universities have provided thousands and millions of citizens with interesting offers of initial and further education. In the age of new ICT it is natural to apply the technology for distribution of learning material. As a consequence of this the importance of *distance* in the learning process is changing. It is now becoming more essential to talk about *open* learning, possibly combined with learning at a distance into *open and distance learning*, ODL.

The definition of ODL varies according to organisation, structure and possibilities included. In this paper we will stick to the interpretation where the *openness* is particularly directed to the open access of learning material through electronic networks. The *distance* of the students is not of the same importance to us; they may well be regular students inside the institution, staff members or individuals in another part of Europe. The important principle is that university courses, learning material as well as exercises and examinations are available to the learners in their part of the world. With certain restrictions the services should also be available to them when it is required, i.e. asynchronous distribution and availability is the general rule.

Further and in-career training through ODL therefore makes it more easily available, costs and regulated working hours can be saved and the traditional universities and colleges may be opened to the public for life long learning programmes. The effort for traditional universities in order to change some of their traditional mass lectures and demonstrations into transferable, ICT-based learning material is quite a scary exercise. It may not even be possible or desirable in many cases, in particular subjects or topics. The latter is certainly the case for some of the special aspects, e.g. in training of nurses or in teacher education, where important values can hardly be detached from the human touch. There are, however, lots of topics and courses related to teacher and nurses training that may successfully be offered through ICT based ODL, and where positive results are already observed.

## Challenges to institutions

The enormous efforts and resources needed for providing ODL material to new target groups of learners simply requires that parallel work and development of products should be avoided. All partners will benefit from cooperation instead of competition, exchange of material instead of protection, specialisation of competence instead of covering all fields at every institution, sharing of duties instead of performing double work. In particular, the learners will benefit from the products and facilities resulting from such cooperation.

There must be regulations and rules to play by, however. Models for cooperation between academic institutions for the purpose of ODL have been tried out in several European projects, providing valuable experience as a basis for revision of models and development of new ways for providing ODL to the optimal benefit for both students, staff and the institutions as such. Most valuable results and experiences have been acquired when both academic institutions and receiving organisations have been working together in the planning and development of ODL courses and material. Examples of such activities will be provided in the following sections.

## Institutional cooperation

Cooperation between academic institutions seems to be an educational policy, nationally as well as internationally, including the establishment of an educational cooperative network between centres of higher education and research. Several countries throughout Europe state in their White papers or other political documents principles and guidelines for cooperation and sharing of expertise between educational institutions. As an example of how cooperation between institutions and exchange of experience are stressed, the European Commission's Socrates programme has *partnership between educational institutions* as one of their criteria to allocate funding to projects (Socrates guidelines 1996).

Enterprises throughout the world claim that there is a huge need for updating of personnel. To meet this need we already see a growing tendency of real cooperation between enterprises and the formal educational system in order to update their employees. Normally, the employer has the responsibility for updating their staff, but by now we more often see a combination of updating the staff by offering them formal qualifications. Development of necessary curriculum to obtain formal qualification is based on cooperation of enterprises, between the companies and the formal educational system, where the companies play a central role in describing the needs and also are the ones to find or provide the know-how.

Introduction of electronic networks, e.g. Internet, increases the functionality and facilitates practical activities among co-operating institutions. Both academic staff, learners and the outside learning society are supposed to benefit from diverse specialisation and expertise, sharing of duties between institutions.

Together, the collaborating institutions may become able to provide a greater variety of studies to their learners than any one of the institutions can manage on its own. Collaboration should emphasise the importance of being able to utilise the various profiles, specialities and professional expertise of the different institutions and enterprises. This should increase both the width and depth of the learning environment.

One example of how institutional cooperation has been practised is the way the NITOL project has organised their work. (NITOL = Norway-net with IT for Open Learning). Four academic institutions in Norway have successfully practised their own model of cooperation since 1994. Much of the success in this pilot project is probably based on long-standing relations and trust between the key personnel involved. The project's primary goals were to:

- Gain experience and develop methods for ICT based, open, flexible and distance learning at university level
- Facilitate cooperative research and development between geographically separated academic units and personnel.

In order to approach these goals partners had to:

- Establish an open network making education within Norway-net available to students and other groups and individual participants from business, schools, administration, etc.

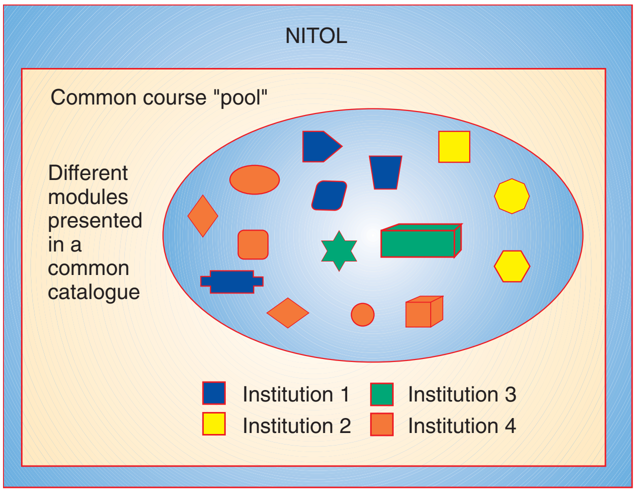


*Figure 1  The Open Access Model*

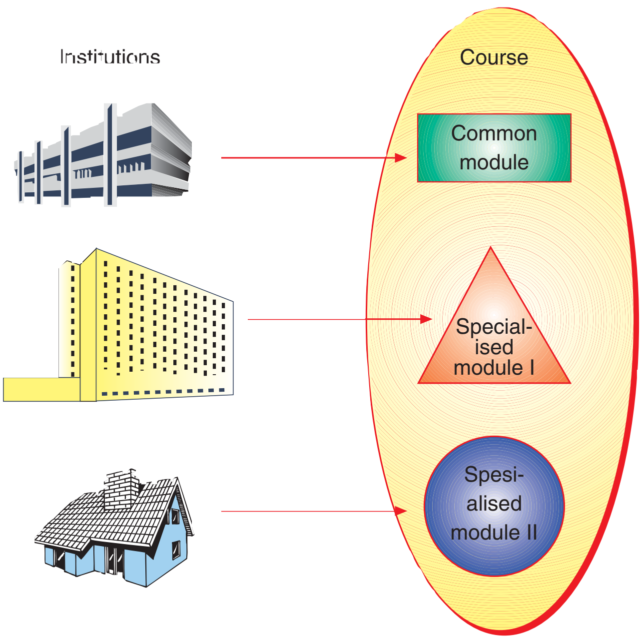


*Figure 2  The Composite Model*

- Gain experience on distribution of educational materials through electronic networks
- Test the use of electronic conferences and mail systems as the basis for group work and co-operative learning
- Develop an extensive, dynamic and creative electronic learning environment based on local and wide area electronic networks.

## Organising NITOL

Despite the close relations and friendship between the active partner representatives in the project, a formal organisation had to be established in order to be prepared for disagreements or conflicts that might arise over economy, responsibility for students, networks, software, academic property, etc. To meet this requirement two formal contracts were established, one general agreement of cooperation between the four institutions, signed by the heads, and one particular NITOL contract signed by the project representatives from each institution.

The signed contracts are mostly dormant. In a few cases it has turned out very useful to have them as reference and guidelines for disputes that arise. The project agreement is mainly in line with the project group's feeling of common sense, while the institutional contract is an important document when institutional authorities sometimes forget their commitments to NITOL.

Technical support and standards have proved to be important issues for an ODL project based on ICT. This always turns out to be a touchy issue between experts. Among the 'experts' in such a project are tens of teachers and hundreds of students – who all have their own, well founded preferences for software and communication systems. On the other hand, there are also hundreds of 'non-experts' or novices who need to be given simple solutions that fill their present needs. Among the latter group are also some of the course providers. It is therefore of utmost importance that the project group is able to make firm decisions, stick to the solutions given, and that there are able and committed people to support the technical system decided upon. As new technology develops and becomes available – outside the project – a careful balance must be found between existing, stable solutions and introduction of new, improved facilities for the project services. Responsibility for these technical decisions lies with the project group, while implementation and support are placed with one of the partners.

## Objects of collaborative activities

### Course material

Together, the collaborating institutions are able to provide a greater variety of studies to their students than any one of the institutions can provide on its own. The collaboration emphasises the importance of being able to utilise the various academic profiles, specialities and professional expertise the different institutions stand for. The colleges are able to enhance their curricula at both undergraduate and graduate levels, thus providing their students with a greater variety of subjects than can be offered at any one institution alone. In addition, quite a few students want a more flexible programme that allows them to study at the time and pace of their own choice, with fewer restrictions on attendance and place of study. Collaboration around flexible and open learning makes this possible.

Because of the variety of professional profiles at the co-operating institutions, close collaboration strengthens the whole teaching and research environment at each institution. Experience is that through electronic communication it is possible to work together in a close and efficient manner in a "virtual" environment of co-operation. This has already been established between the NITOL institutions, and is spreading throughout the rest of the IT environment. This is a system that effectively establishes and utilises contacts across the boundaries of institutions, regions and countries.

Course material is developed along three different paths or models for institutional cooperation:

**The Open Access Model** (Figure 1) is one of several models within the NITOL activity. This was the first one tested, where each institution offered some of their traditional courses, revised or re-developed for electronic transmission to their own students as well as to outsiders.

The beneficiaries of this model were mainly the students, having easier access and more courses to choose between. The institutions and the professors gained experience in dealing with distant students and the colleagues' ways of presenting learning material. A golden opportunity to have a look at how colleagues presented and designed their teaching material was a fringe benefit.

**The Composite Model** (Figure 2) is practised when the institutions compose larger courses by joining two or more smaller modules developed at different institutions.

The result could be a tailored study for special purposes or just an extension of a small course, which a single institution is not able to develop alone, due to restrictions on time, staff, expertise, etc. This model seems to have its strength especially when colleges/institutions are small or medium sized, where resources and the variety of the staffs' expertise is limited.

In the composite model, the institution responsible for the specific module, also takes responsibility for the students' exercises within the actual module. Elaboration and marking of exercises are also tried out as a collaborative, composite work, while assessment normally has been dedicated to one institution.

**Joint Venture Model** (Figure 3) is a model where the main idea is continuous, real collaboration between the professors in the development of course work. This means that two or more institutions within the network join forces in developing open, flexible learning materials in the form of lessons. One or more lessons forms a module, and the final course consists of several modules. Mature students and professionals jointly contribute to the understanding and learning of a topic or subject. This is not utopia, it is already a reality in the joint venture model. As an extension of the model, a virtual, joint venture learning society on the network does not seem far away.

A first evaluation of collaboration, assessing the intentions and the models described, identifies characteristics like *inspiration* both to students and professors, *improvement* in the quality as well as an *increase* in quantity of the courses offered. All parties involved seem to be satisfied and inspired to further efforts for open and flexible learning

## Mutual services

An important issue in the partnership agreement is the mutual recognition of credits, courses and modules between the partners involved. Students may thus choose modules and courses from a larger menu, combining it into more varied and specially tailored lines of study. It is, however, still up to the institution that issues the certificate to recognise the final combination of subjects and courses.

External funding has played a central role in the early stages of NITOL. Applications and proposals for funding have turned out to be more positively viewed in cases where a collaborative organisation has already been established. The NITOL partners have therefore in several cases joined forces in the process of application, and afterwards shared the benefits obtained through decisions by the project group. The basic principle is sharing of funds acquired in equal parts. Often the group agrees to reserve particular sums for special services, e.g. technical support, printing of catalogues, administration, etc., and then to share equally the remaining sum.

## Marketing

Instead of competing over the same target groups with parallel courses in related fields, the NITOL group has consequently, from the start, issued a common course catalogue for all the courses provided by the group. Even though the courses are provided by individual staff members at separate institutions, and marked this way in the catalogue, there are great advantages in joint marketing. Distribution of information becomes easier, potential students get a better overview, and large scale customers, like the Navy, can find a more varied offer for their members.

After only two years the NITOL concept already has more meaning to a lot people interested in ODL, than the name of each of the partner institutions. At the same time, each institution benefits from belonging to this group.

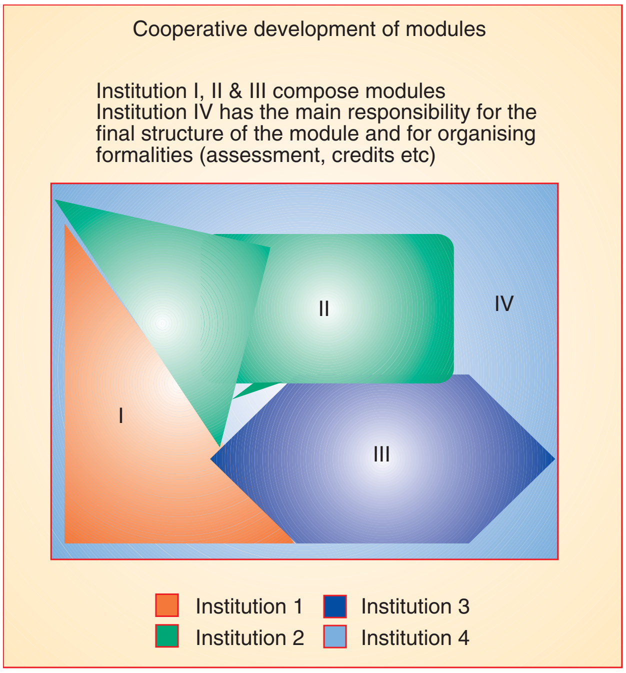


*Figure 3 Joint Venture Model*

## Visions

The models for ODL through telecommunication, taking advantage of the institutional cooperation described above, may open up for simpler access and higher flexibility for all kinds of professionals to obtain in-service and further education, as well as taking new formal degrees, without leaving their regular work/duties or their families. With the growing familiarity of Internet, telecommunication and similar facilities in homes and work places, the time may soon be ripe for higher education modules to be available *when* and *where* the learner finds need or desire for it. This will compose an important aspect in the policy and possible success of *lifelong learning*.

# From electronic mail to Internet – where does it take us?

BY TORSTEIN REKKEDAL

## Introduction

This article discusses the theoretical background and practical reasons behind the decision of one specific institution, NKI (Norsk Kunnskapsinstitutt), to research on and develop distance education based on computer mediated communication, and reports experiences from teaching through electronic communication for nearly 10 years. Thus, perhaps a more correct title of this article could have been 'From correspondence teaching to organising individual and group learning on the Internet', as our decision to direct our efforts to develop a distance education system based on electronic communication, was taken as a result of our continuous experiments on developing the NKI distance education system. Computer mediated communication was in this connection considered to be a medium qualitatively different from all other technological developments of media for distance education because of its flexibility and its potential of integrating presentation of learning material in different forms and capacity for individual, small group and large group communication.

NKI is a multiform teaching institution offering full-time and part-time programmes on secondary and tertiary level. NKI courses and programmes are offered on-campus, by distance education or as decentralised courses. The distance education programmes may be supplemented by local face-to-face classes or seminars. NKI Distance Education offers a number of programmes at university and college level. Some of these are organised in co-operation with Norwegian universities or our own "Polytechnic College" (Den Polytekniske høgskolen). The majority of the NKI distance education programmes are secondary level studies preparing for public or internal exams.

## Distance education and new media

During the last 25 years distance education nationally and internationally has generally changed from organising individual learning based on printed material and two-way communication via the ordinary postal system to multi-media learning based on an integration of print based media and new media and communication technology. NKI has followed these developments closely and tried to develop and modernise the distance education system along different lines:

### 1 Student support and counselling

The individual adult learner has generally a great need for support to be able to cope with the studies normally in competition with other demands from job and/or family responsibilities. Research has shown that distance education systems should develop administrative and teaching support systems to help the students adapt to the demands of part-time studies to succeed and complete. In this connection we have researched on follow-up systems, initial and continuous counselling, training in distance learning study techniques, turn-around time involved in two-way communication and specific training for distance tutors (see e.g. [21]).

### 2 Media research

The correspondence teaching system of the 1960s has gradually been changed into a multi-media distance teaching system by the introduction of video-tapes (both video-taped lectures and complete learning programmes) audio-tapes, computer software and laboratory kits, as well as, in some cases, video-conferences, radio- and TV-programmes. Some of our research projects in this area have been carried out in co-operation with other distance teaching institutions and Telenor. Supported by and in co-operation with Telenor we have carried out experiments on telephone tutoring [22], telefax as a medium for individual tutoring and guidance [24], audiographics [25], video, local cable television, satellite distribution and video conferencing [7], [8].

### 3 Computer mediated communication

Computer mediated communication has been one specific priority branch of the media research since 1986. NKI launched the so-called "EKKO Project" in 1986. The acronym, EKKO, denoted "Electronic Combined Education" (in Norwegian the combination of distance education and local face-to-face classes) a name that signified that the computer software should constitute a virtual school or classroom substituting the need for physical presence in a local class. The aim was to develop what we called the "Electronic College", a teaching system offering study programmes independent of time and space and facilitating flexible communication for administrative, social and teaching/learning purposes. Our understanding was that the developments within computer communication would constitute teaching and learning possibilities which really could change distance education dramatically. This article accounts mainly for this research, experiences and achievements (see e.g. [15], [16], [18], [19]).

## Technology and competitiveness of distance education institutions

The rapid developments concerning new media and communication technologies constitute both new possibilities and possible dangers for distance teaching institutions. The new media create, at least in theory, new possibilities for preparing better and more cost-effective learning. At the same time these developments have resulted in new types of institutions entering the market of education, and have incited traditional schools, colleges and universities to offer media based teaching. Thus, distance teaching institutions and universities have encountered, sometimes unexpected, competition on the educational market. This situation was stated in extreme form by Tony Bates in an introductory article in an issue of "Open Praxis" focusing on technology under the title: "Hello technology! Goodbye, distance teaching institutions?" [1]. The changes in distance education caused by the emerging technologies have made some writers describe the new initiatives as 'third generation' distance education [12], the first being correspondence education and the second multi-media teaching. Bates foresee that the technological developments require new types of organisations, these new types can either develop from distance education institutions, universities and colleges or new institutions created from scratch. Until now, it seems that distance education institutions have not changed dramatically concerning the organisation of their teaching and their application of new media. For instance, Bates ([2], p. 20) states:

> *"There is more talk than action about the use of technology in distance education. Even in the most technologically advanced of our member (EADTU) institutions, print, correspondence and face-to-face teaching*

*still predominate. For most European distance learners, these are still the only media currently that really matter."*

There is reason to believe that this is the situation also today, even after the explosion of interest in the Internet since 1993. According to Bates [2] there are good reasons why the technological development has been so slow in the distance education institutions. One is, obviously, that distance teaching institutions have long traditions and investments bound up in the 'old' technologies and the natural inertia of large institutions acts against rapid changes. However, there are also rational reasons for the slow technological developments. Print, correspondence and face-to-face are well tried methods. As Bates ([2] p. 21) puts it:

*"The use of more advanced technology can be justified only if it meets one or more of the following criteria: lower costs; greater teaching effectiveness; increased accessibility to students. These are proving hard criteria to meet, so it is not surprising that there is still major academic and management resistance to the use of new technologies in most of our member institutions."*

We shall briefly comment on two other writers who have discussed the options available for distance education providers to be able to compete in the new technological environments, one representing the distance teaching universities, the other representing secondary education. John S. Daniel [4], vice-chancellor of the British Open University, concluded in his analysis of the competitive advantages of the 'mega-universities' that:

*"... networking students from their home computers should reinforce the competitive advantage of the mega-universities. Distance education has already evolved through two generations, correspondence courses and multi-media packages. The knowledge media ('the coming together of telecommunications, television and computing is producing a media environment for distance education that is more than the sum of its component elements' (p. 11)) represent a third generation of supported open learning that enriches distance education by giving students rapid communication with the people and learning resources of the academic community."* [4]

Margaret Gamlin [5] of the New Zealand Correspondence School discusses the transition of distance teaching institutions from print and postal-based delivery of traditional correspondence education to a more immediate interactive technology-based delivery. She points out that the drive in many countries today to a competitive education system encourages conventional providers to use technology for innovative delivery of courses. However, most current technologies (such as audio and video conferencing, including audio graphics) tend to support the replication of the conventional classroom – the extended classroom model. She stresses the 'openness' of the correspondence education model and stimulated among others by Bates' article [1], she foresees a development in her institution, which builds on this openness and flexibility and learner centred focus, and changes the school's teaching into a 'multi-media' model.

The above considerations are the reasons behind NKI's decision to go for the development of computer-based communication and the development of 'The Electronic College'.

## NKI Electronic College – 10 years experience of computer mediated communication in distance education

In one of our early papers on computer conferencing titled 'Computer conferencing – a breakthrough in distance learning or just another technological gadget?' [17] we discussed developments of media and technology and concluded that computer conferencing or computer-mediated communication constituted a development qualitatively different from all other media with exceptional possibilities for developing flexible and open distance teaching of high quality. After 10 years of experiences we believe that we may conclude that computer mediated communication in some form will become an important technology in distance teaching and learning and over time change the whole concept of what distance education is. On the other hand, this has not at all happened so far.

### The virtual school

The basis of our ideas for establishing the 'electronic college' was largely taken from [6] as introducing computer conferencing as a means to establish a 'virtual classroom' with computer-based communication structures similar to those normally taking place in the normal classroom. The 'virtual school' as, we conceived our aim, should not only emulate the classroom activities, but all other places and activities within the school system.

Morten F. Paulsen, the manager of the EKKO project [14], pointed out the following requirements for the virtual school:

1. *It should emulate all the main tasks of a school: teaching, administrative and social.*
2. *It should be generally available concerning geography, technology, economy and student competence.*
3. *It should be independent of time, i.e. continuously available and accept asynchronous communication.*
4. *It should emulate the different needs of human communication, one-to-one, one-to-many and many-to-many.*

## Some important functions of computer conferencing in distance education

Based on NKI experiences and information from other sources (e.g. [13]) some important functions for the computer conferencing system in distance education were identified:

**Distribution of information:** Distance teaching systems have a large need for increased efficiency in updating and distributing information to the students, full-time and part-time teachers and administrators.

Examples: Information about courses, seminars, student associations, examinations and updating of learning material.

**Two-way communication between tutor/counsellor/administration and student:** In most distance teaching systems, submission of assignments for correction and comments is an important element. It has been demonstrated that long turn-around times may have


*Home page of the NKI Electronic College*

destructive effects on course completion [20]. It also takes a long time for students to receive answers from their tutors when they really encounter problems in their studies. To some extent, the telephone has been applied as a means of communication. Electronic mail is independent of both time and space.

Examples: The student may ask questions at any time, without the time delay of mail services. In principle, draft solutions may be submitted and commented on, thus introducing a more flexible organisation of tutoring and assessment. If desired, student answers may be made available to other students, before or after the submission of their work. Included in the system can also be on-line computer-scored tests, as a substitute for off-line testing which we have seen in some distance learning systems. On a higher level, the two-way communication may serve as a guidance for individual student projects.

**A substitute for face-to-face teaching, introduction of group discussions and project work:** A number of distance learning systems include the possibility of face-to-face meetings with tutors and/or fellow students. For many distance learners, the possibilities of taking part in such activities are restricted. Some theorists have argued that direct teaching may have disruptive results on student autonomy and ability for self-study.

Examples: While face-to-face teaching in distance learning systems often seems to have developed into lecturing/presentation of subject matter, computer conferencing concerns information exchange and discussion. Discussions taking place in the classroom can develop into exciting experiences of group learning. The discussion is time and space independent, the medium seems to foster equality of status between students, and between students and tutor. Specifically designed group learning methods may be applied, such as group submission of assignments, group learning and presentations, group seminars and project work.

**The public tutorial:** Student questions of a general academic or administrative nature may be accessible to all students, as a question from one student normally will be of interest to others. Pre-produced comments on general aspects of a course can now be distributed on-line, and the tutor is given an opportunity to expand on the pre-produced learning material.

**Peer counselling:** As peer counselling and informal co-operation is a natural part of the on-campus activities of any teaching institution, the possibilities in computer conferencing are obvious. It has been demonstrated that computer conferencing in general may give peer help in solving problems – often from an “unknown friend”. In large-scale systems, where hundreds of students are studying the same subject, peer help may be of particular importance.

**Free-flow discussion:** A number of educational conferencing systems have formally established informal meeting places for continuing discussions such as the “Cafeteria”, or “Local Pub”. Through the computer, informal discussions and student association activities may be included.

**The Library:** A collective database can be developed within the conferencing system, to facilitate the availability of relevant articles, short lectures, etc. to the distance learner.

**Registration, administration, teacher conferences, etc.:** Modern distance learning systems have developed complex administrative systems for student monitoring. These systems can and should be integrated with the conferencing facilities.

**Development of teaching material:** The system may efficiently be used for co-operative development of printed material – both within the institution and between institutions.

**User directory:** The system contains information on its users, e.g. where one may find fellow students with common interests. Phone numbers and addresses can be made available. The information actually increases possibilities for direct communication and via other media.

## Initial stages of the EKKO project

The aim of the project was to: Develop a computer based conferencing system for distance learning and apply the system for experiments in different contexts to gain pedagogical and administrative/organisational experiences within distance education based on computer conferencing – in order to install conferencing as a standard option for NKI distance students.

The project followed these stages:

1. Introductory search in the field
2. Development of a specific conferencing system on the NKI mini computer, HP 3000
3. Pilot experiments with “on campus students”
4. Study visits to institutions in Europe and North America

5. Pilot try outs in distance learning
6. Introducing computer conferencing on a larger scale in distance learning.

## The First Generation: 1986 – 1993

The first version of EKKO – the computer conferencing software emulating the 'Electronic College' – was designed and implemented during 1986. During autumn 1986 we carried out the first pilot experiments with on-campus students, autumn 1987 the first distance education course was delivered to a small group of 4 students. The next semester, spring 1987, two additional courses were offered. From the spring semester 1990 NKI Distance Education has been offering a complete college programme (equivalent to one year of full-time studies) based on computer mediated communication. This programme in 'Administrative computing' includes 10 different courses totally. In addition, from the same semester, NKI offered its distance training programme for distance tutors through the same system.

During its most intensive period EKKO served more than 3000 users, including on-campus students, prospective students, active distance students, former students, tutors and administrative staff. The system included an e-mail system, closed and open conferences for administrative, teaching and social purposes, and bulletin boards. During the first generation period the 'Electronic College' delivered more than 1000 courses with an average completion rate of above 80 %.

The following were some of the effects and experiences of the first generation of the 'Electronic College' at NKI:

From 1990 NKI was one of a few institutions world-wide delivering a complete study programme based on electronic communication. Prospective distance tutors could qualify for their work through distance education based on computer communication. The system was applied also for administrative communication and discussions. Full-time staff members had been qualified to teach through the conferencing system, and a part-time staff of competent computer conferencing tutors has been built up.

Computer conferencing had been applied in subjects with different didactic solutions; subjects emphasising individual study, subjects with emphasis on group discussion and in project work. To be able to exploit the possibilities for discussion, group learning and peer support, most of the initial courses required the students to start at the same time and follow a fixed common progression during the semester towards the exams. This made the computer conferencing courses less 'open and flexible' than the 'correspondence type distance courses'. Many students express clearly that they prefer – or demand – the freedom known from un-paced individual study. Thus, courses where the students can start whenever they wish and study at their own pace has also been offered. The students who have experienced this individual freedom in their studies have also been generally positive, and we see a great challenge in developing didactic arrangements combining the flexibility of individual un-paced study with the possibilities for social interaction in the virtual school environment.

We also learned during the first generation experiments that teaching via computer conferencing often becomes "labour intensive" on the part of the tutor. Originally, we had a hypothesis that the supposed increase in learning quality in the "virtual school" could be compensated for through less emphasis on the development of learning material. So far, our experiences have not supported this assumption. Thus, it seems that investments in pre-produced learning material will be approximately the same as in other large scale systems if the total quality is to be satisfactory.

The tutors have reported that teaching via EKKO has been very stimulating, but very demanding concerning the number of hours used and the "continuous" attention needed. We see a challenge in developing teaching/learning strategies that stimulate student-student communication without putting unrealistic demands on tutor resources.

Concerning student participation, NKI experiences and experiences in other settings, such as the British OU [11], prove that conferences may become too small or too large. The users fall into groups of 'active', 'less active' and 'passive users'. There must be a sufficient number, or 'a critical mass' of active users to make the conferences attractive.

It seems necessary to have an active conference moderator in the conference. The tutor (or another person) must take the role as organiser, active contributor, and/or social integrator. After we formally engaged one student as host of the 'on-line cafe', the social activity and student satisfaction and motivation seemed to increase considerably.

The teaching/learning and administrative functions which can be handled by the system, and the quality and quantity of contributions depend on whether participation in the system is voluntary or obligatory. Voluntary participation may result in low activity which may become a self-fulfilling circle of diminishing interest.

In our computer conferencing courses we have experienced a somewhat higher number of non-starters than in comparable correspondence courses, probably due to initial technical difficulties, and higher completion rates among the starters. Students having completed courses based on computer conferencing, achieved better at exams than both correspondence students and face-to-face students. We do not have data to make certain whether these differences are a result of characteristics of the media/methods or by differences in recruitment.

In general, the students report favourable attitudes to computer conferencing as a form of study. They seem to be more active in the social conferences than in the academic conferences. This may be a result of the fact that most NKI courses depend highly on individual work and assignments for submission rather than group discussions. Most students state that the mail system is the most important subsystem of the first generation of EKKO. This may indicate that the optimal way of organising the studies has not yet been found. On the other hand, it seems that many part-time distance learners have to find time efficient study strategies to be able to cope with the demands of study beside job and family demands. This means that many would not give priority to social or academic interaction relative to individual study and exercises in preparation for their exams. These experiences seem to be in line with other findings indicating that part-time distance learners often adopt time saving techniques in their approach to learning to survive the demands of study beside job, family and society pressures [9], [10].

## The Second Generation: from 1994

NKI considered the first generation of the electronic college to be quite a success – both as a computer system as such, and also concerning how we managed to organise the distance learning system. We continuously followed other developments in teaching/learning methods and software on the market and examined different products, such as CoSy, PortaCom and FirstClass, with the aim of developing an improved 'second generation' system. When we had to introduce new solutions because of retirement of the old host computer, the requirements were that the system should

- Be based on standard software
- Provide access to the Internet
- Be attractive to all NKI departments and available from any computer network within NKI
- Be attractive to possible collaborators
- Be as user friendly as possible.

From January 1, 1994 the new 'open' Electronic College was introduced. This second generation system was based on a philosophy of being as open as possible to other networks and services. Accordingly, it was based on Internet, e-mail and the Listserv conferencing system. From the beginning the user interface for modem users was text-based. From January 1995 modem users were offered communication software developed for MS-Windows and SLIP (Serial Line Internet Protocol). The second generation stimulated the development of many new courses and study programmes, such as a complete programme on Information Networks and courses in the use of Internet, WWW-presentations, Java-programming, etc.

All the courses and programmes developed after the introduction of the second generation system are un-paced and put no limits on times for enrolment. This solution has been chosen as a consequence of our conclusions from an interview survey among EKKO students on recruitment and study barriers:

> *"... it is a major challenge to develop methods and organisations in distance education based on computer conferencing systems which take care of the students' need for autonomy and flexibility."* ([23], p 92)

As mentioned, for the second generation system NKI decided to use Internet focusing on SLIP, e-mail and ListProcessor (a Unix version of the Listserv conferencing system). Listserv offers an advanced distribution system which may be explained as a conferencing system based on e-mail. Such systems can support more users than any other conferencing system because they communicate with the system via e-mail. The lists can be configured as open or closed, for instance open to members of the whole electronic college (such as the 'on-line cafe'), a class or a specific group (such as teachers). Lists can further be configured as one-to-many (information and bulletin boards) or many-to-many (conferences/class discussions) lists. Each list is managed by a 'list owner' via e-mail. In addition to the lists directly related to teaching, social and administrative purposes of the electronic college, the system includes some international lists: 'Andrea', an open one-to-many list for distance educators in Europe, 'Norwaves', an open one-to-many list for distribution of 'News from Norway'; and 'Norweave', an open many-to-many list for 'International friends of Norway'.

The first semester with the new generation was marked by transitions and adjustments to the new system. In some ways, the old system was felt more to emulate an 'image' of a virtual school. The open system introduced new problems due to lack of standard interpretations among e-mail systems. However, students and staff seem to have adjusted and become familiar with the new system. The general access to Internet resources outside the NKI realm seems to be an advantage appreciated by the students. Access to Internet is offered to all students at tertiary level and at the NKI Technical College and consequently, application of Internet resources can be integrated in some of the study programmes.

Recently, NKI introduced the first three courses based completely on electronic distribution and communication, Java programming, WWW-presentations and Multi-Media networks. In these cases the learning material is available on the Internet/WWW only.

We have just started to adapt the Course for Distance Tutors for presentation on the WorldWideWeb with links to internal and external national and international resources.

## Some conclusions

We consider the decision to base the electronic college on Internet, public available software and with 'open' solutions, to be a sound conclusion. There is reason to believe that more efficient and user friendly software adapted for teaching and learning will be introduced and available for our purposes.

Access to Internet and use of Internet are appreciated by students and tutors and open opportunities for sharing of experiences, learning from others and new possibilities for arranging effective learning situations.

Designing attractive and effective learning is no easy task. To repeat what we have said many times, there is a long way to go before we know how to design for learning adapted to the ever changing possibilities of computer mediated presentation and communication.

Adapting organisational and administrative procedures and systems to the activities of the electronic college is not a trivial matter. It may include major changes in organisational systems, working styles and administrative computer systems.

Computer based communication is demanding and time consuming both for administrators, student counsellors and tutors.

There are still many questions that remain unanswered or that are only partially answered. For instance, how will students generally accept electronic communication in distance education? Today, after nearly 10 years of delivering the NKI computer science programme via computer mediated communication and the same study by correspondence methods, two thirds of the students (who study computer science, who have to apply computers and software as part of their studies) prefer correspondence education rather than computer mediated communication. One reason might of course be the differences between these two options concerning flexibility and freedom.

An important question remains: How can this technology be applied to represent a more attractive and efficient learning environment for distance students, and how can we design the courses and tutoring and administrative systems to make distance education based on computer mediated communication really cost-effective?

Sometimes it seems that educators believe that presenting the students to the Internet as a resource of information and means of communication solves the problem of offering effective and efficient education at a distance. Our conclusion is that this is not at all the situation. The challenge for distance teaching institutions is to find ways of planning, organising and carrying out teaching in ways who help students learn according to individual needs independent of time and place restrictions. This means that the medium itself does not solve any problems [3]. We must learn how to design instructional programmes including student learning activities based on this new medium to achieve optimal outcomes for different kinds of learners in different subjects having different aims and objectives.

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# Design guidelines for WWW-based course environments

BY ANKE EEKMA AND BETTY COLLIS

**WWW-based course environments are rapidly appearing, before there has been time for much theoretical development with respect to guidelines for their design. In this article we describe a set of 20 guidelines which could be a contribution to this development. The guidelines are illustrated through their application to a particular case, the redesign of a WWW-based course "Environmental Management", now in operation, with more than 120 learners in six countries.**

***Guideline 1:*** *Be consistent in designing an interface, especially when using text, pictures or icons to instruct the learner.*

***Guideline 2:*** *Use metaphors that correspond to the user's daily life, so that he has concrete expectations about the result of an action.*

***Guideline 3:*** *Set as few heading styles and subtitles as are necessary to organise the content, then use the chosen styles consistently.*

***Guideline 4:*** *Many basic typographical guidelines for paper lay-out design apply also to designing texts for computer screens. The page should look attractive, so make a structured pattern on the page.*

***Guideline 5:*** *Consider carefully which colours to use and in which situation.*

***Guideline 6:*** *Because icons and virtual metaphors are not unambiguously understood across all computer interfaces and international borders, they should be investigated before put into a page.*

***Guideline 7:*** *Do not confuse the user by putting more than seven (navigational) icons on a page. The preferred number of icons on a page is five, plus or minus two.*

*Figure 1 Design guidelines for presentation aspects of WWW-based courses*

***Guideline 8:*** *The user should get a clear overview of the structure of the hyperlinked site. This can be accomplished by adding navigational buttons which link to the previous and the next page in the same sequence, as well as a link to a local homepage.*

***Guideline 9:*** *The user automatically generates a mental model of a hyperlinked site. The user should be helped to make this model a structured one, by adding functional and graphic continuity between the various components and subsections of the site.*

***Guideline 10:*** *Menus lose their value if they don't carry at least four or five links; text or list-based menu pages can easily carry a dozen links without overwhelming the user or forcing users to scroll through long lists.*

***Guideline 11:*** *Page design in hyperlinked environments should emphasise the power of hypermedia links to take full advantage of this medium.*

***Guideline 12:*** *The user should know what kind of information he can expect when following a certain link. Therefore, make the name of the link clear, or add some additional information to the link.*

***Guideline 13:*** *Don't let the user get lost in the information. A page for a hyperlinked environment should contain no more than two to three 640x480 screens worth of information.*

***Guideline 14:*** *Keep in mind that some users want to save or print the material rather than interacting with it as hyperlinked material from the computer screen. Make a separate print file or design the pages so that the user (particularly the networked user) is able to print pages of the course in a reasonable fashion.*

*Figure 2 Design guidelines for WWW-based course environments relating to the hyperlinked aspects of those environments*

## WWW-based course environments

WWW technology is increasingly being used to support course delivery, for both face-to-face and distance learners (see [3] for an inventory and analysis). In some cases, the support is a new feature of an existing course, outside of the course itself. For example, the WWW is being used as an information system for courses, with both one-way broadcast-type communication from institution and instructor to students as well as integrated access to information related to the specific learner. The WWW is already familiar in the role of "virtual library", providing hyperlinked access to course resources, including those specific to the study material of a course; those involving multimedia databases of images, text and even audio; those located external to the course but linked to the course by the course designer; and those found by the learner himself with the use of embedded search tools. In addition, the WWW can now integrate various forms of communication support to course information and resources, where the communication can take many forms and modalities. Continual technical developments in the WWW now allow integration of other digital materials, such as tutorial and simulation programs as well as various forms of interactivity via CGI scripting and Java aplets. Groupwork and collaboration, both in real and deferred time, are also now supported by WWW-based tools. Furthermore, many courses are now being entirely offered through WWW environments (for examples, see [4]).

## Instructional design for WWW-based courses

Given all these possibilities, it is not surprising that an increasing number of courses are including some combination of these WWW functionalities, and as the combination increases the WWW site becomes more and more the central medium for the course. Through one WWW-based user interface, the learner can access a wide range of resources and be able to carry out a wide range of activities. However, the rapid development of the WWW technology and the ideas being put into practice via the technology have not yet been supported by cohesive sets of instructional-design principles to guide their form and logic when they are to be applied to course design. Such principles need to reflect at least four streams of considerations: traditional instructional-design insights relating to how learning takes place and can best be organised; design insights from human-computer interface and human-computer interaction research relating to principles relating to the usability of systems, including design considerations relating to layout and presentation on computer screens; design considerations specific to hyperlinked learning environments; and design aspects unique to the WWW environment itself.

## Design guidelines for WWW-based courses

We have responded to this need for a cohesive set of design guidelines for WWW-based courses through a careful literature review of the various design aspects noted above [7], and have developed a set of 20 design guidelines as a contribution to this need [6]. We are now applying these guidelines in a number of ways, to test their applicability and to supply insights for their on-going revision. The guidelines themselves can be grouped into four categories: presentation, hypertext, pedagogy, and technology. We present them briefly here.

### Presentation aspects

Presentation aspects relate primarily to the user interface of WWW-based courses, how the course is presented to the learner (and instructor). Guidelines in this context are strongly influenced by HCI and user-interface design experience, and relate not only to specific considerations such as typography, colour, and the use of images, but also to overall aspects of interface design, such as the application of metaphors. From relevant literature, (see for example [12]), we have extracted the following seven presentation guidelines as particularly relevant for WWW-based course environments (Figure 1).

### Design guidelines for hypertext-related aspects of WWW-based courses

From the literature relating to hypertext systems, (see for example [11] and [10]), particularly the problems that users may encounter when navigating such systems and the problems that learners may face in using such systems as learning environments, we know that making the structure of a hyperlinked system clear to the

***Guideline 15:*** *Enable the learner to study whenever and wherever he wants by making the learning materials accessible at any time and anywhere.*

***Guideline 16:*** *Learner commitment and motivation can be increased by integrating questions into the instructional materials.*

***Guideline 17:*** *The learner should be able to answer questions within the learning material. The answers to the questions should also be available for the learner, preferably after he has answered them.*

***Guideline 18:*** *The learner should be able to get in contact with other learners, in the form of co-operative working or discussion as well as informal contact.*

***Guideline 19:*** *The learner should be able to get some form of (local) tutoring.*

*Figure 3 Design guidelines for WWW-based course environments from the educational perspective*

***Guideline 20:*** *Both the learner and the tutor should have access to support services to help with technology-related aspects of the course experience.*

*Figure 4 Design guideline for WWW-based courses related to implementation support*

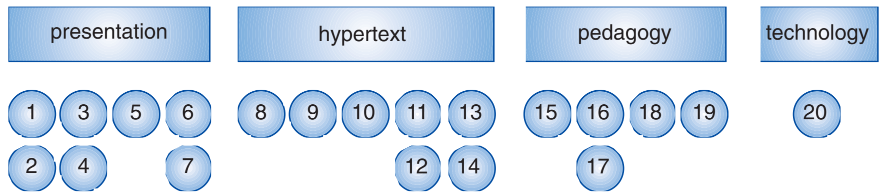



*Figure 5 Map of the design guidelines for an individual learning environment*

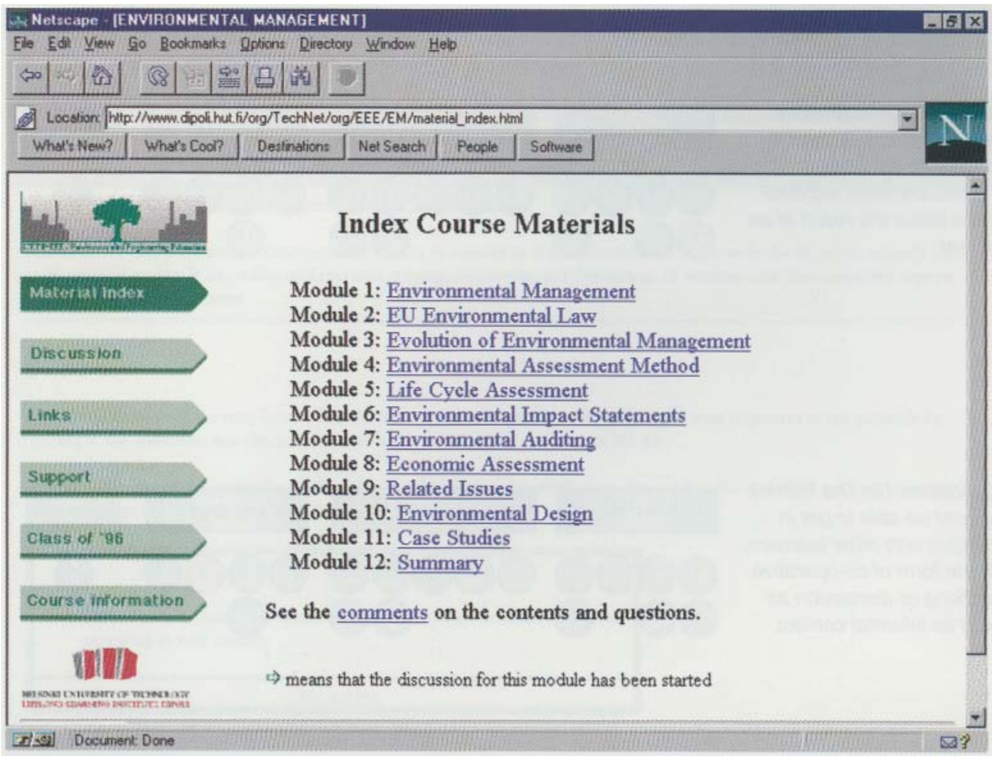
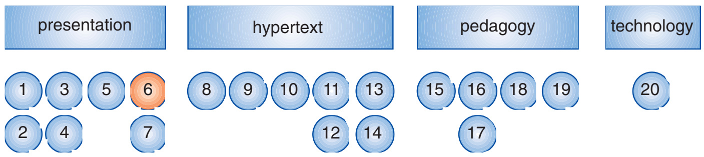
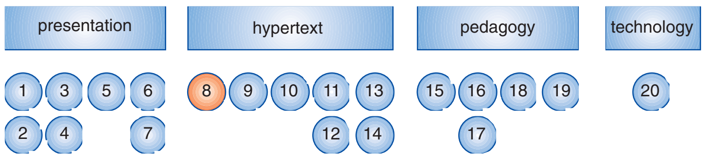



*Figure 6 Index of the course materials*

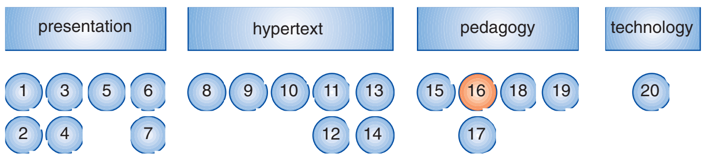
***Guideline 6:*** *Because icons and virtual metaphors are not unambiguously understood across all computer interfaces and international borders, they should be investigated before put into a page.*



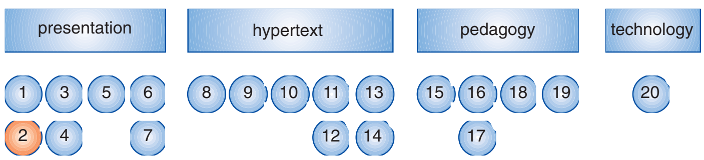

***Guideline 8:*** *The user should get a clear overview of the structure of the Web site. This can be accomplished by adding navigational buttons which link to the previous and the next page in the same sequence, as well as a link to a local homepage.*



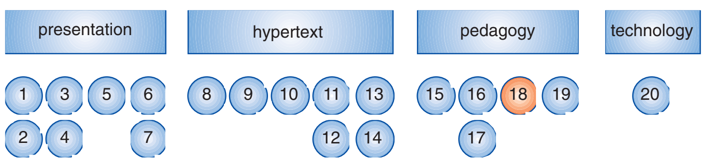

***Guideline 16:*** *Learner commitment and motivation can be increased by integrating questions into the instructional materials.*




***Guideline 2:*** *Use metaphors that correspond to the user's daily life, so that he has concrete expectations about the result of an action.*




***Guideline 18:*** *The learner should be able to get in contact with other learners, in the form of co-operative working or discussion as well as informal contact.*




user is a key consideration. From this and other insights ([9] is particularly recommended), we derived the following seven design guidelines as particularly relevant to WWW-based courses (Figure 2).

### Design aspects relating to pedagogical aspects

The educational literature offers many different insights into what can be obtained relating to the design of WWW-based course environments even though the insights were developed before WWW environments existed. Some of these insights relate to the individual's interaction with learning materials in themselves; others (particularly from the distance education literature; see for example [8]), relate to the support of adult learners who are studying at a distance from their instructor and classmates. The following design guidelines were extracted as particularly important for WWW-based course environments (Figure 3).

### Design guidelines relating to use of the WWW technology itself

Finally, WWW environments are a new form of technology for all concerned. From decades of experience with the implementation of technological innovations in education, we know that instructors and learners alike predictably encounter confusion and frustration when confronted with a technology that is new to them (a review of this appears in [3], Chapter 7). Unless appropriate help is available, many never go past this frustration in order to continue with the new technology. Thus, the last of our design guidelines relates particularly to this important aspect of WWW-based course design, an aspect that may be outside of the course itself but critical to it (Figure 4).

We find it convenient to represent all the design guidelines in one graphic. Figure 5 shows this representation.

## Applying the guidelines to the redesign of the "Environmental Management" course

An important way to validate and improve design guidelines is to apply them in practice. From the designer's perspective, the usefulness of the guidelines during the design process can be evaluated. From the learners' perspective, the influence of the design guidelines within a course developed around those guidelines can be indirectly evaluated based on the learner's reactions to the overall course and its component aspects. Both of these perspectives were employed during the application and validation of the design guidelines with respect to a WWW-based course called "Environmental Management" (Version 2). In the following sections, we briefly describe the course, illustrate a few of the ways that the design guidelines were applied to its redesign, and give a summary of learner reaction to the course.

## The Environmental Management course

Version 1 of the Environmental Management course was developed in 1995 in the framework of the TeleScopia Project, for trans-Europe delivery of courses making use of a variety of technical platforms (see [1], [5]). One of the course deliverers in TeleScopia was the UETP-EEE (University-Enterprise Training Partnership in Environmental Management Engineering), a network of European universities, enterprises and professional organisations involved in environmental engineering. The Environmental Management course was especially designed for the TeleScopia Project [13], and was the only WWW-based course in that project.

Various evaluations were carried out of the first version of the course, and a second version, for a cohort of approximately 120 learners participating during the period October 1996 and March 1997, was designed[1] [6]. Learners access the course via a WWW environment (http://www.dipoli.hut.fi/EEE; note that a password is needed to enter, contact the first author for a guest password) via a

[1] *The second version of the course was developed and is used within the scope of the ATLAS (Atlantic Mobility for Academic Studies in Engineering and Environment) Project funded by the European Union. The Lifelong Learning Institute Dipoli at the Helsinki University of Technology, working together with the University-Enterprise Training Partnership in Environment Management Engineering (UETP-EEE), is responsible for the re-design of the course.*

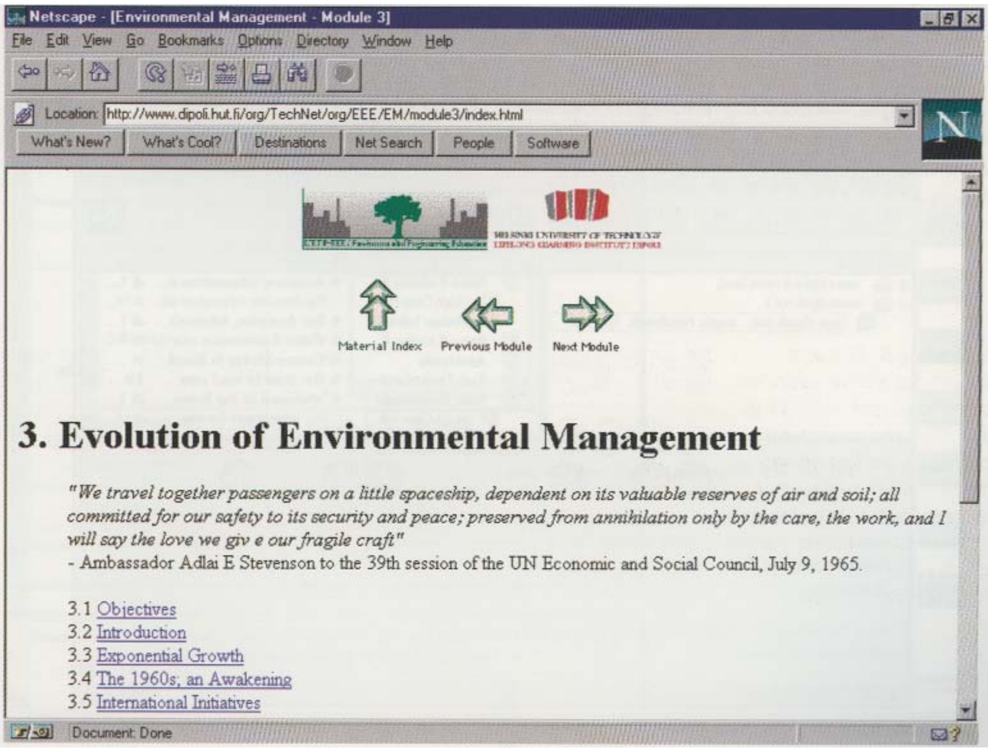



*Figure 7 Index page of a module*

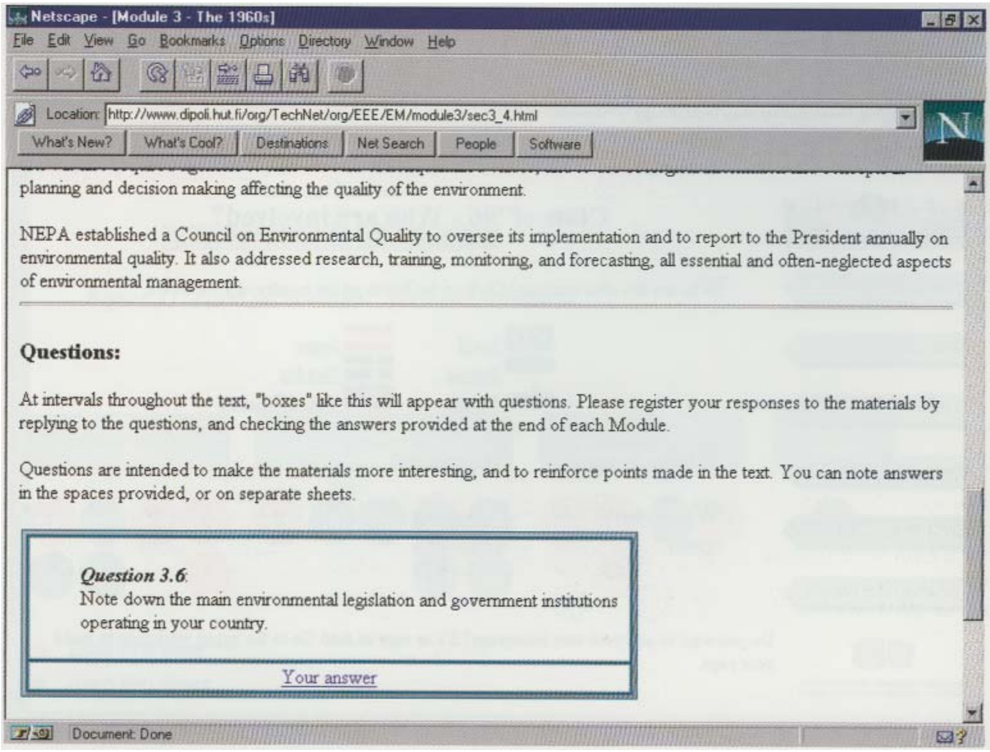



*Figure 8 Example of a question integrated in the learning materials*

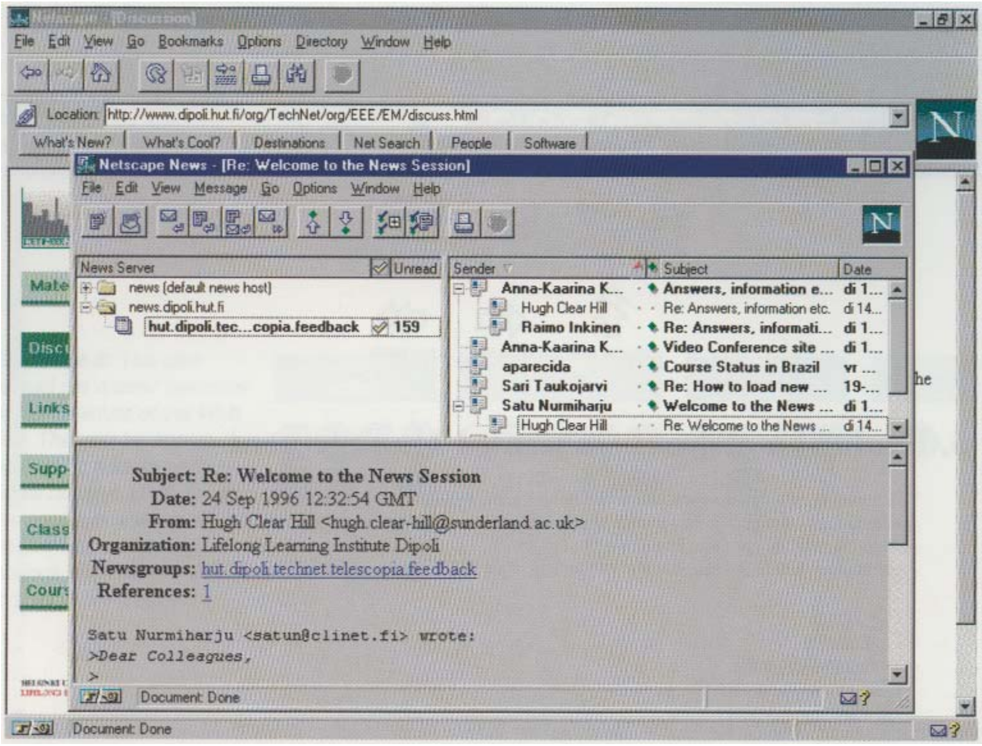



*Figure 9 Netscape newsgroup interface used for discussion in the EM course*

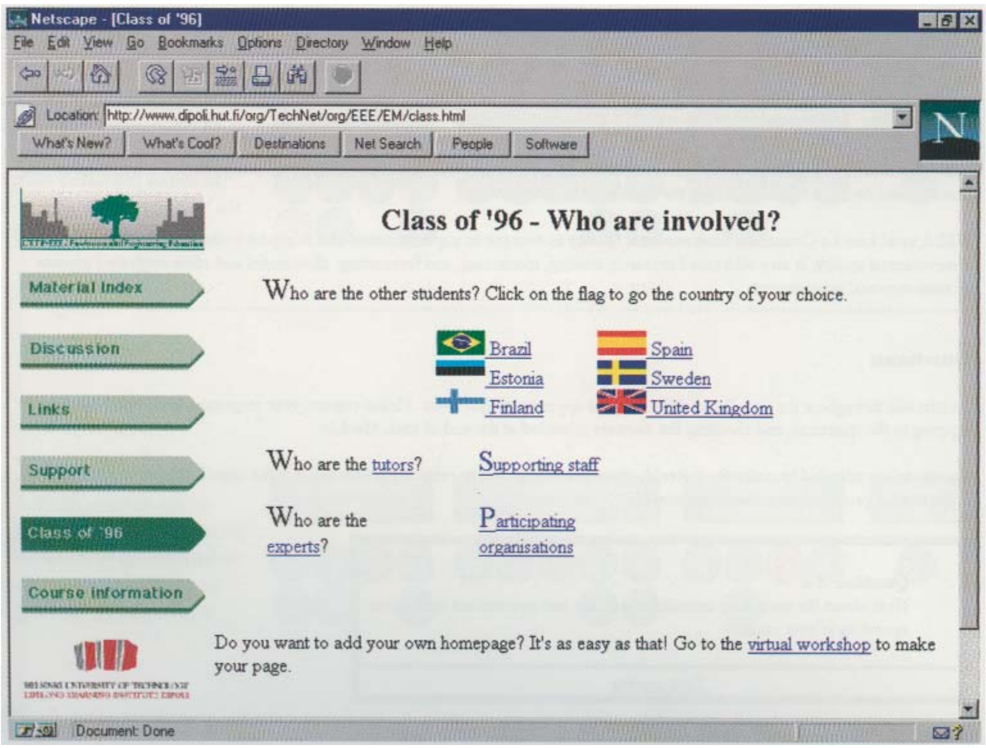



*Figure 10 Class of '96-page*

modem or ISDN connection. Through the course environment, learners access not only the course materials and information about the organisation of the course, but also a variety of forms of communication among themselves, and between themselves and local tutors and others involved with the overall delivery of the course. Local face-to-face tutoring sessions are also available. In addition, the course includes three international video-conferencing sessions which currently are not integrated technically within the WWW environment. The language used in the course is English.

## Application of the design guidelines in the design of Version 2

The design guidelines were applied to every aspect of re-design of the Environmental Management course, Version 2.0 (see [6] for a detailed summary). Because of space constraints here, we can only give a sample of how this application occurred.

For example, the original course did not use many graphics. In the materials section of the new EM course, use has been made of graphics, although they have been kept as simple as possible, and small in size (in kilobytes) because of the long loading time that can occur when using sophisticated graphics. Figure 6 shows an example of the presentation design of the course, in this case, the menu from the "Materials Index" component.

Guideline 6 was thus taken into account in this design decision: icons should be investigated before put into a page.

Arrows are used in many user interfaces, perhaps the most universally understood ones relate to the interface of a radio-cassette player, with play, fast-forward and rewind buttons. Arrows suggest movement; an arrow that points to the left is interpreted as going back, an arrow pointing to the right usually refers to moving forward. An arrow pointing to top means usually "up". Figure 7 shows the index of Module 3 of the course. The double arrows that point to the top refer to the "material index"; the double arrows pointing to the left take the learner to the index of the previous module; and the double arrows pointing to the right bring him to the index of the next module. These decisions were made in reference to Guideline 8, the user should get a clear overview of the structure of the Web site.

Arrows are in this case navigational buttons which link to the previous and the next page in the same sequence. This at least helps the user to have a sense of his immediate location in the site.

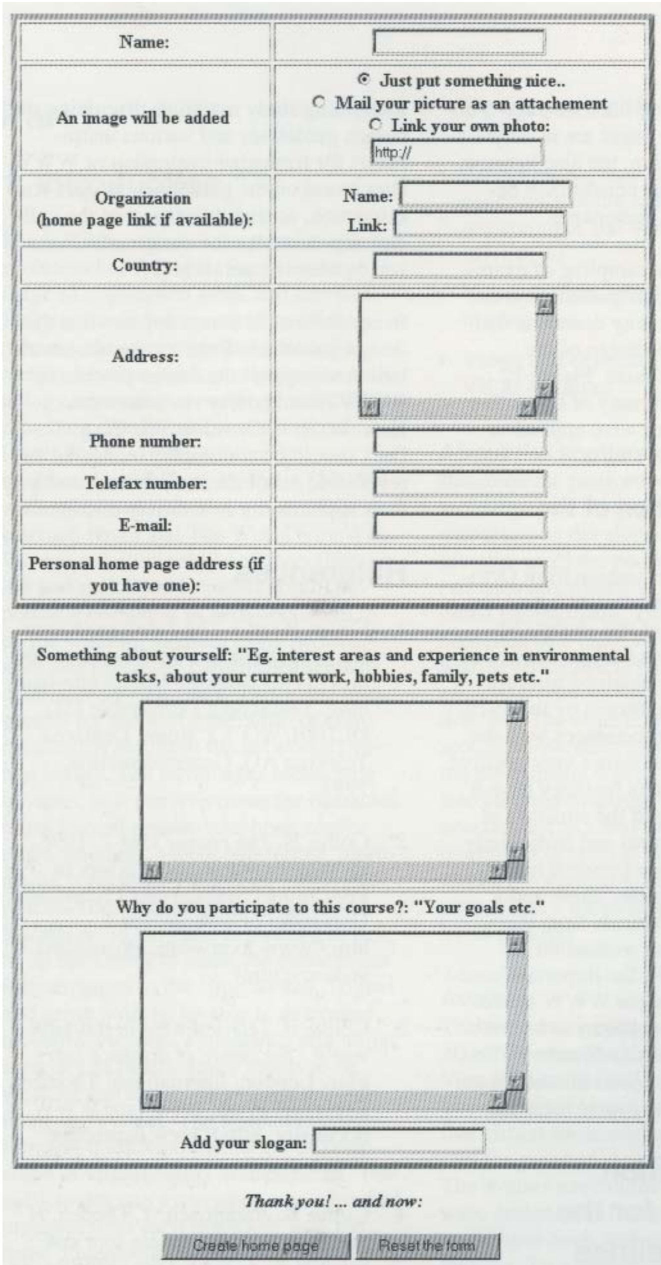
Questions integrated in the learning materials can increase motivation and interactivity (Guideline 16). The EM Course integrated several questions into the learning materials. Figure 8 gives an example.

In addition to the video-conferencing portion of the EM Course, Guideline 18 is also applicable to a WWW-based two-way interactional element of the course, namely the Discussion component. From the discussion page, the learner can join two newsgroups (see Figure 9). In the design of this part of the course, Guideline 2, the use of metaphors was particularly important.

On the screen two buttons are visible that each link to a different newsgroup. In the first newsgroup, learners can discuss the content of the course with other learners, with tutors, and with experts, as recommended in Guideline 18.

Since it is impossible to send the learners in the EM course all over the world to meet their fellow learners, an introduction via video-conferencing has been added to the course. But the video-conferences are only short, and not all the learners get the chance to talk to each other. This is the reason that the Class of '96 pages have been integrated in the course (see Figure 10). These pages are based on the idea of the "yearbook" or "almanac", where pictures and small biographies about the learners are presented. At the Class of '96 site, the learner is free to look around in the pages of the tutors, to get a glimpse of the tutors, the experts, and of course the other learners, if they have added their own "homepages".

In the virtual workshop, associated with the "Class of '96" component, the learner can easily create his own Web page. This activity is not compulsory, and does not have any impact on the learner's study results. In the virtual workshop, the learner can fill in a standard CGI-based form, displayed in Figure 11.


| | |
|---|---|
| Name: | |
| An image will be added | Just put something nice.. / Mail your picture as an attachement / Link your own photo: http:// |
| Organization (home page link if available): | Name: / Link: |
| Country: | |
| Address: | |
| Phone number: | |
| Telefax number: | |
| E-mail: | |
| Personal home page address (if you have one): | |

Something about yourself: "Eg. interest areas and experience in environmental tasks, about your current work, hobbies, family, pets etc."

Why do you participate to this course?: "Your goals etc."

Add your slogan:

*Thank you! ... and now:*

Create home page | Reset the form

*Figure 11  Form for adding a "personal homepage"*

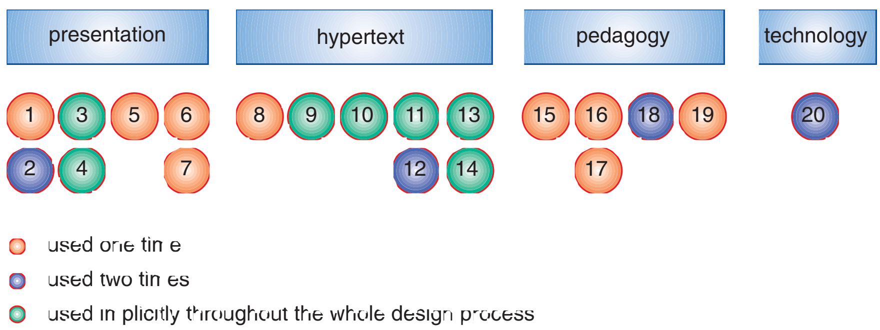



*Figure 12  Guidelines used in the design of the new EM Course*

As can be seen in Figure 11, the learner is restricted in the amount of text and pictures he can add to his own page. This is done because the pages are mainly meant for introduction, but also because there should be some consistency between the learners' homepages.

The above are just a sampling of examples of how the design guidelines were used to inform the many decisions that were taken in the re-design of the WWW-based EM course. Figure 12 shows a general summary of how often the design guidelines were applied to Version 2 of the EM course.

### Learner validation of the guidelines

The EM course is in session from October 1996 through March 1997; thus, at the time of writing of this report (November 1996), only a first impression of the course could be obtained from the learners. A survey returned by the learners after their first experiences with the WWW-based course shows very positive responses: the learners feel they have a clear understanding of the structure of the course environment and particularly value the easily-made personal home pages within the course. These and a variety of other comments from the WWW-based learner evaluation are given in detail in [6]; the important conclusion to date is that the WWW-based course environment appears to be well received by its distributed learners. This in turn implicitly supports the design guidelines on which the course is based.

## Other validation approaches for the design guidelines

Certainly more than one experience of application of the design guidelines is needed for their validation and refinement. Another type of validation is also taking place: the use of the design guidelines within a course focused on the specific topic of the design of WWW-based learning materials themselves. Such a course (WWW-based itself) is in operation at the University of Twente [2], and the design guidelines have been integrated into the Study Materials for the course. In addition, they are being used as the criteria for the learners' formative evaluation of their self-designed WWW materials, and will be used as the criteria used by the course instructors for summative evaluation of the learners' WWW-based products. The course site, integrating study materials discussing the design guidelines and various instruments for formative evaluation of WWW sites based on the guidelines, is open for inspection, so that this aspect of the validation process for the design guidelines can be seen in operation [2].

In conclusion, to date it appears that the design guidelines form a valuable contribution to support the design process for WWW-based course environments. However, it is also clear that the guidelines should be continually evaluated and revised, to refine their usefulness and test their applicability in a variety of contexts.

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# Learning in collaborative virtual environments
## – Impressions from a trial using the Dovre framework

BY OLA ØDEGÅRD AND KARL ANDERS ØYGARD

**This paper focuses on aspects of collaborative virtual environments (CVE) or Televirtuality. The first part will be related to interaction issues and the results of a field trial based on Televirtuality. The next part of this paper will focus on technical aspects of a generic framework for such systems, and how these utilise the network and the technical platforms in an optimal way.**

**Part I**

**This part deals with the subject in the perspective of other conferencing systems. It pays special attention to Virtual Reality (VR) as a medium and how it can be used to support social interaction and collaboration between persons located in remote areas. A networked application, based on the idea of city planning (The Little Houses on the Cyber Prairie), has been used in a trial consisting of several VR stations linked in a local area network. In each group three persons have entered the city, confronted with some tasks which they had to solve in collaboration with each other. This paper reveals some of the findings and experiences the test users had. The experiences so far seems promising in using this new medium in distance education and remote work.**

**Part II**

**This part gives an introduction to DOVRE[1], which has been used to build the application for city planning. This system makes it possible for several users to enter a shared virtual space and interact with enhanced functionality. Then it describes briefly the Dovre framework, what design goals it is based on and some of the technical solutions we used when implementing a first version of the framework.**

[1] D*istributed* O*bject oriented* V*irtual* R*eality* E*nvironment. Incidentally, Dovre is also the name of a much cherished mountain range in Norway.*

# Part I

## 1 Introduction

The last 20 years the telecommunication evolution has found its form in a huge range of application areas and services. This evolution has coexisted with the information revolution and the media merger between telecommunication technology, computer technology and content providers. We have seen the birth of LAN, WAN, connected through modems, leased lines, ISDN, ATM. The wide spread of IP-based services like the Internet, email and The WorldWideWeb. We can use services like videoconferencing and multimedia conferences. The personal computer in networks seem to be the winning medium as its performance and rendering capabilities seem to double every two years. This is the background for the next generation of communication medium; the networked virtual reality. The advantages seem quite obvious, as it can overcome the obstacles of traditional remote telephone conference meetings, videoconferences, multimedia conferences and computer conferences. These obstacles are related to limitations in the various media and first of all the ability to make the participants fully engaged in the conferences. To feel and sense objects, be able to determine its own viewpoint, appearance and utilise a variety of functionality seems to be what we can expect of a future teleconferencing system. The alienating nature of many traditional media can be overcome in virtual reality conferencing. The participants can experience a new kind of presence with each other and with the three dimensional objects and documents they collaborate on, as they are present in the same virtual room.

## 2 Field trial: Interaction in The Cyber Prairie

The initiation of the networked trial was that we wanted to know more about the following topics

- Interface, how do the participants experience the use of HMDs[2], and joysticks in the virtual world
- Experiences and views on using avatars[3]
- Co-operation, how do the participants experience being in the same virtual environment and work together to solve tasks
- Views on networked VR as a medium in education
- Views and expectations on networked VR as medium.

[2] *Head Mounted Display with head-tracking.*

### About the application

Based on the platform development (see second part of the paper) an application scenario was developed. The idea was to give the users the possibility to co-operate on a city planning process in a distributed environment. The virtual world consisted of a piece of virtual landscape with several objects like houses, a hospital, a ruin (historical), streets, a gas station, etc. The objects were scattered around in disorder, and the objective for the participants was to put the objects into an order of a city. The system was also created in a way so that it would require co-operation. Before entering the virtual environment, the participants were given a list of tasks that they should try to perform.

### Avatars

The three users were represented in the 3D environment with so-called avatars or Virtual Identities (VID) (see Figure 1). The use of avatars is crucial in collaborative virtual environments, as they represent the point of view of each participant. The avatars used in the Cyber Prairie were designed as humanoids, but they could have been without resemblance to humans. To a certain extent we were also interested in examining the effect of using avatars, and how they were comprehended.

### Interface

It was possible for the users to move their avatars and their subjective point of view with 6 degrees of freedom in space. The application did not use collision detection to objects or surface. The main input device was a joystick for direction and movement along the X- and Z-axis, equipped with buttons for object (house) selection and rotation in the Y-axis.

[3] *Avatar, from Hindu; half god, half human.*

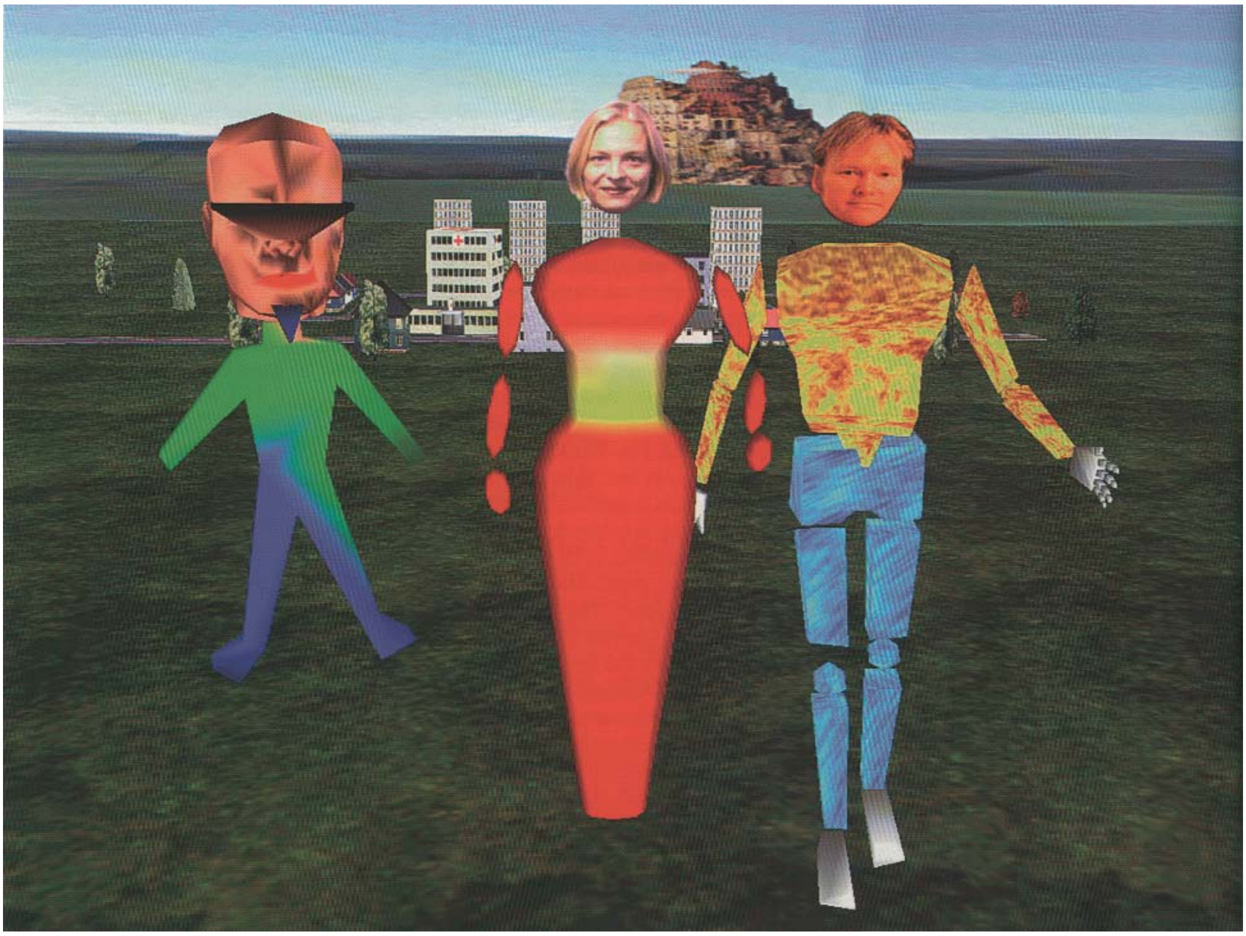

*Figure 1 Avatars on the Cyber Prairie*

## 2.1 Technical configuration and method

Each of the three VR stations consisted of a Pentium 200 with a Head Mounted Display[4] with head tracking and a simple joystick. The application Cyber Prairie performed in a frame rate around 10 frames per second in 640 by 400 pixel resolution. The three users were placed in separate rooms. Each VR station ran a client application, and they were connected through a Local Area Network to a server which ran on a Silicon Graphics workstation[5]. This server also ran a client application. This made it possible for the researchers to observe the interaction in the virtual world. The VR stations were equipped with microphones which were connected to a mixer that sent sound back to the HMDs.

[4] *I-O Glasses from Virtual I-0.*

[5] *SGI Indigo2 Maximum Impact.*

In this way, the researchers could follow the interaction both by choosing their own point of view and listening to the conversation between the test persons. The idea was not to interrupt the test users unnecessarily, and to let them learn by doing. On a couple of occasions one of the client applications crashed, or the test person got lost in the virtual world. Then it was easy for us to help when needed.

In addition to the trial a questionnaire was developed[6]. The test persons were given a hands-on experience using the VR equipment. Then they were introduced to some tasks which they should attempt to solve. These tasks were related to environment issues, like where to put the hospital and where to put the villas.

[6] *The questionnaire and methodological approach were developed in co-operation with Marianne Skogerbø, who is using this material for her master thesis in Pedagogics at The University of Oslo.*

The background for the test was based on the following assumption:

> *It is easier to collaborate and learn in networked virtual environments than in other teleconferencing environments.*

We wanted to acquire experiences with the use of avatars and the possibility to choose their own point of view. We wanted to observe the shared awareness of the participants. Compared to traditional videoconferencing or multimedia conferencing some difficulties have been recorded in sharing objects and knowing who is doing and seeing what. We wanted to observe if these problems were more easily overcome in virtual environments.

*Figure 2 Three VR stations configuration*

## 2.2 Interface, avatars and co-operation

The tests were carried out with three groups of three persons each. Two of the groups were high school students around 16 to 17 years of age. The last group consisted of three researchers in the thirties. After the test a structured interview was conducted with each group.

### Interface:

In general, the youngsters had more experience in using the joystick. None of the test persons had any significant experience in moving in virtual space or using an HMD. Here are some quotes about the interface:

> *"I had no control of the joystick, the houses just flew back and forth, then I had to learn how to use the joystick."*

> *"In the beginning the head tracking did not work, but later it did, and then it became much more alive."*

> *"I thought we just should watch it in the head mount. I did not know that we were able to go around and do things."*

> *"Some limitations on how and where to move had made it easier."*

Each group spent around sixty minutes inside the virtual environment. All groups used around half the time to figure out how to use the joystick and the HMD. There were two ways to choose direction of the movements, either by using the joystick, or by using the HMD by turning their head in the desired direction.

### Using an avatar:

The avatars had various colours which were the only identificator, or difference between them. They were static in the sense of body limb movement. They could, however, see from the position of the avatar which direction they were looking. Here are some quotes:

> *"It was no problem using an avatar; however, you did not see yourself, just the other avatars."*

> *"Even though I was flying around, I did not feel that I had any different body."*

One observation we did was that none of the groups had any difficulties in using avatars. To most of them this was just a natural extension of themselves in the virtual environment. Some of them expressed a special kind of freedom in virtual space:

> *"I felt as if I were identical to my avatar, but I felt a bit handicapped not being able to use my hands."*

> *"This is a real experience, different to a movie, because you are in the movie."*

> *"It would be real nice to travel into space with your friends."*

### Co-operation:

The next thing to do for the participants after getting used to the joystick and HMD, was to figure out how to select objects (houses) and to move them. As they had managed this, the next thing would be to move them to desired position. The participants had to discuss among themselves to come up with an agreement on the desired position or desired plan of the city. There was no city plan that was "right" or "wrong". The main idea was that they should co-operate and organise themselves in the planning and to put the plan into (virtual) life. Here are some quotes:

> *"In the beginning I had quite enough moving and orienting, but after a while we started co-operating."*

> *"We did not have any leader, but that worked fine."*

> *"It is easier to work face to face, but if I had this system at home for one month, it would have been easier."*

> *"I experienced it more intense to co-operate in VR than in real life. Because you were there all the time."*

> *"More fun and more interesting than actual co-operation!"*

> *"It was really important for co-operation that we could both see the avatars and speak to each other."*

### Reflections on VR as a medium:

> *"This is a different experience; I have been some place else, I have escaped from the normal world."*

> *"You have a TV screen in front of your eyes, and you move into these pictures, there is nothing dangerous there, you can be driven over by a car and nothing happens, go through walls, go underground and into space."*

> *"We were in for 60 minutes, but the time just disappeared."*

> *"Good for emergency meetings."*

### Reflections on VR in schools:

> *"Go to school in VR? Then there would be a lot of dropouts!"*

> *"In schools first of all, the pupils should have their own PC, then the books should be on CD-ROM and on the Internet, then they would be less expensive and more up-to-date."*

*Figure 3 The Cyber Prairie*

*"The teacher in future VR schools will be the little avatar that flies around"*

*"I sometimes felt that it was the computer that had control over me, I hope this is not how the school of the future will be."*

## 3 Conclusions on Part I

It became apparent for us that all test users had no problem in enjoying this experiment. All three test groups managed during the period of sixty minutes to agree on some plan for the city, and to some extent to realise this plan. Here we observed that all groups were good in organising themselves. In order to get the best result, all groups had to place one of the avatars above the city (birds eye perspective). This user had to guide the other users as they moved the houses. Most of the groups took turns in performing the various task. One of them always took on this leadership. We were also a bit astonished by how naturally they related to using avatars. All participants got used to the joystick and HMD, but they expressed the need for a better 3D input device, like a glove for grasping. After spending sixty minutes using an HMD, we expected that some of them might feel sick, but this proved not to be the case. Some of them of course felt a bit dizzy. The VR application Cyber Prairie was just a research prototype, and could have been improved in lots of ways to make interaction easier, but it still proved promising for this kind of collaboration. The three groups gave many similar views on the experience. The greatest difference was between the youngsters and the researchers. The researchers seemed much more analytic in their approach to the tasks they should perform, but they were not so clever at performing them. The youngsters were more spontaneous and explorative in their approach to the virtual worlds. In this test we observed two kinds of learning; first they learned how to move and orient themselves in the environment, then they learned how to collaborate on specific tasks in a virtual environment. The results of this trial have given us more confidence in Collaborative Virtual Environments as a useful way to learn and interact.

# Part II

## 4 Design issues

### 4.1 Rationale

When we set out to write our first applications that would demonstrate some of the principles of Televirtuality, we soon found that there existed no frameworks for developing distributed Virtual Reality applications on low end computer equipment. While solutions such as DIVE existed for Silicon Graphics class machines, we thought these unsuitable for consumer Windows PCs. Also, many Virtual Reality application frameworks were strongly biased towards visualisation of the virtual worlds, neglecting basic features such as interaction with the virtual world itself.

In the end, we decided that in order to easily implement the application we wanted, we needed to develop a new framework. To this purport, we started work on *Dovre*.

### 4.2 Design goals

When we designed the *Dovre* framework, we had the following goals in mind:

**Active objects**

During the design phase of *Dovre*, we took much inspiration from the real world. Most notably, this has resulted in the introduction of active objects. Rather than being passive objects that must be manipulated by higher level algorithms, *Dovre* objects are active and have their own behaviour and state. The active object paradigm is supported by a strongly object oriented line of thought and greatly simplifies tasks such as implementing agents with artificial intelligence.

**Biased towards ATM and TCP/IP**

One of our main goals was that Dovre should utilise the ATM network technology to its fullest. Since ATM is inherently connection oriented, this effectively excludes connection-less protocols. Standards for multicasting over ATM are still rudimentary, so the initial implementation was based on a symmetrical client/server model. Future versions of *Dovre*, however, may be extended to use multicasting in a server-less environment.

The TCP/IP protocol is a standard component of nearly all networking capable systems and works with most network layers, so we chose to base the initial

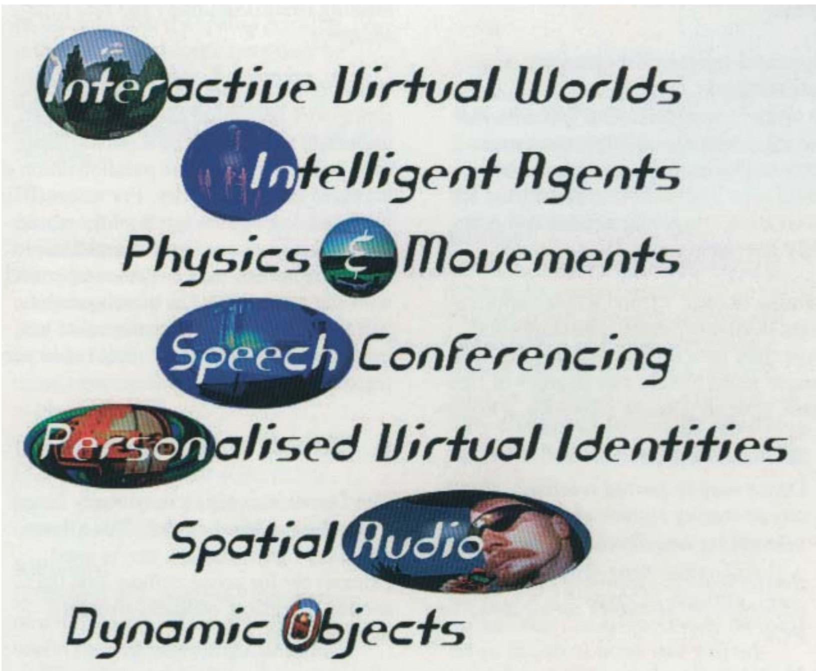


*Figure 4 Features of the Dovre framework*

implementation on TCP/IP. Note that the I/O system of *Dovre* has been completely abstracted, so that implementing support for other network protocols is completely invisible to applications and most of the framework itself.

### High degree of abstraction

In order to construct a system that is architecture and operating system independent, a high degree of abstraction is required. In the *Dovre* framework we have used abstraction to hide operating system, rendering engine and sound system details from the application.

The current implementation supports the following operating systems and rendering engines[7]:

- Windows NT 4.0 and 95/OpenGL
- Windows NT 4.0 and 95/RenderWare[8]
- IRIX 6.x/OpenGL
- Linux 2.x/Mesa[9].

Sound is supported on all platforms.

The framework may be used without visualisation and sound support, which can be highly useful for generating automated agents. Such agents are entirely computer driven and act only on interaction or triggers from other participants, and have no use for visualisation of sound locally, but may otherwise use all the functionality that the framework offers.

### Support advanced sensors and interaction

In order to support interaction with the virtual world, *Dovre* supports sensors such as gloves, motion trackers, joysticks, etc. The sensors may be used for navigating, triggering actions and generally interfacing with the computer.

Sensors used in Virtual Reality applications exhibit different behaviours and have their own output formats. While a mouse gives merely two degrees of freedom, with no point of reference, a Polhemus Fasttrak allows for six degrees of freedom in a fixed space. In order to support the various sensors in a generic manner, a scheme for querying the sensors for their capabilities has been implemented.

Currently, *Dovre* supports the following sensors:

- Mouse
- Joystick
- I/O glasses
- 5th glove
- Polhemus Fasttrak.

*Dovre* offers full object and ray intersection detection in the object hierarchy.

### Efficiency

To maximise throughput and to construct a system that scales well, we have gone to great lengths to streamline and fine tune *Dovre*. The framework is based on the hierarchical world model, which allows for many optimisations. We use our own highly optimised math library and advanced template mechanisms that, when inlined properly, generates code that rivals that of hand coded assembly (see for example [8]).

The OpenGL implementation uses many of the most common optimisation techniques in order to achieve high frame rates, as well as special features of more expensive SGI hardware, such as anti-aliasing (multisampling) and real time shadows.

With high end computers with multiple processors becoming cheaper, it is also important to consider how performance may be increased by the parallelisation of accesses to the hierarchy. For example on high end computers, much of the rendering engine has been implemented in hardware, which may execute in parallel with the main CPU. On these systems, parallelisation is not only desirable but imperative in order to get reasonable performance.

## 5 Object organisation

The *Dovre* framework is strongly based on the hierarchical model. This allows for many optimisations, and is used extensively for scene culling, fast intersection detection, efficient structure manipulation, etc.

The world is partitioned in *domains,* which are separate hierarchies built up of objects and containers. Domains may be connected with *portals,* allowing for very large worlds.

All hosts (i.e. both clients and servers[10]) have at least one domain. This domain is entirely built up of *real objects,* objects which are local and belong to that host. All objects that are imported from other hosts become *virtual objects,* objects which are mirrored from another host.

When two hosts connect, they will attempt to exchange object hierarchies with each other. This is first done by the hosts exchanging any portals they might have with each other. If the hosts have portals which may connect, they will then proceed with distributing the hierarchies of those portals to each other. Eventually, all hosts in the network will have a local copy of the part of the hierarchy that is relevant to that particular host. All these imported objects are virtual objects. Any changes to the hierarchy or its objects will be distributed to all hosts that need to know about it.

All this is automatically done by *Dovre,* and is completely transparent to the programmer.

### 5.1 Real objects

Real objects are, as the name implies, the real objects in the hierarchy. They may receive messages and act upon them. If the real object chooses to act on a request, it reissues the request as a command to itself, which is distributed to all its virtual counterparts on other hosts. This implies that both the real objects and all its virtual objects have the same state, and integrity is ensured.

### 5.2 Virtual objects

Virtual objects are mirrors of real objects. They may receive requests, but may not themselves take on any action, rather they must pass them on to its real objects. Virtual objects receive commands from their real object which they must then do their best to fulfil.

[7] Dovre *may be ported relatively easy to any operating system which supports networking and threads.*

[8] *RenderWare is supported because of its higher performance on inexpensive PCs.*

[9] *Mesa is a freeware rendering engine with an API which closely matches the OpenGL 1.1 specification.*

[10] *The only thing that differs between a client and a server is that a server can accept connections from several clients, while a client connects to one server. Note that a client can operate without a server.*

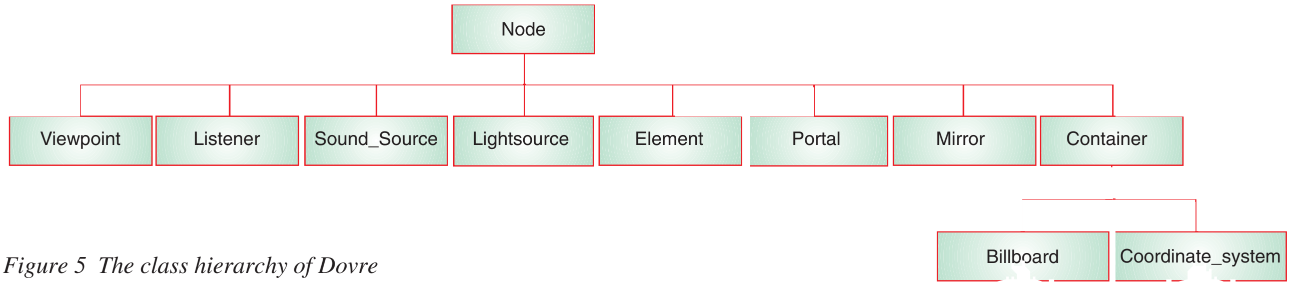


*Figure 5 The class hierarchy of Dovre*

## 6 The message system

The *Dovre* framework is an event-driven system, in that all interaction between objects must be done with messages. Indeed, the very core of *Dovre* is the message system. The message queue is basically a distributed queue with messages that can be updated if they lose scope, not entirely unlike the updatable queue described in [6]. The message system may change, however, with the advent of MPEG4.

Messages may be sent directly to the receiving object, for time critical purposes, effectively bypassing the message system, or it may be queued for delivery when the system has time, optionally with a time delay.

### 6.1 Messages

Any real object may issue a message to another object. The message will then be delivered to the real object. The receiving object may choose to act on the message or ignore it. Note that the receiving object may not update internal state according to the message, as this would introduce inconsistencies in the hierarchy. This has to be done with commands.

### 6.2 Commands

Commands are used for updating internal state in an object. When a real object needs to update internal state, it issues a command, which is distributed to all its virtual objects, as well as itself. In this way, the hierarchies of all hosts are updated simultaneously, and consistency is ensured. Note that only real objects are allowed to issue commands.

## 7 Object types

The following is a short description of the basic object types in *Dovre*. These object types are the building blocks for virtual worlds, and may be subclassed and overloaded to get new behaviour.

- **Node**
  The Node class is an abstract base class, from which all objects that can be put in the hierarchy have been subclassed. It simply implements the capability of being a child (i.e. having a parent).
- **Container**
  The Container node can contain any number of nodes, and may be used for grouping objects and optimising the hierarchy.
- **Coordinate_System**
  In order to specify spatial position, co-ordinate system containers may be used. A Coordinate_System has a transformation matrix which transforms the co-ordinate system of all its children.
- **Element**
  Elements are the visual objects in the object hierarchy. These have a geometrical model, which can be generated dynamically or loaded from file. File formats currently supported include DXF, NFF, 3DMF and some more obscure formats. VRML support is planned.
- **Lightsource**
  Lightsources provide light in the scene. Lightsources may be directional, positional or spotlights.
- **Billboard**
  Billboards are containers that always turn to face the viewpoint. This may be useful for implementing menus and similar. Note that billboards can be pretty non-deterministic to work with; they are relative to the viewpoint, which may give some surprises when using intersection detection and similar.
- **Viewpoint**
  Viewpoints implement a means of looking at object hierarchies. By binding a viewpoint to a window, the scene can be rendered real time on the screen.
- **Sound_Source**
  A sound source emits sound which may be heard by listeners within the domain that the sound source is located in. Sound sources may read sample data from a file, or may receive it directly from a microphone. They may also have different characteristics as regards sample rate, number of bits, etc. In the future we plan to implement advanced features such as customisable filtering of sound sources (for example flanging, chorus or distortion).
- **Listener**
  Listeners hear sound sources which are located in the same domain as the listener itself. Sound is spatialised according to the relative positions of the sound sources.
- **Mirror**
  Mirrors make simple reflections of objects located perpendicular to the mirror. It actually only redraws the scene with a new transformation matrix that has the Z axis inverted. Mirrors should be used with care, as they effectively double the number of elements that need to be drawn in the scene.
- **Portal**
  Portals are used to connect different hierarchies with each other. This is useful for a number of reasons. Two portals that can connect may be located on different hosts and will not rendezvous before a connection between the hosts has been made. This allows for distributed worlds.

Portals also allow splitting a very large world into smaller domains, which will improve performance considerably. During rendering of a scene, the portal itself is tested for intersection with the viewing frustum, similar to the Potentially Visible Set technique described in [7].

## 8 Future development

*Dovre* is a platform for constant research and development. Some of the most important features that we are currently working with include:

### 8.1 Inverse kinematics

In order to simulate the real world as closely as possible, natural and realistic movement of avatars is necessary. Inverse kinematics provides a solution to this problem, but is computationally intensive and currently difficult to use. We are undertaking research on how to optimise such algorithms, so they may be applied in real time simulation.

### 8.2 Dynamic models and MPEG4

Currently, *Dovre* does not have the capability of coding models and distributing them to other hosts. Work is being done that will change this. We will proceed with implementing support for audio and video streams, most likely through support for MPEG4.

### 8.3 Graceful degradation of network services

With ATM comes a wealth of new possibilities as regards controlling the quality of the network services provided. In order to handle the highly variant nature of the data streams associated with *Dovre,* we need to support QoS management and graceful degradation of network services. The current implementation does not do this, but we are working actively with supporting it. The MPEG4 SNHC[11] group is performing research in this field, which we hope to put to use in *Dovre.*

[11] *Moving Pictures Experts Group, Synthetic and Natural Hybrid Coding.*

### 8.4 Java

Java is making a great impact on the computer world, and is particularly interesting in the context of active objects. We are looking into how Java amongst other things could be used for agents with programmable intelligence.

## 9 Conclusion on Part II

So far, we have had very good experiences with *Dovre.* The framework provides us with a platform for further Televirtuality research and a quick and simple way of implementing new concepts and ideas for distributed virtual reality applications.

Performance is excellent, and *Dovre* has no problems handling relatively large worlds. We have more ideas for optimisations that should increase performance even further, and we will continue adding support for new technology.

The object oriented, active object point of view provides a good basis for developing distributed virtual reality applications. Since objects have their own behaviour and state, they can virtually act on their own. In the future we will continue to explore how the active object paradigm can be used to bring virtual environments to life and to implement intelligent user interfaces.

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# Distance education in Norwegian manufacturing industry and the education sector
## – Current situation and future needs

BY TOM ERIK JULSRUD

## 1 Introduction

Over the last decades we have witnessed a very rapid diffusion of telecommunication and computer technology in private homes as well as in the education and business sectors. These new communication tools have radically changed the scope and potential for distance education, and they are gradually giving new meaning to the concept itself. Still, there is reason to believe that we are only beginning to see a new generation of distance education, based on advanced broadband communication technology and digital networks.[1]

Telenor Research and Development has closely supervised this development, and the first comprehensive survey on the use of telebased distance education in Norway was launched in the late eighties [24]. A field study of higher education and universities was followed by a similar study of manufacturing industry [10]. Five years later the two surveys were repeated, using the same questionnaires (but not the same sample) [12], [13].

These broad field studies cover the rapid *diffusion of new telebased distance education* within the crucial part of society concerned with education, teaching and training. In retrospect, this gives us an interesting view of the rapid changes within this field. The object of these studies, however, was not restricted to recording only the number of students or teachers using new technology for educational purposes. In addition, the research intended to explore the *future needs* for distance education, both in a latent and more overt sense. For this reason the surveys deploy a broad view of the concept of distance education, including all activities where teacher and student are separated in time and/or space.[2] We also gathered information in fields which could tell us about the possible long-term needs for telebased education. For example, the surveys of manufacturing industry cover all kinds of training and education within the enterprises, and the surveys of the education sector cover the use of external teachers and lecturers in traditional education.

This article presents some main results from the quantitative user-need research at Telenor Research and Development, focusing on the changing patterns of distance education over the five year period from 1989 to 1994. Manufacturing industry and the education sector, including upper secondary schools, regional colleges and the universities, will here be treated in separate chapters. One of the reasons for this is, as will appear from the discussion, that the areas are quite different regarding the way distance education is initiated, managed and implemented. Each of the chapters will, however, report both on the current situation and the future needs. Finally, I will present some general conclusions and recommendations on further research and development within the field.

## 2 Distance education in manufacturing industry

### 2.1 Introduction

A central idea in Norwegian educational policy has been the principle of "lifelong learning", where knowledge and competence is maintained, renewed and extended throughout a lifetime [22]. The ability to build personal knowledge is viewed as a common good which as many as possible should have access to. Education and knowledge open the doors to individual development, and are an important premise behind a living democracy. In this context, education and skills is a founding element in the Norwegian ideal "welfare society". At the same time, competence and knowledge represent a factor of major importance for the economic development of the country. During the last 10–15 years, the value of education and training has been emphasised in official documents, focusing on the national need for a more competitive industry.[3] In the White Paper "Knowledge for all" ("Mer kunnskap til flere") this was made very clear:

> *"To develop knowledge is a precondition for strengthening Norwegian economy, ensuring full employment, achieving effective changes and preparing the way for new activities in the economic life. (...) in the economic sense education is of strategic importance for our value creation."* [14]

The quotation reflects a central theme in the discussion of education for new skills within the industry: To elevate the level of competence of employees represents a major strategic weapon to meet new, international competition. At stake here is not only the question of strengthening the local labour markets. Inability to cope with the challenge of upgrading skills in the industry will threaten the competitiveness in the future information society. 'Knowledge' is the keyword for everyone who wants to take part in the new information-intensive global economy.

The dynamics behind the growing importance of skills and competence within the labour market are of course many-faceted and complex. Nevertheless, it is possible to emphasise at least some central factors: First, the fast introduction of new technology into the labour market has raised new demands for knowledge and skills. The extended use of information technology in almost every sector of the industry, has on the one hand radically changed the work operations involved, demanding new skills to make an optimal use of the technology. On the other hand, the deployment of new technology has in some

1 *It has been discussed if this technological change is best characterized as a "paradigm shift" or a "shift in generations". Some scholars have presented this development in different phases (generations), from traditional letter-based education to education through computer networks. Rekkedal and Søby [25] have remarked that it may be more correct to view these chategories as a pool of technologies and methods to choose from when organizing distance education.*

2 *The definition of distance education used in this article is as cited in the article* "Telecommunications in distance education" *in this issue of* Telektronikk.

3 *This is true on a European level as well. A report from the European Committee for Research and Development (IRDAC) states that; "the output of education and training systems (...) in terms of both quantity and quality of skills at all levels, is the prime determinant of a country's level of industrial productivity and hence competetiveness. (...) If sufficient attention is not given to the skill shortage problem, in particular technological advance, Europe's competitive position will be threatened." [9]*

*See also [4], [21] and [28] for similar argumentation.*

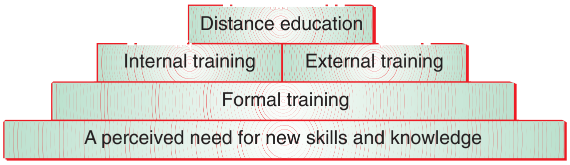


*Figure 1 The relation between distance education and formal training*

cases substituted for jobs and tasks, resulting in a need for re-educating employees.

Second, there has been a growing globalisation of trade and commerce activities in the last 10–15 years. One effect has been that major parts of traditional industry have been re-located to countries with lower wages and expenses. Technical and industrial co-operation has expanded between nations, together with the rise of more global markets. For Norway and other European countries, this has fuelled an engagement in more knowledge-based industry, and more specialised production. One of the consequences has been a general expansion of jobs generated from market and non-market services such as finance, banking, tourism, consultancy, etc., at the expense of manufacturing and products.

Third, it should also be mentioned that the amount of knowledge is growing very fast, and still more efforts are needed to keep informed. Today, a considerable number of those employed are engaged in the production of new information, and even more people are busy collecting and structuring this. It is estimated that the total amount of information in the country is doubled every 10 years [23]. One effect is that constantly more efforts and skills are required to stay well informed.

Thus, the process of strengthening the competence of employees has been strongly advocated by representatives of the state and the government. There seems to be an urgent need for industry to redevelop and upgrade the internal level of competence. In practice, however, it is local industry who will have to invest money and time in new competence, and there are several barriers to overcome to manage this.

## 2.2 The implementation of distance education

The training and the development competence at the workplace include a lot of different activities. In a very general way, the concept of *competence* refers to "knowledge and skills which are used or may be used in professional activities"[4] [9]. This is the way we will make use of the concept here. In a more extended sense, the concept may refer to a collective body of knowledge, reflected in an organisation or a social system.

The development of competence in an organisation may be described as a process of both *planning, implementation* and *exploitation* [20]. Various internal or external changes may trigger a need for higher education or development of skills. This may come as a decision from the management, but also as a demand from the employees. The experienced need for new competence in the organisation may be met with new employment or development of the skills internal to the organisation, which in turn may be implemented and exploited. This is what may be called "the chain of competence". (Ibid).

The development of competence in the organisation includes several possible choices, such as investing in more research, or trying to strengthen the work ethic or organisational culture. Of special interest to the use of distance education, however, is the more traditional *formal training* of the personnel. This training is either organised by the organisation itself, or by external institutions. The former is more common in larger enterprises or official organisations, while small and medium sized enterprises mostly use externally organised courses or seminars in co-operation with universities or other educational institutions.[5] [19]

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[4] *Original formulation: "... kunnskaper og ferdigheter som er i bruk eller som kan brukes i rollen som ansatt."*

[5] *There are certain differences between internally and externally organized training, with respect to motivation by the organisation. While internal training in most cases is triggered by certain needs within the organization, external education appears on an open market. For this reason the latter may be less dependent upon the needs and strategies of the single enterprise or organisation [8].*

In this context, tele-based distance education represents expanded opportunities for enterprises to develop their competence, and more specific, the skills and knowledge of the individual employee. It comes as a result of the same needs as ordinary education and training (see Figure 1). The difference is that the teachers are seated at a distance from the students, and different communication media are used to support the learning. Although the most common organisational form is to use technology to bring the distant competence into a group of employees in the organisation, it will also include more complex forms: Students may be located at different places, as well as the teachers and different sources of information used for instruction.

The advantage of distance education compared to regular face-to-face education is first of all that it may be more efficient and economic than traditional education. The amount of money spent on transporting employees to and from the external locations is significant, and will, it is argued, soon compensate for the necessary investment in communication technology. When this investment is done, however, it will open up a wider range of education possibilities than before. For instance, implementing a video conference studio will in principle give access to every learning institution and university with similar equipment. Moreover, the equipment can easily be used for other purposes, such as business meetings and video conferences.

The factors of special importance for development of distance education in industry are therefore the access to the desired knowledge (both in time and space), and the economic situation of the enterprise.

## 2.3 Distance education in manufacturing industry

Let us then turn to the result of the research on the use of distance education among Norwegian firms in the manufacturing industry. The survey was based on telephone interviews with representatives from 795 enterprises, which provided a representative sample of about 7 % of the population. The respondant was in most cases the manager of the enterprise or the person responsible for internal training. As mentioned in the introduction, the 1994 survey succeeded a former study in the field.

Firstly, the survey showed that there has been a growing demand for distance education in the training programme of the enterprises. While in 1989, 7 % had used distance education in their training programme, the survey showed that this had increased to 11 % five years later. According to the general penetration of communication technologies in the industry, this does not indicate a very rapid diffusion of distance education (see [27]). The major explanation for this seems to be in the general economic conditions during this period. This becomes more evident when we compare the results to the general investment in training programmes, which in the same period was cut by almost 20 % (see Figure 2). In relation to this general reduction, the share of distance education in training programmes has actually increased by 9 %. An interesting supplementary finding was that the number who reported that they "did not know" if their enterprise used distance education, had dropped from 16 % to 1, suggesting that general knowledge of the topic had been strengthened.

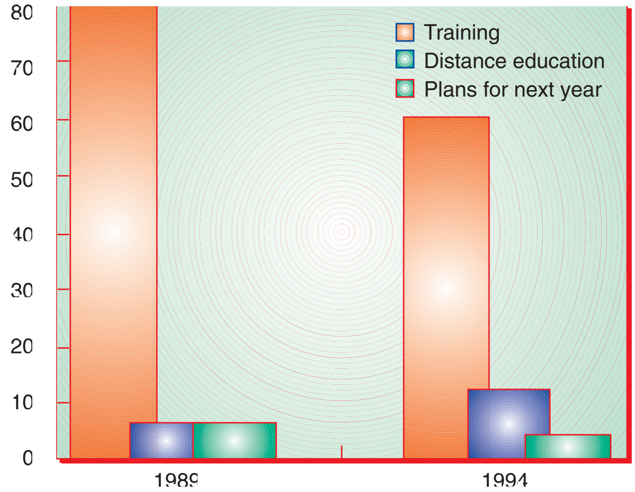


*Figure 2 The extent of training programmes, distance education and estimated future use of distance education in the manufacturing industry, 1989 and 1994, in per cent*

Most of the distance education consisted of small-size projects, involving no more than 1 – 5 employees. There were, however, some large projects pushing the average up to 11 employees per programme. Altogether, there were not many long-lasting projects, and every second one had been started during the last three years.

Secondly, the survey showed that there were certain differences among the firms, both in respect to number of employees and line of business.[6] On average, the large enterprises more frequently made use of distance education in recent years, than the smaller. In enterprises with more than 150 employees, 25 % of the employees had used distance education in the last years, but for the enterprises with less than 30 employees, the corresponding number was only 5 %. These findings are in accordance with the results from the 1989 survey, and they reflect a pattern known from similar research, reporting that the smaller enterprises have problems giving their staff as much training as the larger ones (see [2]).

Furthermore, the results showed that distance education was more common in the sectors of "chemical production", followed by "basic metals" and "food, beverages and tobacco". The high number of distance education in the latter two is partially explained by the many big enterprises in these sectors. "Chemical production" and "food, beverages and tobacco" were also characterised by high rates of regular training, as were "Other industries" (see Figure 3).

What kind of communication technologies did the enterprises use in their distance education programmes? Letter/post services was the most frequently used technology, mentioned by nearly 70 % of the respondents, followed by ordinary telephone, used by 20 %, and electronic mail / computer conferences and video cassettes used by 15 %. Hence, the traditional ways of carrying out distance education were still dominant, although computer based communication (CMC) played an increasingly important role. The result also confirmed earlier findings, showing that ordinary telephony is an important means for consultations between teacher and students (see [3]). The telephone service was used to an equal extent by small and medium sized enterprises, as by larger. The number of available media technologies in general increased with the number of employees.

## 2.4 Future needs for distance education

There are several ways to estimate the future demands for distance education. The easiest way is simply to ask the informants what they intend to do in this field in the coming years. On the question of their future preferences, 6 % of all the enterprises answered that they were planning to launch a project next year. These were mostly large corporations which expressed interest, with a predominance of companies from "textiles" and "food, beverages & tobacco". There was, however, a certain interest for starting distance education in every industrial branch, ranging from 3 to 10 %. This kind of self-reported judgement, however, is not necessarily a very reliable index: In the 1989 study we asked the respondants about their preferences for the next years. Compared to the actual

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6 *The enterprises were analysed in accordance with the Standard Industrial Classification used by the official Statistics in Norway [31]. The classification of manufacturing industry consists of nine main activities (lines of business): Manufacture of food, beverages and tobacco; Manufacture of textiles; Manufacture of wood and wood products; Manufacture of paper and paper products; Manufacture of chemicals; Manufacture of mineral products; Manufacture of basic metals; Manufacture of fabricated metal products, machinery & equipment; and Other manufacturing industries.*

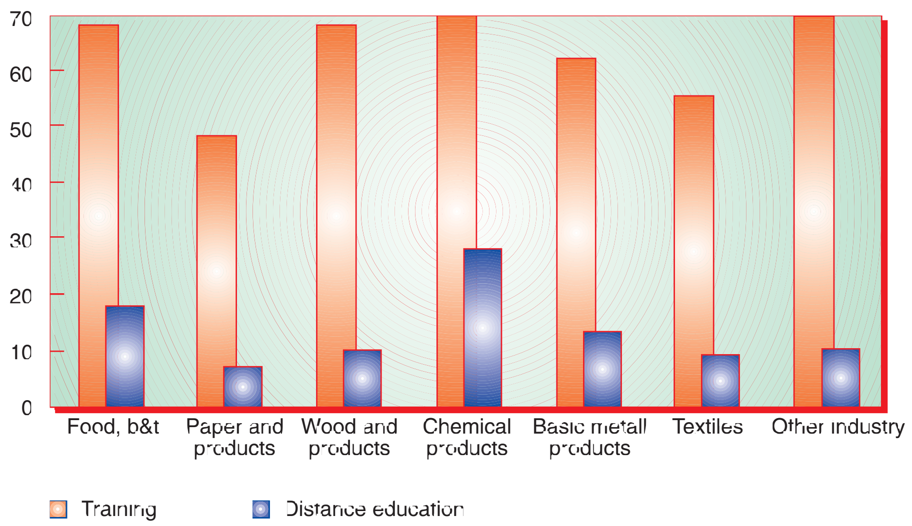


*Figure 3 The use of training programmes and distance education in manufacturing industry and activity classification, 1994, in per cent*

registered number of distance education programmes in the later study, this proved to be a rather poor indication.

A more indirect way of valuing the future need for these services, is to take a closer look at the way the enterprises are structuring their regular training activities. In the introduction above, we made the assumption that both internal and external circumstances were facilitating the need for formal training programmes. Thus, a new market situation may trigger decisions to change the products, to engage in new markets, to adopt new technologies in production, etc. Internal training is here one of many alternative responses. The strategic reason for implementing distance education is that it offers easy and fast access to the education providers with lower expenses, when a need for training already exists. Distance education may therefore be viewed as a product of 1) high demand for training, combined with 2) distance to the knowledge/competence, and 3) a need for reduction in training budgets.

How is the outlook, with respect to these three conditions? Firstly, it appeared from our analysis that the general use of *internal training* in the industry is rather unstable. As mentioned above, there was a significant reduction in the training programmes in the period 1989 – 1994. This was in a period when the economic situation in the country was worsening, resulting for instance in a reduction of the number of people in employment.[7] This may be part of the explanation behind the reduced efforts in training.

The reduction was most evident in the smaller firms; many of the larger enterprises had actually increased their formal training. For instance, 50 % of the smallest companies (less than 30 employees) did not have any training at all the previous year, but all of the larger firms did. The number of enterprises where more than 50 % of the staff had enjoyed a training programme, had also increased among the largest firms, but decreased among the smaller ones. Hence, the training programmes in the larger firms seem to be less vulnerable to economic cycles than in the smaller. Interestingly, distance education seemed to hold its ground, despite the general cuts in internal training, probably due to the fact that most of this activity was taking part in larger enterprises. Still, these fluctuations in the demand for formal training make it difficult to predict the future use of distance education.[8]

Secondly, it appeared that the use of external teachers or lecturers was very common, and had increased over the five year period. In 1989 every third enterprise relied totally on their internal teachers, but five years later, this constituted only 8 %. In 1994 every second training programme was held by an external specialist, and over 40 % used both internal and external teachers.[9] In reality then, over 90 % of the enterprises had used teachers from other institutions, or organisations in their courses. This finding was supported when we considered the venue for the courses. In 1994 the number of enterprises who held their training outside the company building had increased from 31 % to almost 80 %. The majority preferred a combination of internal and external courses. Thus, it seems to be the case that the use of external teachers and external courses is supplementing, and not substituting, the regular (internal) training. The use of internal teachers or lecturers was more common among the enterprises with many employees, while smaller enterprises as a rule hired the necessary competence (see Figure 4). This was evident in both the surveys. The increase of external organisers and tutors seems to be the result of higher demands for training in the larger companies,

*7 From 1989 to 1991 the number of employees in manufacturing industry dropped by 13,000 people [31]. During the period 1986 to 1990 there was a reduction of the total investments in development of skills and knowledge in the industry, even if the non-material investments were kept relatively constant [6].*

*8 There are signs indicating that the investment in education has been increasing in the last year, at least in some lines of business. A recent survey of European business and enterprises showed that the Norwegian private sector was spending about 3.5 % of their salary expenses on competence development, only surpassed by Swedish, French and Swiss enterprises. The results showed, however, that the local government in Norway spent minimal amounts on educating their employees, pulling Norway down in the international statistics (*Aftenposten*, 17.10.96).*

*9 There are some differences in the way the registration was done in 1989 and 1994, on this question. In the first one, the answers were registered as either "internal" or "external". In the latter one was added a registration possibility for "both". This might have influenced the reliability of the data.*

resulting in extended use of supplementary providers.

Summing up, this might point in the direction of higher demands for distance education, which in essence is a very efficient way of getting access to know-how located outside the enterprise. On the other hand, there may be several reasons for bringing an external expert into the organisation, and it is not easy to say to what extent distance education can substitute for this. In a very similar way, there may be different reasons for letting the staff go to externally arranged courses, reasons that are not easily substituted by distance education. Examples could be: to get away from the everyday environment, have a new experience, enjoy a trip together with colleagues, or to get an award. To gain knowledge about these circumstances would require further research of a more qualitative character.

Thirdly, the enterprises reported having large expenses on training activities. Most of the enterprises have separate budgets dedicated for this, and the average sum spent on training was almost 5,000 NOK. The respondants who reported having no training budget were in 90 % of the cases representing firms with less than 30 employees. Compared to the total budget, however, it was the medium-sized enterprises which spent the largest sum on education. "Other industry" had the highest proportion of their total budget dedicated to formal training; about 4 % on average. When it comes to expenditure on travelling, the geographic location of the enterprises proved to be a decisive variable. In densely populated areas (Akershus, Oslo, Nord-Trøndelag) almost half of the respondents reported that they did not use any of the training budget on travelling. In contrast, every second enterprise located in certain districts on the west coast (Aust-Agder) and in the north (Finnmark) reported using more than half of the total training budget on travelling and accommodation.

Hence, the budget on training and travelling interacts closely with the rate of training in general, as well as the number of employees. The prediction value of this variable is therefore not very strong, and the analysis did not investigate the need for cutting costs related to the training. The analysis showed, however, that the use of distance education was more common among enterprises outside the city areas, suggesting that geographical distance may be of importance. The low budget for training in smaller firms indicates that the economic situation is more critical here than in larger firms, even if this has not resulted in more distance education.

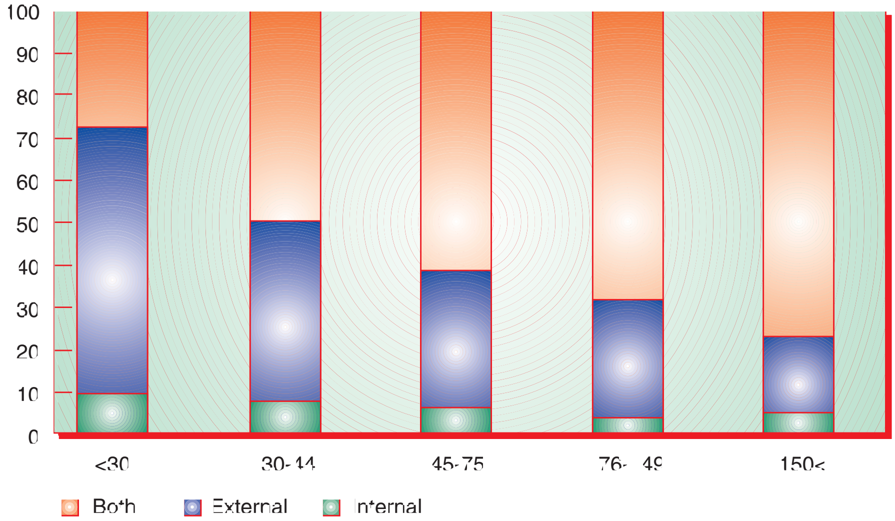


*Figure 4 The use of internal and external lecturers in manufacturing industry, and number of employed, 1994, in per cent*

## 2.5 Summing up

The survey on the use of distance education in manufacturing industry showed that there is a growing number of enterprises which use distance education, despite a general decrease in formal training, during the period 1989 – 1994. Distance education is primarily used by medium-sized and larger enterprises, particularly within "chemical production", "basic metals" and "food, beverages and tobacco". There was also more distance education among enterprises outside the city areas.

Moreover, there appeared to be a certain interest for more distance education among the respondants. The increased use of external education and externally organised courses, and the rapid diffusion of computer based communication also suggests a higher adoption of this in the future. Still, it is difficult to predict the development. Firstly, because there are different needs accounting for the use of external competence, not all of them can be supplemented by distance education. Secondly, the training activities in the enterprises seem to be very vulnerable to changes in external factors, particularly among smaller and medium-sized enterprises (SME).

Thus, the political arguments for more education and training in the industry are not necessarily followed up by the individual corporation or enterprise. The reduction of education programmes indicate, on the contrary, that more insecure economic situations make enterprises reduce their training activities. The general investment in necessary technology and equipment seems to be difficult to manage, especially for smaller enterprises, even if distance education in the long run could help reduce the expenses of training. This may end up in a "vicious circle" where the SMEs are closed off from sufficient development of training and education, while the larger corporations enhance their lead.

# 3 The education sector

## 3.1 Introduction

The debate on the use of information technology in the education sector has been very intense in recent years. The background for this is a general awareness and understanding of the prospective importance of this technology in almost every higher level study, occupa-

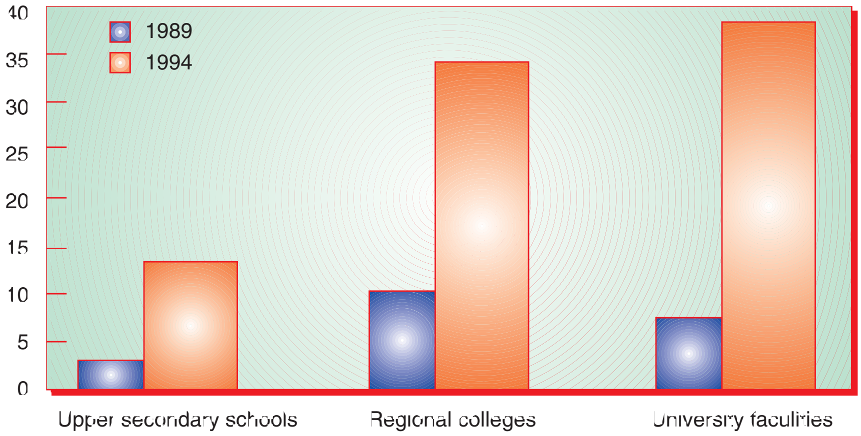


*Figure 5 Number of upper secondary schools, regional colleges and university faculties offering distance education, 1989 and 1994, in per cent*

tion or workplace. It appears to be of crucial importance to provide students on every level with a good understanding of technology, and how it best can be exploited. Moreover, it has become evident that information technology has a potential for making the education itself better and more efficient. The very rapid diffusion of the Internet in recent years has demonstrated the great advantages this may imply for students and teachers; the innumerable databases connected on the network offer a unique opportunity to enrich and supply the education sector.

The discussion in Norway has also included a regional dimension. Since the education sector has a very decentralised structure, it has been an intention to use telecommunications and IT to link the institutions together in a "knowledge-network" ("Norgesnettet"). In that respect, an infrastructure has been established between the central universities and regional colleges, with the intention of co-ordinating the development of specialised competence and training. In addition, a broadband network has been implemented between the universities (34 Mb/sec), and a wide access to the Internet has been provided for all the upper secondary education and regional colleges.

The acknowledgement of the importance of information technology and telecommunication in education has led to an interest for telebased distance education in the education sector. Actions have been put forth to speed up the development of such activities, and considerable expenses have been invested in equipment [14]. A recent survey shows that there were 5.9 students per PC in upper secondary education institutions, and 6.1 in the colleges, which indicates a fast implementation [15], [16].

Telenor Research & Development conducted its first survey on the education system in 1989, and a subsequent study was launched in 1994. The latter, which will be emphasised here, included a representative sample of 733 institutions, including 560 upper secondary education institutions, 192 colleges and 38 university faculties. Both studies were directed towards all schools, colleges and universities in Norway.[10] In this chapter, I will present some of the main results from this work. For the purpose of the presentation, I will discuss the results from all the levels in parallel. It should be mentioned, however, that the entities here are not entirely comparable, since universities are organised differently from the more traditional upper secondary education institutions and colleges. There are also important differences regarding the way they are managed and financed: While universities and colleges are state owned, upper secondary education is financed by the local administration.

[10] *This included students from private colleges, but no private upper secondary education.*

## 3.2 Distance education in the education sector

The number of Norwegian schools using distance education appeared to have increased markedly in the period from 1989 to 1994. In upper secondary education institutions 13 % were offering distance education in 1994, which represents a 10 % increase, compared to the former survey (see Figure 5). Among the regional colleges, about 35 % of the schools were offering distance education, indicating an increase by more than 20 %. The fastest implementation of distance education, however, was registered at the universities, where 14 out of 37 faculties were offering distance education in 1994. Compared to the 1989 figures, when only 3 out of 45 faculties used distance education, this implied an increase by more than 30 %. It was the regional colleges that included the largest group of students, and in the school year 1993–94, a total of 7,825 college students were receiving distance education.

Most distance education in upper secondary education involved subjects such as "general and business studies", "health and social studies" and "music, dance and drama". At the regional colleges, the typical distance education was taking place within "pedagogics", "general and business studies" and "technical science". At the universities this involved a wide range of subjects, including social science, humanities, medicine, law and technical studies.

Distance education played a role in schools all over the country, but in upper secondary education there was more distance education in schools located in rural parts of the country. In northern and western parts (Finnmark, Nordland, Møre- and Romsdal) the rate of schools who used distance education was twice the total average. This difference was relevant to the distance between regions and city areas. The predominance of distance education outside the central areas became even more evident when we considered the schools which were receiving this from other institutions. While less than 18 % of the upper secondary education institutions in the cities were receiving distance education, 35 % of the schools in rural areas did. This was the case even for regional colleges: At the city colleges, approximately 30 % offered distance education and 17 % received it. Among the rural schools, in contrast, 46 % were offering and receiving distance education.

Furthermore, the occurrence of distance education was related to the number of students at the regional colleges and faculties. Among the largest colleges (with more than 700 students) more than 60 % had given distance education, but only 20 % of the smallest schools (fewer than 300 students). Among the biggest faculties (more than 1,000 students), 69 % had used distance education, but only 8 % of the smallest (fewer than 500 students).

Which medium was used in the education sector? In upper secondary education institutions and the universities ordinary telephone was the most used technology, used by 50 % and 77 %, respectively (see Figure 6). In the colleges letter/post was the most frequently used medium, mentioned by over 60 %. In the upper secondary education institutions 48 % had used letters in distance education, and the equivalent figure for the faculties was 62 %. It is interesting to see that at the regional colleges, e-mail is being used more frequently than for example telephone conferences and television. By and large, however, the colleges and universities used more "advanced" technologies than upper secondary education institutions. Telefax, e-mail, telephone conferences and databases were more often applied on the higher levels.

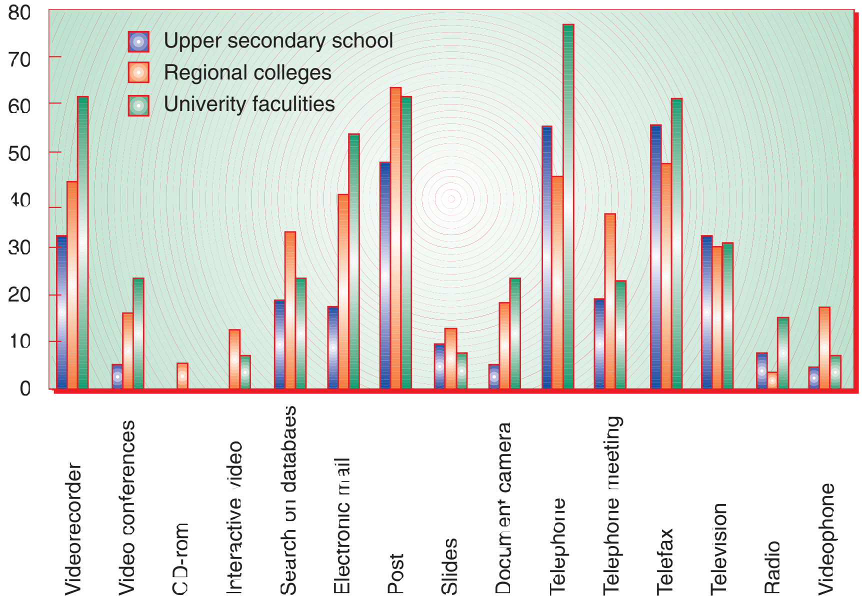


*Figure 6 Media used in distance education in upper secondary schools, regional colleges and university faculties, in per cent*

## 3.3 Future needs for distance education

The results presented above document a very rapid implementation of distance education in the education sector. If we look at the respondents' plans for the future, there will be no slowing down of this development. First, at all levels the majority planned to *escalate* their distance education activities. At the upper secondary education and college level, approximately 86 % of the schools which today have distance education programmes, reported that they where going to extend the activities. At the universities, 11 out of 14 faculties which currently offer distance education, reported that they would extend their activities. Second, a lot of schools which had not yet used distance education, planned to *start new projects* within the next years. 20 % of the schools on the upper secondary education level and 30 % on the college level were planning to launch a project during the following three years. At the universities, 9 out of 23 faculties without distance education planned to launch projects.

To gain a better understanding of the future possibilities, however, we should take a closer look at the underlying needs that may trigger further distance education in the educational sector. The context of distance education is quite different to what we found in manufacturing industry, primarily because the education system in essence is directed towards training and teaching, and not implementing products, as in industry. The schools consist of larger entities, more controlled by political decisions and resolutions than fluctuations in commerce and business. On the other hand, the advantages of using distance education are more or less equal; easy and fast access to knowledge, reduction of expenses in relation to travelling and accommodation.

Thus, one major reason for using distance education is to *reduce travelling* for employees at schools and universities. In Norway, there is quite a tradition for "decentralised education", where teachers travel to small groups of pupils. Our survey found that 164 upper secondary education schools practised this type of education, that is almost one third (see Figure 7). Further, this was a 20 % increase since 1989. This pattern was evident among the regional colleges as well as universities. Every second regional college had provided decentralised education to students in 1994, a 10 % increase since 1989; and every third university faculty, representing a 15 % increase. This indicates that the potential for reducing travelling among teachers may be one important reason for the great interest in distance education. It also suggests that there may still be a considerable potential for substituting travelling activities by distance education.

Another aim for using distance education is to gain fast and easy *access to external teachers*. It appeared to be quite usual to draw upon externally employed personnel in education. At upper secondary education level, two thirds of the schools reported to have obtained competence from other schools or institutions. This was done by 89 % of the faculties, and almost every regional college. Despite this, however, the schools reported receiving a lot of inquiries from students on subjects which they were unable to accommodate. This was most prominent among the regional colleges where 60 % admitted that they had received this kind of enquiry, followed by 50 % at universities and 40 % in upper secondary education. At the same time, there was a lot of competence among teachers not currently

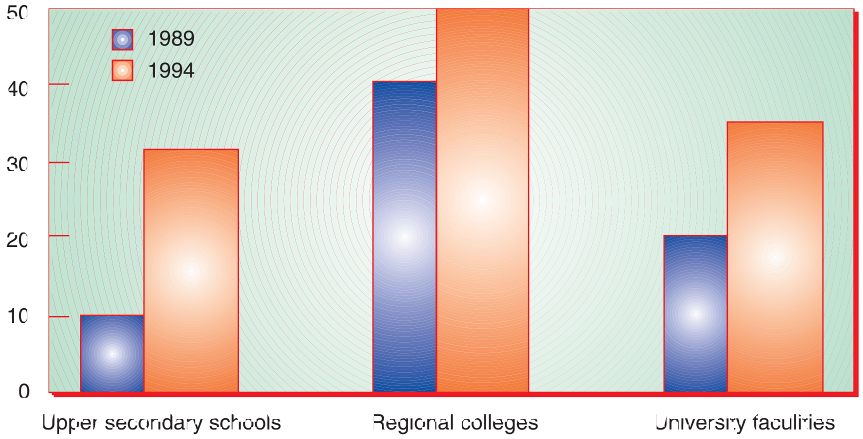


*Figure 7 Number of upper secondary schools, regional colleges and university faculties offering decentralized education, 1989 and 1994, in per cent*

used in education. Every other college and upper secondary education institution reported that the school was in possession of competence that was not applied, and 40 % of the university faculties. At all levels, there was more "surplus" than "deficiency" of competence in most subjects. However, certain subjects, such as "general and business studies", appeared to be a field where there were parallel needs for more competence and a lot of unused knowledge.

Interestingly, this reported "deficiency" and "surplus" of competence seemed to have increased over the period. For instance, the number of regional colleges with unapplied competence had increased by 30 %, and the number without necessary competence by 10 %. This tendency was apparent for upper secondary education schools as well as for faculties. This would suggest that the education sector has become more "competence-intensive" over the five year period, with higher demands for knowledge and teaching capacities. This seems to be of particular relevance for subjects which fall within the category "general and business studies".

### 3.4 Summing up

The analysis of the education sector documented that distance education has changed, both qualitatively and quantitatively during the years 1989 – 1994. The number of distance education projects, and the number of students involved, have increased at all levels. Upper secondary education has the highest rate of distance education projects, while the education at regional colleges involves most students. The fastest implementation rate, however, has taken place at the university faculties. To a certain extent, this must be considered a deliberate consequence of the official politics in this field, which since the late eighties have been emphasising the use of distance education in various forms (see [14]).

New computer and telecommunication media play an important part in this development, and e-mail has been greatly adopted by distance education in recent years, especially at the regional colleges and the universities. Here, e-mail is more frequently used in distance education than television and telephone conferences. The broad range of media indicates that education has become more media-intensive, even if it is difficult to tell how the technology is used (as supplement, consulting means, etc.). However, subjects such as "music, dance and drama" reported on the list of distance education, suggest that the technology often plays a secondary or supplementary role.

Moreover, the analysis indicates that the education sector has become more dependent on technology, as well. There is a general demand that schools offer more diverse and specialised education and training, putting pressure on the schools to develop and expand their own competence. Since a lot of schools have limited budgets, distance education is often an acceptable substitute for hiring competence or launching regular courses. The increased demands for specialised knowledge may be the single most important factor behind the push towards more distance education.

## 4 Conclusions

### 4.1 Differences and similarities

The building of a high capacity information and telecommunication network is said to represent one of the greatest long-term investments in the 20th century [26]. Distance education is in this connection repeatedly emphasised as one of the applications which justify this investment [28], [4]. There seems to be a general agreement that education will be one of the most important elements in the future information society, both in respect to personal development, business and industry, and culture.

In many ways, this trend has been visible for several years already; the number of higher-level students is still increasing in all western countries, and it is estimated that the working part of the population must be prepared to re-educate themselves at least four times during their career [26].

This development costs money and time, and industry and the education sector should have a shared interest in applying information technology and telecommunications to make education and training more efficient, and of a higher quality. Computer mediated communication has a potential to function as a common knowledge-network, enhancing the contact between industry and teaching. Our survey research on the manufacturing industry and the education system has proved that the education sector is in the vanguard, implementing distance education on a much faster scale than manufacturing industry. While the rise of distance education in both upper secondary education, regional colleges and university faculties must be characterised as significant, manufacturing industry is developing at a slower pace.

The differences between the two sectors must be viewed against the background of very different contexts surrounding the industrial enterprise and the school or faculty. For the enterprise, training activity is only one among several strategic initiatives to develop the organisation, and in turn be more competitive. An investment in internal competence is balanced against the long and short term assets and expenses. This makes the efforts behind the use of distance education far more vulnerable to changes from external sources or internal strategies. The school, on the other hand, is part of a greater education system, more politically controlled and co-ordinated. It has a responsibility to provide education to students connected to the school (even if there are differences regarding the three levels) and is not in a position to change this from day to day.

These different contexts explain the distinct patterns for adopting distance education. Regarding the use of telebased distance education, however, there are also certain interesting similarities. First, in both sectors, distance education is dependent on large institutions. The small schools, as well as the small enterprises, did not apply distance education on the same scale as the larger ones. The size of the institution seems to be closely related to the ability to invest in necessary technology, but also the willingness (and financial capacity) to experiment with new organisational forms. Second, the geographic location had to a certain extent impact on the use of distance education, among both schools and enterprises. This was most evident in the upper secondary education schools outside regional areas, but also regional enterprises were more prepared to use distance education in their training programmes than the central industry. Third, there were parallel patterns in respect to the use of media technologies: Post/letter and telephone was still the most used technology in distance education, although at the regional colleges and universities, the telephone was more used than letter/post. E-mail appeared as the most rapidly growing medium for distance education purposes, both in the education sector and among industrial enterprises. Altogether, however, the education sector used a wider range of electronic media in their education, particularly at colleges and universities.

## 4.2 Future challenges

What, then, are the future developments appearing from this analysis? I will content myself with pointing out some major challenges, which follow from the discussion above. First, the investigation shows that there is no obvious link between the political requirements of an escalation of knowledge and education, and the actual development in the smallest parts of the system. Small enterprises and schools have generally less access to distance education with telecommunication and computers. In Norway, where the majority of enterprises are small and medium-sized, there are only vague signs of a regional knowledge network. The challenge will be to help these organisations gain easy access to both the global and the regional networks. Lower prices on simple technological solutions relevant for distance education, may be one important effort. Still, it is important for the managers to orientate themselves in the new possibilities for getting access to training via distance education, that is to say, to “be competent in competence”.

Second, it is to a certain degree possible to trace a development of polarisation between different regions. In the education sector, the universities seem to appear as the “knowledge providers” for upper secondary schools and the colleges. None of the university faculties were receiving distance education from external institutions, while this was an important trend in the regional colleges and the upper secondary education schools. This approach to the problem is relevant for the development of knowledge-based products in different parts of manufacturing industry as well. There is a risk for transforming the city areas (where universities and most of the industry are located) to “knowledge providers”, and the regional areas to “knowledge users”.

Third, the analysis indicates that a lot of the distance education projects are rather short lived. This is especially apparent in manufacturing industry, where every second project has been launched during the last three years. It has not been within the range of this work to analyse the distance education projects in detail, but this provides some hints of the problems connected to developing good technical and organisational solutions. To get a clearer view of the situation, more research should be conducted in this field, preferably trying to analyse the individual distance education projects in a concrete organisational setting.

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# The globalisation of education

BY ROBIN MASON

## Do we need it?

The reaction of many people to the notion of global education is resigned exasperation, querying whether we really need yet another revolution in the teaching/learning paradigm. The spectre of people dotted in continents here and there around the world studying the same Physics 101 course does not conjure up images of a high quality learning environment comparable to the cosy picture of student-led seminars, heads bent over books in library carrels, passionate arguments in late night coffee houses, and brilliant lecturers spellbinding young undergraduates. Why is global education then such a burgeoning phenomenon? Are we being driven to this by non-educational pressures, or are we expanding in this direction voluntarily? And who is it that is leading the pack?

I begin by considering the extent of the phenomenon – how much education on an international scale is actually taking place? It is hard to avoid encountering the avowedly evangelical predictions about the educational implications of the digital this and the electronic that, and the triumphalist announcements of the optimists introducing the education superhighway here and the virtual university there. It would be easy to think that global education is already established practice, with courses, programmes and whole institutions jostling for position in the global marketplace. Whilst competition amongst tertiary education providers is certainly brisk in most developed countries, the market in question, even for those offering distance education courses, is primarily regional, in some instances national, but rarely international. In fact, the number of truly global courses, let alone programmes or institutions, is still very limited. Nevertheless, I can only conclude from my studies that global education is a phenomenon to be reckoned with for all those in higher education and training.

## The arguments for global education

There are a good many economic, socio-political and technological reasons underpinning current developments both of the plans for and the practice of global education. Perhaps they will prove to be the strongest forces driving change. However, committed teachers and educationalists would prefer to feel that a pedagogical rationale for a global student body or a global curriculum is the primary consideration. Undoubtedly there is a case to be made for global courses on purely educational grounds, and I have divided these according to the reach of the course, the access to the course and the development of the course.

The strongest argument relates to the benefits of a global student body:

> The diversity of participants made for a far richer course than I could ever teach myself. Take, e.g., the time our correspondent in Istanbul reported on a lecture given there on medieval Christian philosophy by a Franciscan priest to the faculty of the (Islamic) University of the Bosporus. Well and good, the faculty opened when it was over, but it's too bad Christianity is not a truly rational religion, like Islam. Leaving aside the question of comparative rationality of religions, I think it is undoubtedly good for my students at Penn [State University], taking a course on a very traditional, 'western' figure, to be reminded that the whole picture looks quite differently if you happen to be in a different seat. ([20] p. 113)

Here is the case of a course on the work and thought of Augustine, taught face-to-face to undergraduates and beginning graduates on a traditional campus, being offered over the Internet in order to supplement the intake on such a specialised topic. Over 550 subscribers from around the world – Bangkok to Istanbul – joined up and undergraduates, scholars, and Internet-surfers all contributed to the discussions. The taste of global interaction given to this teacher by his first venture onto the information superhighway, left him concluding:

> I cannot imagine ever passing a semester in the classroom again without the umbilical cord to the network to energize, diversify, and deepen what we do. (op cit, page 114)

O'Donnell's experience is echoed by many others who have discovered the educational benefits of a global student body. What is particularly welcome in this example is that the globalisation of the course countered the usually dominant western world view.

The second most compelling educational justification for globalised education is that of access. Whether potential students be geographically remote, time constrained, financially constrained, house-bound, disabled, or simply unable to find a course on the subject they want locally, there exist large unmet educational needs which every research report, policy study and educational analysis shows is increasing.

For an institution which has an access remit in its mission statement, global education is now part of the moral high ground and new technologies are providing them with the means for reaching out to people anywhere, anytime, who want to learn. The UK Open University (UKOU) is one of the most prominent examples of an institution enshrining access to educational opportunity and openness to students of all backgrounds not only into its name and mission statements, but into the very heart of the organisation: its preparation of course materials, its enrolment procedures, its tutorial support provisions and its commitment to developing similar organisations around the world. This is how the UKOU rationalises the extension of this approach into a global strategy:

> The University is committed to addressing educational disadvantage and widening educational opportunities for an increasingly large and diverse number of learners. Its mission statement, with its emphasis on openness to people, places, and methods, underlines the University's commitment to respond to need and demand wherever the means of delivery exist. In the past, limitations of educational technology and funding have confined that ability to deliver to fairly strict geographic limits. Those constraints are rapidly diminishing. The OU now has the potential to extend educational opportunities to a much wider body of learners not only in the UK but throughout Europe and more widely in the world. In doing so, it has the ability more fully to satisfy its mission. It has the power to transform peoples' lives, without regard to geographic frontiers. [21]

Related to the notion of access is the third purely educational rationale for global courses: that the expertise of the few can be made available to the many, such that those in remote areas can have the same access to educational resources, specialist courses and renowned experts as those located in large cities and developed parts of the world. A student who signed onto a Web-based course on the

Principles of Protein Structure offered by Birkbeck College, London, listed one of the main advantages of this virtual course as the easy and informal contact it provided with a large number of fellow scientists around the world.

> Everyone is on first name terms and the mailing lists, along with the group structure, provide a convenient way to discuss issues raised by the course material, and to deal with any problems people may be having. [22]

Athena University, one of the newly established electronic universities, sees its mission as providing high-quality educational opportunities on the Internet as inexpensively as possible. It is able to carry out this mission by utilizing the Internet resources of the entire globe (http://www.athena.edu).

The expertise located at one university in the United States is shared with ninety students in three other countries: Mexico, Finland, and Estonia, providing access to a Certificate Programme in Distance Education, through a combination of audioconferencing, computer conferencing and recorded media. [5]

Finally, and some might say most importantly, a good many areas of the curriculum are inherently global in nature and some particularly lend themselves to course development on an international scale, providing students with a much broader perspective than a course presented by a single lecturer or developed by a single institution. A good example of trans-national course development is that of the European Association of Distance Teaching Universities which has encouraged the joint authoring amongst its members of two programmes: the European MBA and a comprehensive course in the humanities, entitled ’What is Europe’. The advantage of this kind of international collaboration is elaborated by Trindade, President of the Portuguese Open University:

> In Europe, the very old universities tend to perpetuate rigid (not to say extremely conservative) educational systems ... This weight of tradition is reflected in university programs that have scarcely varied in format or designation for at least half a century, despite intense basic and applied research activity in advanced or innovative fields ... Distance Teaching Universities seem to be more accepting of new ideas or new models, more pragmatic in their approach to cooperating with each other, and more daring in their attitude towards trans-national collaboration. ([28] p. 40–41)

These, then are the major advantages to global education as cited by some of the practitioners teaching and learning at the coal face. At its most visionary, the ideal of global education is one of a movement away from the bounded classroom, seen as a haven from the world, self-contained and static, to a dynamic synergy of teachers, computer-mediated instructional devices, and students collaborating to create a window on the world. Interaction with learners on a global scale leads to an increased awareness of the extraordinary complexity of interrelations and a relativistic comprehension and tolerance of diverse approaches to understanding.

Other advocates of the movement in this direction, however, see a range of less idealistic factors driving education onto the Superhighway.

## Pressures encouraging global education

The reasons behind the, in some cases, drastic reduction in funding of public universities, as well as the falling population of traditional 18 – 20 year old students, at least in western countries, are outside the scope of this article. Suffice it is to say that financial pressure on institutions of higher education world-wide is probably the most critical factor forcing administrators and policy makers to look to global markets as a way of making up for falling government revenues and falling numbers of traditional learners.

While the search for new sources of revenue has provided the impetus for universities to look for new markets, larger social changes have steered that search towards globalisation. In fact, global education is a reflection or extension of society’s increasing understanding of the interrelatedness and interdependence in the physical world. The development of this global consciousness has been heightened by the spread of global communication systems and particularly the entertainment media.

> Distance open learning appears to be uniquely suited to the emerging world order. As borders open up across the globe to traffic of almost every kind, so distance open learning flows increasingly across national frontiers. [11]

Field contends that trans-national education represents both an outcome of and a primary factor in the intensification of global interconnectedness. Education, he points out, used to be regarded as an essential element in nation-building. As with other social and political trends, education is increasingly being thought of as a commodity to be shaped according to consumer demand.

Some commentators on globalisation see the trend towards student-as-consumer as having positive educational outcomes. Teachers and course developers are being forced to consider the requirements of learners, and the global telecommunication systems allow students’ opinions to be embedded into the learning environment.

> Technologically-mediated knowledge provides the basis for individualising learning in a more complete and active way ... Here distance is subservient to the discourse of open learning and ‘educative’ processes are displaced and reconstituted as relationships between producers and consumers in which knowledge is exchanged on the basis of the usefulness it has to the consumer. It is therefore a discourse of open learning which might be said to more fully govern the practices of those operating at a distance in the post-modern moment, as increased marketisation is introduced into the provision of learning opportunities and mass markets fragment and become more volatile across the globe. [8]

For Edwards, the globalisation of education through the use of telecommunications technologies will empower the learner and force the providers of education to concern themselves with students’ needs, rather than with the transmission of a pre-established canon of knowledge. Educators, just like businesses, will have to become more flexible – in their staffing ratios, in their approach to students, and in their considerations of the curriculum. Various structural rigidities of traditional universities will have to be overcome: constraints on what constitutes the academic year, on where credits can be accumulated, and on how courses can be modularised. The kinds of courses which the global consumer is demanding are flexible, adaptable, portable and interactive.

## Dangers of global education

Although the enthusiasts for the globalisation of education are more prominent in the media, they are probably equalled in number by the voices crying for a halt to the headlong expansion of global education on the Superhighway. I have found it useful to classify their arguments as primarily cognitive, educational, social and cultural.

The cognitive argument is based on the fact that the new delivery mechanisms for most global education are electronic and rely largely on the digitisation and computerisation of knowledge. Many people decry the cognitive effects of learning from screen-based information rather than traditional text-based material, pointing to the breakdown of linear, narrative structures associated with the book, and the resulting fragmentation and superficiality induced by the hyperlinked structures of the Web and multimedia CD-ROMS. One of the more eloquent apologists for the culture of books is Sven Birkerts, who tots up the cognitive losses we are encurring with the rise of an electronic culture:

> In the loss column are (a) a fragmented sense of time and a loss of the so-called duration experience, that depth phenomenon we associate with reverie; (b) a reduced attention span and a general impatience with sustained inquiry; (c) a shattered faith in institutions and in the explanatory narratives that formerly gave shape to subjective experience; (d) a divorce from the past, from a vital sense of history as a cumulative or organic process; (e) an estrangement from geographic place and community; and (f) an absence of any strong vision of a personal or collective future. ([3] p. 27)

Birkerts acknowledges that these are enormous generalisations, but he feels that they accurately reflect the comments of his students about their own experience.

The educational argument against global education centres on the undesirable aspects of consumerism, wherein learning ceases to be about analysis, discussion and examination, and becomes a product to be bought and sold, to be packaged, advertised and marketed. In the previous section I presented the case in favour of competition in course provision. However, just as there are many who do not accept its value in a whole range of social services, so there are those who view the growing competitive, consumer spirit amongst educators as detrimental to the learning outcomes (see, for example [19]). This marketplace philosophy of higher education is particularly associated with distance education, which in turn is the foundation of the movement towards globalisation.

One example of the shoddiness of global competition in education is the number of MBAs offered by a range of Western institutions in the advanced countries of the Pacific Rim. Some are outright cons; others are just poor quality; many are 'sold' for high prices which are then used to defray the deficit incurred by students taught face-to-face in the home institution. Together with legitimate, high quality, well supported programmes, they all jostle in the marketplace to the bewilderment of prospective students, who have fewer standards for and less experience with assessing the quality of global courses than they have in judging local programmes.

Social arguments against globalisation are related to the breakdown of community. This phenomenon is part of a much larger, more complex web of changes associated with Post-modern society; nevertheless, education which has always been a net contributor to the positive benefits of physical communities, is now seen as undermining still further the physical experience of community and offering instead a much less substantial substitute in the form of virtual communities.

The global classroom does have a communal atmosphere: it has interaction between students and teachers, and networking and serendipitous encounters with other learners both those following the same course and those simply out browsing, searching or talking on the Internet. There is evidence of many of the elements of traditional communities: people help each other (by forwarding information to each other which they think will be of interest; they answer queries from strangers, providing them with the benefits of their expertise, for no personal gain; they trade confidences and intimacies; they play games together; they meet regularly. Nevertheless, some observers of this new phenomenon see great danger and significant social loss in the demise of physical community and its replacement by virtual community no matter how educational:

> There seems to be a great difficulty in holding onto the truth – as obvious as it is – that ease and flexibility of switching do not constitute ease and depth in making human contact. Certainly the connectivity makes communication 'easier', but it achieves this precisely by rendering contact more incidental, more shallow.
>
> I suspect that every major technical advance in communication since the invention of writing has marked the path away from community rather than toward it. Community is, in the first instance, something to be salvaged from information technology, not furthered by it. ([26] p. 74)

Others warn about the loss of our fundamental assumptions regarding identity and subjective meaning by moving from the physical and substantial to the virtual and electronic. The notion of community has always been rooted in a sense of the particular and this has characterised our experience over millennia. The essence of our education system has been the community of the classroom and the physical reality of the textbook. It has changed relatively little over the past few hundred years.

> What we will have in the next few years is an education system that is part of computer culture. It is not just the physical environment that will be transformed. Whereas books have encouraged us to think in terms of a stable body of knowledge, a form of content that we can read, digest, learn, and know, computers dispose us to think differently – to be engaged in a constantly changing process where information is not stable or fixed. ([25] p. xxiii)

The effects of this destabilisation on social and personal assumptions has been analysed at length by Poster [23], who speaks of the dispersal of identity through computer networking.

Finally, the cultural arguments against global education systems are equally compelling, and harken back, of course, to old concerns about imperialist attitudes, the loss of indigenous cultures and the relentless imposition of Western values. Global educators are seen as the new colonisers, insensitively spreading their own views of the world onto developing nations in the mistaken belief that they are actually helping people:

> The access to this sort of provision can be seen to have considerable educational (and possibly, social and economic) benefits to a developing nation. However, as an invasion, it can be seen to weaken national initiatives to develop local educational provision which might be better suited to local needs. It also creates the potential for a post-colonial dependency on another 'developed' nation. [9]

Evans argues that despite the value of global education in offering diversity of choice, this comes at the expense of encouraging local initiatives which value local culture and promote national beliefs, skills and knowledge. The potential power of globalised teaching to spread dominant ideologies and to crush emerging structures, whether wittingly or unwittingly, is the main cause for concern. Moore, who also expresses concern about the cultural implications of global education, says that truly international distance education courses would involve all participants (including the teachers, experts and Western students) in a re-examination of their educational philosophies, their views of the subject being taught and their cultural perspective of the content of the course. In practice, he feels, Westerners tend to be arrogantly uncritical of the assumptions underlying their teaching and unreflective of their fitness for teaching across cultures ([19] p. 189).

## Current practice

I have presented some of the most significant views of the enthusiasts and practitioners of global education and have outlined the wider pressures leading to the global expansion of higher education. I have also represented the arguments of those concerned with the negative impact of global education. So having briefly considered why it is happening, I turn now to an analysis of what is happening under the guise of global education.

I suggested earlier that there is a good deal less global education being practised than would be imagined from reading newspaper articles, browsing the Web or listening to media hype. Let me begin with a listing of the various elements which characterise global education. Many self-designated global courses are in progress which do not meet all of these criteria; indeed, I have not found a single course which has all of these characteristics. My list is roughly in order of significance:

1. students spread roughly evenly in three or more countries of the world
2. an express aim on the part of the teacher or institution to attract international participation
3. course content which is devised with trans-national participation in mind
4. support structures – both institutional and technological – to tutor and administer to a global student body.

For the purposes of this article I am not going to consider the various global initiatives operating at the level of primary and secondary education. While some of the issues I discuss will also apply to some extent to these schemes – cultural benefits and threats, cognitive effects of computerisation and screen-based learning, educational value of a global curriculum – I want to focus primarily on the higher education sector (including training and professional updating), and on the notion of a university without place, rather than on a classroom without walls.

Secondly, I know that there have been a number of global programmes running for some time, even quite large-scale operations, which are based on print and postal systems only. I do not intend to include these non-telecommunications based programmes within the compass of my discussions, because I consider that they have been effectively superseded by the advent of the Internet and global telecommunications systems. In fact, many of these programmes are already beginning to introduce elements of telecommunications into their support or administrative procedures.

As is apparent from some of my arguments so far, I will include current debates surrounding Virtual Universities and on-line courses, whether or not they are actually operating globally, because the issues and outcomes of these practices are fundamental to global education; indeed they are the forerunners of it.

Using the four attributes of a global course listed above, I can discuss current practice on a continuum from courses with global aspirations to those already in operation.

### 1 A global student body

By far the largest number of 'pseudo-global' courses – and most originate from North America – have no face-to-face requirements, and all course material, administration and support are provided either electronically or by post. The majority of students are North Americans, but occasionally a student abroad (British or Australian perhaps) will hear of the course and ask to enrol, particularly in specialist areas where a similar offering is not available locally. More commonly, a number of North Americans move abroad or are sent by their company during the period of the course or programme, and they continue their studies from the new country. These courses are global in fact but not in spirit – the content has not been altered; the interactions are amongst people of the same culture; the institution has not been re-engineered for a global mission.

Nevertheless, there are some courses and even programmes currently taking place which have students from a number of different countries and cultural backgrounds. For example, many training programmes offered by global companies have trainees in North America, Europe, Asia and Africa following the same course. The delivery medium is usually satellite television with the employees accessing from the workplace.

### 2 An international aim

A most interesting class of courses are those where the instructor, often a single enthusiast within the institution, designs and writes a course (usually Web-based) and makes it available globally to anyone with access. In many respects this 'early adopter' class of courses provides the model of best practice for true globalisation. The big difference obviously, is that these courses are free, are not accredited and usually 'one-off'. Because of their outstanding success, the instigators move on to institutionalising (accrediting, charging, marketing) them. One example has already been mentioned: the Principles of Protein Structures at Birkbeck (http://www.cryst.bbk.ac.uk/PPS/index.html). Others in this category continue to be offered in their original form: for example, Roadmap is a free, twenty-seven lesson Internet training course which 80,000 people in 77 countries had taken by email in 1994, and by 1995, the number had increased to 500,000. Spectrum Virtual University offers free courses about the Web and the Internet, as well as ‘focus groups’ for ‘hands-on’ learning in small exploratory teams (http://horizons.org).

A few courses specifically aimed at a global audience, which nevertheless are fee-paying, accredited and on-going, do exist, and many more are in the planning stages. See, for example, the Graduate Certificate in Open and Distance Learning by the University of Southern Queensland (http://www.usq.edu.au), and the UKOU’s Masters Degree in the same subject (http://www-iet.open.ac.uk/iet/iet.html).

### 3 A multi-cultural course content

There have for many years been twinning projects between universities in which one (usually a Western) institution develops a course or programme in conjunction with one or several (usually non-Western) institutions. Recently, the courses resulting from these collaborations have been delivered electronically. The Télé-université in Quebec has carried out this kind of course development with other French-speaking nations [29] for example, and many universities have long standing arrangements with institutions in South America, Asia and Russia.

A number of franchise arrangements also fall into this category – the core content remains the same, but the local institution adapts the material (by translation, by including local case study material, or by customising the length or degree of difficulty of the material). The resulting course is often of very high quality, containing the best of both worlds – an international perspective with a grounding in local or national concerns. The UKOU has large programmes in Eastern Europe, Singapore and Hong Kong which demonstrate this quality of globalisation [27].

Finally, there are a range of collaboratively developed courses across all areas of the curriculum which encompass the perspectives of different cultures and approaches to the discipline. Gayol describes the activities of NADERN, the North American Distance Education and Research Network [12] and the ‘What is Europe’ course authored by several European institutions is another example.

The shortcoming of most of these programmes is that the student body remains national, and therefore does not benefit from interaction with students or teachers from a mix of countries.

### 4 Global support structures

Very few universities have developed truly global support structures; the training programmes within globalised industries are probably closer to realising this aspect of global education. Whilst the Internet (in the form of electronic mail) provides a relatively trouble-free mechanism for administration, sending in assignments and receiving one-to-one tutoring, none of these features scale up to handling large numbers of students. Indeed, what we find most commonly, is that any course or programme operating globally, is only doing so with very small numbers of students (typically under 100, and usually closer to 20). Frequently the course is administered and tutored by the course author – what can be categorised as a one-man band!

In many respects, the technology is not in place yet to manage large-scale global teaching. The aspects of support required in global courses include:

- a system for many-to-many communication, such that students can interact not only with the tutor, but also with other students, and is accessible at reasonable speeds and reasonable cost on a global level
- a system for handling the electronic submission of assignments, both for the purposes of annotating, commenting and marking by the tutor, but also for recording, monitoring and storing by the accrediting institution
- a system for marketing courses and programmes, handling registrations, fees and queries from around the world, preferably electronically.

Examples of these systems operating more or less successfully do exist, but certainly not on any large scale. Monash University has a system for managing the electronic submission of assignments [17]; a number of universities use various computer conferencing systems on an international level for many-to-many communication [13] and a combination of Web pages, Web forms and email, allow many on-line courses to be advertised electronically and for perspective students to register and obtain further information. [7]

While the number of truly global courses is quite small, there are many global activities and events taking place within the higher education and training sectors. These can be categorised as:

- global research projects, in which participants communicate, exchange data and draft joint reports and books electronically, using simple email, audiographics, videoconferencing and CUSeeMe on the Internet
- consortia development activities, in which perspective partners develop mutual understandings which are intended to lead to global educational partnerships, or, as with the Globewide Network Academy satellite videoconferences, which foster a climate for global educational activity
- conferences held electronically, using the Web, computer conferencing, listservs or videoconferencing, either as a substitute for any face-to-face meeting or as a method of extending access to those unable to attend physically (two examples are Teleteaching 96, Virtual University Web-based discussion at http://www2.openweb.net.au/TT96University/, and [1]).
- global programmes in which the administrators and/or the tutors communicate electronically, but the students do not
- global videoconferencing in the workplace for such activities as presentations to all employees, for product promotions, job interviewing, or international project work.

The point is that these activities promote understanding and acceptance of telecommunications media and develop relevant technical and social skills in handling global communications.

## Global institutions

What I have presented so far is a picture, not of a revolution in the higher education sector, but more of a sliding scale from ‘traditional’ distance education, to international distance education, to on-line courses to virtual universities and finally edging to globalisation. Most of the operations are piecemeal, consisting of a good deal of flag-waving from senior staff, or idealistic visions of new educational paradigms from educational technologists, or financial officers rubbing their hands in expectation, but at the end of the day, a very few academics actually delivering something that could be called global in parts.

I turn now to the question of who is leading the globalisation movement. One response can be given with certainty: it is not the established institutions! This is not surprising considering their investment in physical buildings, their academic traditions and their self-imposed guardianship of quality, standards and research. One then looks to the newer institutions as being more flexible, more in need of making their mark and more desperate to find sources of income. Certainly this sector has adopted computer technology more wholeheartedly and is experimenting more readily with various forms of distance education. However, it faces many internal barriers:

- lack of appropriate staff training in order to teach with new technologies
- lack of an appropriate reward structure to attract staff to adopt new methods
- lack of resource to fund the development of global courses.

In fact, many of the 'one-man band' global courses do come from institutions (usually teaching face-to-face) where one or two early adopters are enthusiastically going ahead with little institutional support and much hard work, simply because they are committed to the principles or enjoy the actual practice.

The distance teaching universities are obvious candidates for leading the field in the globalisation movement. While the UKOU is one of the most prominent, many distance teaching institutions whether dedicated or dual mode, have some partially global courses – franchising systems, arrangements with one or two other countries, or a few Web-based courses being piloted to test the global waters. Nevertheless, these institutions also have entrenched attitudes, bureaucratic procedures and general inertia to overcome before launching themselves as global institutions. Re-engineering an educational institution to teach in new ways, with new media, to new kinds of students is not an overnight task.

If one institution finds it difficult to gather the necessary resources, train its staff and provide whole programmes rather than odd courses, what about consortia? In fact, many of these exist both nationally and trans-nationally to share delivery technologies, course development, accreditation mechanisms, marketing and registration procedures and programme planning. Some of these are well-known, such as the National Technological University; many others are still in the early stages of consolidation and have not established a reputation. Without a doubt, consortia of all kinds will become the norm in the long term development and large scale build-up of global education. The complexities of teaching, administering, supporting and developing global programmes makes this an obvious solution for the university sector to adopt in responding to the pressures for globalised education.

Another, slightly different solution has appeared very recently, arising from the university sector but based on the new cyber-speak. These are the virtual universities, designed for a global platform and operating purely electronically. Some are idealistic and visionary in aim, such as the Globewide Network Academy (http://uu-gna.mit.edu:8001/uu-gna/index.html), although this originated in 1994, Spectrum Virtual University (http://horizons.org) and Virtual Online University (http://www.athena.edu); others are avowedly 'for profit' such as Phoenix University (http://www.uophx.edu) and IMLearn (http://www.imlearn.com). The scale of these operations is variable: many of them on investigation prove to be working from one office; others have significant numbers (e.g. 2000 registered for on-line course at Phoenix University), although very few students will be non-nationals. On the whole, these are not universities in the commonly accepted sense of the term: they borrow academics from other institutions rather than fund their own established full-time faculty; they do not cover a full range of discipline areas; they do not fund research programmes and they do not support what is usually called an academic environment. Nevertheless, they provide courses which people want; they are capitalising on the phenomenal growth of the Internet and are trail-blazing the global pathways for others.

There exists one final model which might be said to be leading the field: the new educational providers. This group consists of organisations whose primary business is not, or has not been, education. Often they have services or products which have now become central to the delivery of global education. The obvious examples are the telecommunications providers, whether satellites, cable, telephone or combinations. Other examples come from the computer and software industries. The advent of these new providers offering professional updating programmes, adult education courses, life-long learning opportunities and just-in-time training resources to what has always been the market monopolised by universities and continuing education units, has caused ripples of alarm in all but the most un-reconstructed universities [18]. The natural advantages which these new providers have over the established education sector are:

- in many cases they control the means of delivery
- they do not carry the academic 'baggage' of established institutions and are free from their bureaucratic and entrenched attitudes to education
- as 'green field' sites they can set up systems geared specifically to a global market, rather than having to adapt existing procedures
- they hire content specialists from traditional universities, but do not suffer the expense of supporting a research programme from the teaching revenues.

These points raise many questions about quality, accreditation, and ultimately the notion of graduate-ness and the purpose of universities. They are not issues specific to global education, nor are they new problems to the education sector. Several examples include:

- The Global Telecommunications Training Institute is a brokerage service of distance learning courses to supply training on-line for staff of telecommunications companies worldwide. It is based in Geneva, and is currently in the planning stages. (http://www3.itu.ch/VTC/gtu_gtti.htm)
- Microsoft Online Institute (MOLI) is an on-line education programme which at the moment is used only for promoting Microsoft product training and certification. Trainees download course materials from the Virtual Campus Environment, and can engage in real time discussion and feedback sessions with the tutor and other participants. The system is built around Microsoft Network which ships with Windows '95. (http://www.microsoft. com)
- Motorola University, Schaumburg, Il is part of the growing trend for corporate universities to move to the Virtual Campus model, by making strategic alliances with universities and on-line providers. For example, using the engineering courses offered by the National Technological University (NTU), Motorola has over 300 engi-

neers in North America and Asia following masters degree programmes. By acting as NTU's main customer in Asia, they made it possible for NTU to establish an Asian service, and now other global companies such as Hewlett-Packard have joined, making it possible to justify one full transponder devoted to delivering NTU programmes in Asia. (http://www.mot.com/)

- Mind Extension University is founded by Glenn Jones to extend equality of opportunity for higher education to those unable to attend on-campus classes. Using a satellite and cable television network dedicated to distance education, it offers many courses and degree programmes through 30 regionally-accredited universities and education providers. (http://www.meu.edu:80/meu/)

## Technologies for teaching at a distance

That computer technologies change and evolve more quickly than books about them can be published, is obvious fact. But educational use of computer and telecommunications technologies, or at least widespread take-up by institutions, is much slower, so that it is possible to discuss current delivery technologies and speculate about trends with some degree of certainty about the direction, if not the details, of global education delivery media. As I mentioned earlier, it is distance education, as presently practised usually on a national scale, which is the forerunner and first pioneer of global education. It therefore makes sense to study the technologies in use today, in order to assess the benefits and limitations of various media for the global education of tomorrow.

There are three broad categories within which current technologies can be divided:

- text based systems, including electronic mail, computer conferencing, real time chat systems, MUDS/MOOs, and many uses of the World Wide Web
- audio conferencing and audio extensions such as audiographics, and audio on the Internet
- videoconferencing, one way and two way, video on the Internet with products like CUSeeMe, and other visual media such as video clips on the Web .

The implication of this list is that text, audio and video are discrete media. While this is partially true today, the evolution of all these systems is towards integration – of real time and asynchronous access, of resource material and communication, of text and video.

I have not included multimedia CD-ROMs in this list. Although they combine elements of text, audio and video and have tremendous potential as stimulating learning resources, they lack the main ingredient of person-to-person interaction. Furthermore, they are difficult and costly to update, and problematic as a global distribution medium. All of these disadvantages of CD-ROMs are overcome, however, in my fourth technology, which is the rising star of global education delivery:

- the World Wide Web, which integrates text, audio and video, both as pre-prepared clips and as live interactive systems, both real time and stored to be accessed later, and furthermore provides text-based interaction as well as access to educational resources of unprecedented magnitude.

I will discuss each of these four media in turn, looking at the main educational advantages and disadvantages and considering their potential for global course delivery.

### Text-based systems

Without a doubt the most commonly used technology for communicating with students at a distance, is computer conferencing. Text-based interaction, whether many-to-many in conferences, or one-to-one in electronic mail, is practised at most institutions of higher education, whether students are geographically remote, or actually on campus. In fact, with the change towards the new majority (students who are older, or have some kind of part-time employment, or have family commitments or other barriers to attending campus full-time), many face-to-face teaching institutions use text-based interaction as a means of communicating with students, thereby reducing their dependence on physical attendance on campus at specific times. The term 'close-distance education ' is used to describe this new phenomenon.

Some institutions use standard electronic mail systems (which include the facility for sending messages to a group) to communicate with students at a distance. Those accessing from abroad usually use the Internet; those living locally use a modem over telephone lines. The primary use is for students to ask questions of the tutor, but an additional use is the electronic submission of assignments, as an attachment to a mail message. This is the simplest and most accessible of all the telecommunications technologies, with the possible exception of FAX.

More commonly in distance education, a proprietary computer conferencing system is used. FirstClass is a very successful product amongst educators, and Lotus Notes is common particularly in Business Schools and in training organisations. Microsoft Exchange is a new system which is expected to have very widespread use. Several others are also popular, and a number of institutions have designed their own, with a purpose-built interface for the facilities they offer. Computer conferencing systems allow students on one course to share discussion areas, to have sub-conferences for small groups, and to have easy access to all the course messages throughout the length of the course. Computer conferencing systems are slightly more complex than email: they may require the student to have client software; a faster modem may be necessary or at least highly desirable; and in the case of Microsoft Exchange, a personal computer of a particular specification is necessary.

MOOs are a text-based virtual reality development from MUDs, an acronym for Multi-User Dungeon, a class of programs for playing dungeons and dragons over a network. From these real time, text adventure games evolved the MOO, which stands for MUD, Object-Oriented. Unlike conventional chat rooms, MOOs allow the manipulation and interaction with cyber-objects as part of the communication with other people. When integrated into the learning experience, MOOs can be used to create an environment in which students interact more directly with the course ideas than they would in an unstructured discussion.

Text-based systems can be divided according to whether they are primarily synchronous or asynchronous in use. More accurately, while the technologies usually support both, in practice, one or the other is the primary intended use, and this influences the design of the interaction features. Most text-based communication systems are used primarily to support students (with the contents of the course delivered through some other medium); however, some educators run 'on-line courses' in which the primary content of the course is the discussions and activities taking place amongst the students. As this technology has been in use on a relatively large scale for nearly ten years, and as some of these uses have involved students in many different countries, it is the most obvious area to study for issues arising from global education.

One of the major advantages of text-based media is that they facilitate interaction for those using their second language. Most people are better able to write in another language than speak. Furthermore, asynchronous systems allow time for reading messages slowly and composing a response with the aid of a dictionary. Not surprisingly, there are a range of very successful asynchronous text-based programmes at an international level for second language teaching. Usually they provide natural language practice with mother-tongue speakers, which is much more engaging and profitable educationally than artificial classroom practice.

Another primary advantage of any text-based system for global education is that many people world-wide can access them using a personal computer and telephone line from their home. In fact, although there are a few uses of real time chat or even computer conferencing in which students go to a study centre, campus computer room or training centre, most uses of these systems are from the student's own machine (whether at home or in the workplace).

My third advantage of text-based systems is rather more contentious. Much has been made of the equalising effects of textual communication – the concentration on what is said rather than who says it. While it remains the case that the disabled and the disadvantaged can participate without the usual judgmental reactions, text-based systems do not remove bias and 'advantage', they merely shift it around a bit. Clearly those who have regular access (for example, from both work and home) or have no concern about the cost of access, are advantaged in terms of being able to participate in discussions more easily than those who have restricted access and cost considerations. Furthermore, those who have good writing skills tend to dominate by the very quality of their messages, in that less literate participants defer to them or simply are deterred from putting in messages themselves. Finally, the openness of these systems to anyone, anytime to make their opinion known, to respond to other viewpoints and to engage in dialogue, is true in theory, but in reality, messages not following the main thrust of the discussion (i.e. keeping up with the ongoing conversation) tend to be ignored. Abuses of the openness of the system, such as flaming, harassment, and anti-social behaviour, have driven participants away and generally damaged both the image and the value of text-based communication (although this is much less prevalent in educational than social uses). So what was originally hailed as a new democratising medium, inherently more open than other modes of communication has been shown in practice over time to be as flawed as the human beings who use it. Nevertheless, for some groups of people, text-based interaction allows access to education in a form ideally suited to their situation.

## Audio systems

Straight audio conferencing using ordinary telephone lines is a 'low-tech' solution to supporting students around the world, due to the near ubiquity of the telephone. Many print-based distance education programmes use audio conferencing to help motivate students, and it has also been used for small group collaborative work at post graduate level [4]. Nevertheless, there are few uses of this technology in group discussion mode (as opposed to simple student to tutor phone calls) in international programmes of distance education. Audio conferences are difficult to manage with more than half a dozen sites, although it is possible to increase the number of participants by having groups of students at each site.

An extension of pure voice interaction is audiographics: voice plus a shared screen for drawing or sharing pre-prepared graphics. Whilst this technology has had more extensive use in distance education, and examples of it being used between two sites in different countries do exist, I know of only one international, multi-site use in an educational application [16]. As with audio conferencing, audiographics use with more than two sites requires an audio bridge to connect all the lines together. There is no technical barrier to doing this internationally, except cost. Some systems use the Internet to carry the data; others combine both voice and data on an ISDN line.

ISDN, which stands for Integrated Services Digital Network, is a set of international switching standards to which world-wide telecommunications providers are recommended to adhere. However, to date there is no universal agreement regarding the standards. As an integrated digital network, it can be used for more than one service, and in most educational contexts, this involves telephony (voice) and data (graphics or moving image).

Audio over the Internet is a developing technology which a number of educational institutions are trialing. RealAudio, for example, is a product which allows real time lectures on a global scale (http://www.realaudio.com/), but international Internet connections are too slow to permit multi-way audio interaction. Many distance education systems have involved sending audio cassettes out to students through the post. With audio on the Internet products like RealAudio, it is possible for large numbers of students around the world to access these 'broadcasts' in real or delayed time.

The UKOU is developing the use of RealAudio to deliver a global lecture and discussion session with a series of experts. The interface which has been developed on the Web to support the events, is called the KMi Stadium, and provides facilities for slides associated with the lecture. Plans are in hand to develop a range of other tools to provide a greater sense of a global audience: indications of how many concurrent participants there are, buttons to show agreement or disagreement with the lecturers ideas etc.

> KMi Stadium is an experiment in very large scale telepresence. We are enhancing existing media and developing new media intended to give participants a sense of 'being there' at events of all kinds, including master classes, performances, tutorials, conferences, workshops, ceremonies, parties, jam sessions, recitals, industrial training sessions, university lectures, training on demand, town hall meetings, debates, and so on. For us, 'being there' is not primarily about Virtual Reality per se, although VR can certainly help. Rather, it is a question of capturing the right participative aspects of audience presence (such as applauding, laughing, shouting, asking questions, whispering to neighbours) and harnessing those aspects to convey

> as much of the mood of an event as possible. We are interested in telepresence at both live events and on-demand replays, because we believe that both types of event are enhanced by a sense of the presence of others. (Eisenstadt, http://kmi.open.ac.uk/stadium/)

## Videoconferencing

Some educators feel that video is not necessary in supporting students at a distance, and that audio, especially audiographics works better because it concentrates attention on content rather than distracting the learners' attention with the visual image of the speaker. For them, the significantly higher cost of providing video is not justified by the educational benefits. Others feel that we live in a visual age in which it makes no sense to restrict the learner to audio exchange. Video, when well used, contributes to the motivation of the student, makes the learning environment more social, and facilitates the delivery of exceptional learning materials in almost every area of the curriculum (see [15]).

One way video (with two way audio) systems have widespread application in North American distance education and training in national and international companies. Many of these systems use satellite delivery to extend coverage. The educational paradigm of most programmes is the lecture at a distance, with students watching either from smaller colleges, in the workplace, or (most commonly) later on recorded video at home. A very great deal of distance training is carried out by videoconferencing, some of it internationally.

Two way videoconferencing over ISDN is beginning to take over from the one way systems, and a number of multi-site applications are in use, for example, in Australia [14]. Global interoperability of ISDN systems is still problematic due to the lack of agreement about standards, but international point-to-point and even multi-point videoconferences do take place daily in the workplace and are relatively frequent occurrences amongst educational institutions, although usually not directly for teaching. As with international audio conferencing, the barriers to extensive use are primarily financial, not technological.

PictureTel has designed a videoconferencing system called Socrates specifically for the education market (http://www. picturetel.com/). Socrates is an integrated presentation station with a touch sensitive screen which allows the lecturer to see, on one window of the lectern, exactly what is being shown to students locally and remotely, and on another window, to preview the visual aids prepared for the lecture or to browse the remote sites.

Streaming video on the Internet is another developing technology, technically feasible today, but restricted by the bandwidth available internationally. In theory this allows the image to be downloaded by remote sites in real time. What is more realistic today, is video clips integrated with text-based material, to illustrate and highlight, rather than to deliver large amounts of course content.

## The Web

There is little doubt that the Web is the most phenomenally successful educational tool to have appeared in a long time. It combines all the media described above: text, text-based interaction, audio and video as clips, and, with somewhat less robustness, multi-way interactive audio and video. Its application in global education is unquestioned. Although access to the Internet is hardly universal, and large segments of the global population are more remote from access to it (whether through cost, or through unavailability at any cost) than they are to print and post based systems of distance education, nevertheless, vast numbers of people world-wide do have access, many from their home, and this access is growing exponentially.

The Web is merely a collection of protocols and standards which define access to information on the Internet. The three defining characteristics of the Web are:

- the use of URLs (Universal Resource Locators) which provide the addressing system
- the HTTP standard (Hypertext Transfer Protocol) by which the delivery of requested information is transacted
- the development of HTML (Hypertext Markup Language) through which links between documents and parts of documents are made.

Fundamental to the nature of the Web is its client-server architecture, whereby the client (Web software residing on the user's machine) requests a particular document from a Web server (a program running on a computer whose purpose is to serve documents to other computers upon request). Having transmitted the documents, the server then terminates the connection. This procedure allows servers to handle many thousands of requests per day.

Exciting new Web developments which add features useful for students and functions appropriate for course delivery are announced regularly. Some examples include:

- functionalities for supporting animation effects, thus making documents more dynamic
- facilities for handling forms, and input to forms (useful for course registration, evaluation, and other kinds of questionnaires)
- support for presenting tables, footnotes and mathematical symbols
- features to simplify page development and editing
- improvements to the search facilities
- greater functionality to the communication systems linked to Web pages.

I have referred to the possibilities of audio and video on the Internet. One of the mechanisms for implementing this is through the programming language called Java and the HotJava browser:

> HotJava interprets embedded application <APP> tags by downloading and executing the specified program within the WWW environment. The specified program can be an interactive game, animation or sound files, or any other interactive program. Also, when a file or application requires particular viewers, such as for video, Java anticipates this and calls these viewers up automatically. ([6], Interface 3)

Now that it is possible to download programs from the Web along with data, and to receive the appropriate software to handle the program automatically, the institution wanting to deliver course material can manage the maintenance and updating of any software required for the course. The student no longer needs to struggle with the installation of massive packages, and, furthermore, can use a relatively low cost machine – even a portable.

## Synchronous versus asynchronous distance education

As is apparent in this description of different technologies for delivering education at a distance, some of the systems rely on real time interaction, while others can be accessed asynchronously. This difference has major implications for the design and delivery of distance education, as well as for the study requirements of the learner. There are advantages to both forms and in the end, personal learning styles and the larger educational context determine what is most appropriate.

Collis [6] identifies four basic patterns of communication in the learning environment:

- telling, which in the asynchronous mode has traditionally been the printed text, but increasingly is taking on a new form in hypertext Web pages, although many conventional linear texts, articles, reports and original works are also available on the Internet
- asking, which can take place through text messages via email or computer conference, through real time text chat systems, or through any of the audio systems
- responding, which also is supported in delayed time through asynchronous systems, and much more immediately through synchronous systems
- discussion, or collaborative work amongst small groups of students, which can take place over an extended time period through computer conferencing, or for much shorter periods via audiographics.

The following list details the major benefits of each mode in an educational context.

### Asynchronous delivery

There are four crucial advantages to the asynchronous media and I have arranged them in descending order of significance:

- flexibility – access to the teaching material (e.g. on the Web, or computer conference discussions) can take place at any time (24 hours of the day, 7 days a week) and from many locations (e.g. oil rigs)
- time to reflect – rather than having to react 'on one's feet', asynchronous systems allow the learner time to mull over ideas, check references, refer back to previous messages and take any amount of time to prepare a comment
- situated learning – because the technology allows access from home and work, the learner can easily integrate the ideas being discussed on the course with the working environment, or access resources on the Internet as required on the job
- cost-effective technology – text based asynchronous systems require little bandwidth and low end computers to operate, thus access, particularly global access is more equable.

### Synchronous delivery

There are four equally compelling advantages to synchronous systems, although I am less confident of general agreement about the order:

- motivation – synchronous systems focus the energy of the group, providing motivation to distance learners to keep up with their peers and continue with their studies
- telepresence – real time interaction with its opportunity to convey tone and nuance helps to develop group cohesion and the sense of being part of a learning community
- good feedback – synchronous systems provide quick feedback on ideas and support consensus and decision making in group activities, both of which enliven distance education
- pacing – synchronous events encourage students to keep up-to-date with the course and provide a discipline to learning which helps people to prioritise their studies.

There are many distance teaching programmes which are entirely asynchronous (for example, those using print plus computer conferencing, or those using the Web for both course delivery and interaction), and others which are (almost) entirely synchronous (for example, those using videoconferencing for delivery and interaction). However, the trend is very much towards combining synchronous and asynchronous media in an attempt to capitalise on the evident benefits of both modes. The various permutations of media use and the amount of synchronous interaction included are almost as varied as the number of institutions providing distance education. Here are just a few examples:

- University of Twente, the Netherlands, an advanced level course about telelearning developed and taught by Dr. Betty Collis, consisting of some face-to-face meetings as well as extensive use of the Web for resource material, for collaborative activities and for discussion. In 1996, for example, the course had two students participating from outside the Netherlands, and all 33 students operating in their second or third language. (http://www.to.utwente.nl/ism/online96/campus.htm)
- The Open University of Catalonia, Spain currently offers courses to over 200 students in the Catalan region, beginning with programmes in business studies or educational psychology. Delivery mechanisms include print, multimedia CD-ROMs, videos and tapes; support media include electronic mail and study meetings held twice a semester in resource centres linked up by fibre optic cable for videoconferencing. (*The Financial Times,* October 3, 1995)
- Nova Southeastern, Florida, has an M.S. and Ed.D programme in instructional technology and distance education, using electronic mail and bulletin boards, and audio conferences and face-to-face 'summer institutes'. They claim to have graduates in 50 states of the US and 35 foreign countries. (http://alpha.acast.nova.edu/)
- George Washington University, Washington D. C. is a member of the Mind Extension University (ME/U), a cable television network dedicated to distance education. The universities affiliated with ME/U offer undergraduate and graduate courses in a range of subjects, using cable and satellite television and text-based asynchronous conferencing. Students outside the US are sent video recordings. (http://gwis.circ.gwu.edu/)
- The Fuqua School of Business, Duke University, North Carolina, offers a global executive MBA using multiple international programme sites for residential meetings, as well as email, bulletin boards and streaming audio on the Web. Desktop videoconferencing and CD-ROMs are also used occasionally. (http://www.fuqua.duke.edu/programs/gemba)

- CALCampus, New York is an international on-line learning centre offering high school and vocational courses through the Internet. Two formats are provided: directed independent study (using text-based material sent electronically or by post) and live format (using real time chat systems). (http: //www.calcampus.com)
- School of Industry and Technology, East Carolina University, has an M.S degree in Industrial Technology using real-time chat, email, listservs, the Web and CUSeeMe interactive video. (http: //ecuvax.cis.ecu.edu)
- The Virtual College, New York University, offers a small number of courses using digital video and video for Notes software from Lotus, which can be viewed in real time or downloaded for local storage and viewing. [24]
- The Sloan School of Management, MIT, Massachusetts has combined satellite videoconferencing (to Singapore and China) and Web materials and email communication with MIT students and faculty. [10]
- OnLine Education, University of Paisley, Scotland, supplies course materials both in hard copy and on a computer, which along with a modem and printer are delivered and set up in the student's home. Live events take place both face-to-face and by teleconference, and students (in Hong Kong) communicate with their local tutor and with students in Scotland by email. (http://www.online.edu/online/online.htm)
- Birkbeck College, part of London University offers a global Web-based course on the Principles of Protein Structures which includes the use of a MOO to provide real-time interaction. (http://www.cryst.bbk.ac.uk/PPS/index.html)

It would be difficult to overstate the importance of flexibility to most distance education students. The pressures of modern life are such that most people demand programmes which allow them to fit their studying in and around many other commitments. Nonetheless, it is equally the case that most people find synchronous events very beneficial for their learning. Obviously synchronous events raise even more problems in global education than in asynchronous distance education, because of the vast differences in time zones world-wide.

Even though global videoconferences are held with some participants accessing at 'unusual' times, other solutions involve something which might be called 'fast asynchronous'. For example, the University of Phoenix operates an on-line text-based interactive system which is tightly structured to provide daily flexibility but pacing and feedback similar to synchronous teaching:

> Each of your class meetings and the accompanying class discussions will be spread out over a full seven days, giving you the weekends to get much of your reading and papers completed. As discussions build throughout the week, it is important to visit your classroom at least five days out of every week, but at times you choose and that best suit your individual circumstances. Before each week of class begins, your instructor will typically submit a lecture and review the assignments for the upcoming week. Then, throughout the week, he or she will be involved in the class discussions – providing expertise, guidance, feedback and answers to questions.
>
> At the conclusion of each week, you will be asked to provide a summary of the concepts covered. Based upon your summary and contributions to the class discussions, your instructor will let you know how you are doing and respond to any issues or concerns you might have. ([7] p. 328)

Another solution might be called 'pan-synchronous' to describe global events such as the KMI Stadium lectures, which many will access synchronously, yet others can access individually or form groups to participate in on-demand replays anytime thereafter.

## Merging synchronous and asynchronous learning

Much of the above discussion implies that learning itself happens synchronously or asynchronously. In fact, what we have been describing are tools, materials and events which aid the learning process. What is at issue is how to meet students' needs, both for considerable flexibility in when and from where they access course material, as well as for the galvanising power of real time events to keep them on track. The following scenario by Collis provides a vision of how technologies are converging to satisfy both these needs:

> With convergent technologies, this means that the subscribers, through their respective learn stations, may be able to see and talk to each other in real time; to review a real-time discussion that occurred earlier and perhaps make a non-real time follow-up contribution; as well as to participate in familiar asynchronous computer conferencing discussions. And even the familiar asynchronous computer conference will benefit from the possibility of multiple representational forms through the learner station – the tele-learner may choose to send her contribution by text, by voice, or by video clip; any combination of forms can be stored as a incoming contribution to an asynchronous discussion, waiting to be read, heard, or watched when the other participants come to participate in the discussion. ([6] 10–10)

What is so remarkable about the Web, and undoubtedly accounting for its popularity with such a diversity of users, is its capacity to bring together a range of otherwise disparate technologies, opportunities for designing courses, and competing providers of resources for learning. Its versatility can be summed up in the notion that anyone can publish and broadcast on the Web and thus reach large numbers of intended and unintended receivers. Users can choose to access learning materials, to communicate with fellow learners or to prepare their own personal pages. It supports real time personal interaction with its high telepresence through visual and auditory connection, yet it also provides outstanding facilities for asynchronous resource sharing and communication.

Regardless of how technology evolves in the foreseeable future, the Web has definitely set the benchmark against which any new media for global education will be measured.

## Global technologies here and now

If the Web is so powerful and so successful, and so appropriate for global education, why are other media still being used? I will outline a range of reasons which apply to current conditions:

### Inertia

Many institutions have been using other media for a number of years, have naturally built up professional expertise amongst the teaching staff, have developed courses to work with those media and have attracted a market to fill those courses. These are persuasive reasons for remaining with the status quo, while the Web technologies begin to stabilise and the early adopters have begun to develop some indicators of best practice. These arguments apply particularly to the large numbers of organisations using computer conferencing. What will persuade them to move to Web-based courses is a conferencing system integrated with Web pages and offering the full range of facilities they have relied on in current proprietary computer conferencing systems. While Web-based interaction, similar to computer conferencing, is already available, the 'look and feel' of these systems is much less friendly and conducive to intimate, collaborative, and small group interaction than current conferencing systems. This situation will definitely have changed within 12 to 18 months, and the added advantage of using the Web for delivery of course material, is bound to prevail.

### Approach to teaching

Studies show that the approach to teaching of those currently offering on-line courses by computer conferencing is very much a student-centred one [2]. The environment of on-line text-based interaction, especially in asynchronous mode, lends itself to a facilitative teaching role, rather than to a didactic or authoritarian model. On-line courses usually centre around collaborative activities, simulations and problem-based learning. This paradigm of guided discovery learning is the most obvious direction for Web-based courses as well, because of the combination of interactive multimedia capability and the many-to-many communication facilities, most of which will be used in asynchronous mode for some time to come. Consequently, the earliest migration onto the Web will be from those currently running on-line courses via computer conferencing, and perhaps to a lesser extent via real-time chat systems.

Most of the courses currently operating over videoconferencing systems are founded on an expository approach to teaching. One of the key advantages of this medium particularly to large-scale adopters is that it does not disturb the traditional model of lecturers on the face-to-face teaching campuses [15]. While the introduction of remote students at other sites does have some effect on the teaching strategy (the need to acknowledge the remote sites while lecturing, the extra work involved in preparing visual teaching materials) and requires administrative and technical support in managing students at other sites, on the whole the delivery and presentation of the course material need not alter. Translating a lecture-based course to the Web, even assuming that clips of lectures were included, would require a significant re-engineering of the course, from an essentially didactic model to a resource-based model. Although many lecturers will welcome the opportunity to make this transition from videoconferencing to the Web, some of those in areas of the curriculum which are based on the accumulation of factual information and understanding, will find their old approaches to teaching much more difficult to adapt.

### Development costs

Apart altogether from entrenched approaches and valued expertise, there is the cost of developing Web-based courses. While it is common to hear academics talking glibly about putting their lecture course on the Web, and it is sadly all too common to find teaching materials designed for a different delivery medium, 'dumped' on the Web, in fact it is generally accepted that good Web materials need to be tailor made for the medium, and should exploit at least the graphical if not the audio and video capabilities of the medium. Course content needs to be re-thought for the hypertext structure, for the possibility of collaborative group work, and for the opportunity of interaction with the course materials. As with CD-ROM, this requires a team approach, because the skills demanded range from content expertise and distance learning educational technology, to graphical design and broadcast skills.

It will take time for sufficient resources to be accumulated to produce high quality programmes on the Web across a range of disciplines. Nevertheless, many of these are in progress, and new courses are being offered on the Web every day.

### Administering global courses

Systems such as PerformTrac from Computer Knowledge International, have been developed to provide basic administrative functions for computer or telecommunications-based courses, particularly those in the training field using CBT (computer-based training). In addition to on-line registration, scheduling and testing, the system allows the institution to determine how many trainees are accessing the CBT courses, how much time each individual spends working through the material and whether they passed the test at the end.

The kind of tracking which is important in the education sector, is slightly different. Tutors using text-based interactive systems need to know how often their students are logging on, whether they are contributing regularly, and who has read particular messages. This information is useful both on a daily basis throughout the course, and at the end to assess the overall success of the course. If students are being marked on the quality of their contributions to discussions, it is important for the tutor to be able to call up all the inputs of an individual student. Most Web-based conferencing systems do not provide this kind of support; some proprietary systems do have at least some of these features. Email and listservs of course have none of these.

## Conclusions

I have provided an overview of the present state of global education and discussed the delivery media currently in use on distance education courses, dividing them into four categories according to whether they are based on text, audio or video. I have described the ways in which the Web integrates all three, so acting as the fourth category.

There is no perfect medium however, and I have tried to highlight the primary advantages and disadvantages of these systems, based on the often conflicting needs of learners.

While it is still appropriate to talk about synchronous and asynchronous systems, this difference is falling away, as new developments aim to integrate the best of both worlds. The Web is the main technology to which all the others are converging, and its success derives from the fact that it can be 'all things to all people'. Except of course, if you do not have access or are never likely to be able to afford it. There will continue to be a place for 'lower tech' systems such as computer conferencing and electronic mail, and the length of this period depends on how the Internet continues to be funded in the future. Equally, there will continue to be a place for distance taught courses, operating globally, but not using any form of computer or telecommunications technology. All of these technologies, even those which use unsophisticated computers or low bandwidth, are less flexible, more costly and more complicated than the technology of the book and 'snail mail'.

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# The future of learning

BY ANTHONY W. BATES

**It is argued that the rapidly changing context of adult learning requires equally rapid and radical changes in teaching methods and methods of delivery, with profound implications for the organization of post-secondary institutions.**

**The multimedia WWW-presentation[1] on which this paper is based gives examples of some of the new teaching strategies that are being developed which are moving in the directions needed. As the technologies converge, and as access to computers and high-speed networks increase, it will become increasingly possible to provide learners with any course, any time and anywhere they need it.**

**It is critical for government, employers and educational institutions to work towards this goal, because in an age where knowledge and information is the basis of economic growth, those societies that successfully harness information technologies to the learning process will become the economic leaders of the 21st century.**

**This paper was first presented at the Minister's Forum on Adult Learning, Edmonton, Alberta, 30 November – 1 December, 1995.**

## Alternative futures

In a speech to a Labour Party conference in London on 17 October 1994, David Puttnam, the producer of 'Chariots of Fire' and previously head of one of Hollywood's largest film companies, is reported as saying [1]:

> "Multinational media companies are creating education programmes which leapfrog over schools and appeal directly to children and their parents ... one senior executive has predicted that educators would be paid more than film stars by the end of the century ... but this international 'edutainment' material would be driven by baby commercial values ... we risk losing out to a tidal wave of relatively low quality and certainly low cost material with just enough educational content to make it attractive to parents."

The market analysts have targeted adult education and training as an even more lucrative market. Is there an alternative to Japanese and American-originated 'low quality edutainment'? Is this the educational equivalent of cheap textiles and cars? Does it matter if multinational media organizations turn education into a business, and people buy their products?

While there are important roles to be played by private sector organizations in the education and training of adults, there are many reasons why a strong public sector presence is needed in adult education. However, in order to win and maintain public sector support, the public sector will need radical changes in its approach to teaching and learning. This will require a clear and shared vision of the future that we want, a determined and coordinated policy approach, and partnership between government, employers and labour, and the public sector institutions. This paper concentrates on a vision for learning in the future, and attempts to suggest some of the issues that need to be resolved in order to achieve such a vision.

## Technology change

Within the next 10 years, we will see the following important technological developments so commonplace that they will be found in the majority of homes and businesses in most developed countries:

- Integration of computers, television, and telecommunications, through digitization/compression techniques
- Reduced costs and more flexible uses/applications of telecommunications, through developments such as ISDN/fibre optics/cellular radio
- Increased processing power, through new micro-chip development and advanced software techniques.

These developments, all available or currently under development, will result in a single, integrated entertainment/communications/learning 'box' in each home and business. This will provide a much wider range of applications than now available, such as television programmes and music, home shopping and banking, and education and training, all available on demand.

Multimedia, through the integration of high quality graphics, audio, video and text, and more powerful editing and authoring software, provides a major enhancement of computer-based learning. The costs of hardware and the cost of producing multimedia materials are also dropping rapidly. 'Stand-alone' computer-based learning will become even more powerful as artificial intelligence and virtual reality develop.

However, while 'stand-alone' applications of multimedia will continue to be important in education, a much more significant development is the application of high-speed multimedia networks for educational purposes. As well as the convergence of different media within a common computer platform, we are also seeing the convergence of the previously separate technologies and industries of computing, telecommunications and television. For instance, in April 1994, Stentor, an alliance of Canadian telephone companies, announced an $8 billion, 10 year initiative, called BEACON, that will bring broadband, multimedia services to 80 % – 90 % of all homes and businesses in Canada by the year 2004.

The implications for education and training are immense. Learning can be independent of time and place, and available at all stages of a person's life. The learning context will be technologically rich. Learners will have access not only to a wide range of media, but also to a wide range of sources of education. However, the speed and extent to which these new technologies are being developed and applied is both revolutionary and deeply challenging to established educational institutions.

## The need for vision

> *"If you don't know where you're going, any road will do."*
> The White Rabbit, in 'Alice in Wonderland' (Lewis Carrol)

The way educational technology is developing somewhat resembles the frenetic activities of the White Rabbit in 'Alice in Wonderland'; because it does not seem to know where it is going, any road will do. Educational technology applications though should be driven by our vision of education and training in the 21st century. It is necessary to develop a shared vision of what we want the education and training system to achieve. That vision should take into account the potential of technology, but not be driven solely by what is possible technologically; what it can do may not be what we want it to do.

[1] *http://bates.cstudies.ubc.ca*

## The need for change

Those from the business sector are well aware of the global economic changes that are affecting our societies. One of these changes is the need for a much more highly skilled workforce to remain economically competitive and to sustain a prosperous society based on high wages [2]. This is making the training of the existing workforce a high priority, and this training must be continued throughout a person's lifetime. Investment in training is or will become as essential for company survival as capital or plant investment [3].

It is hard to quantify the need for 'workforce' training, but assuming that a person will need to re-train at least five times in a working life-time, and that such re-training requires the equivalent of three months full-time learning (probably a gross underestimate), then the capacity of the current education and training market, public and private, needs to be doubled [4].

This is because of increased demand from two sources. The first is from young people continuing into post-secondary education. This demand will continue to increase slightly in most developed countries (between 2 % to 5 % per annum for another 10 years at least) as more and more young people realise the importance of further education for their future prosperity. However, the major increase in demand will be from all of us in the workforce who need to continue learning if we are to stay employed, and if our employers are to remain economically competitive.

The requirements of this new market for learning are very different from those of the youngsters the system has traditionally served. Much of the learning in the workforce market will be initiated by individuals as part and parcel of their working and leisure lives. It will be informal (i.e. not leading to any formal qualification), self-directed, and piecemeal (broken into small chunks of learning, some as small as a few minutes a day, to some several hours in length). It will be driven as much by short-term needs as by any conscious plan of study. Thus, it will not be determined by some master instructor, but by the task at hand [5].

To see just how prevalent this kind of learning is already, just ask yourself how you have learned to use a computer. How much of this was due to formal training, with an instructor, and how much was picked up piece-meal by trial and error, with a bad manual, and help from colleagues? This is not to say that the learning would not have been much more effective if it had been structured and directed all through by a skilled tutor, but what drives such learning is not the control of an instructor but the needs and the motivation of the learner.

Employers, however, cannot rely entirely on the self-motivation of their employees. This kind of learning, although widespread and surprisingly effective, is not efficient. Management consultants have identified that most companies use less than 10 % of the capacity or capabilities of the computer technology in which they have invested. In blunt terms, most employees do not know how to use their machines properly. As companies increasingly look to higher skill levels from their employees, not just in computer skills, but in the broader skills of verbal and written communication, problem-solving and management, the employers themselves will need to take greater responsibility for making this kind of learning more effective, both to keep valued staff, and to increase productivity.

Traditionally, large companies have done this by establishing their own training centres and programmes; small and medium sized companies have relied more on 'out-sourcing' the training, to private training companies or to the public sector institutions. All of these methods, however, are labour-intensive, and any increase in such activities will lead to proportional increases in cost, at a time when companies need to be more cost competitive.

While employers will be faced with the need to keep their current workforce highly skilled and up-to-date in the field in which they are working, they will not be able to rely on the public sector to provide, free of charge, the training services they require, for several reasons. In many countries, the public sector institutions still concentrate mainly on pre-service education and training. Furthermore, governments in many developed countries are in serious financial difficulties; they have borrowed too much. Merely servicing the debt is taking away funds that otherwise could be used for public services such as education and training. At the same time, these governments have reached the limit of tax elasticity; the public is unwilling to increase the amount they pay in taxes. In other words, governments are expected to do more with less. Consequently, many public sector institutions are looking on private sector training as a cow to milk, rather than to feed.

Lastly, many employers and members of the public are growing increasingly critical about the quality of education being provided through the public sector. There seems to be a mis-match between the skills taught and the requirements of the labour market [6].

In some ways, this is an unfair criticism, since educational attainment of students in public schools has increased over the last 20 years; the problem is that the demands on the workforce have increased at an even faster rate [7]. For instance, production line workers need greater literacy skills today to deal with written instructions, manuals, etc.; they now need more than just an arm and a leg to operate the production machinery; they need intellectual skills as well. Similarly, with greater emphasis on teamwork and worker involvement and motivation, the level of communication and social skills required from managers and supervisors has increased. While a great deal of attention is being paid to the gap between the skills of those entering the workplace and the needs of employers, less attention is being paid to the much wider gap between the skills of those already in the workforce and the demands of the workplace. For instance, the older the worker, the lower the functional literacy level in most developed countries.

Another area which needs more attention is the gap between the way educational services are provided, and the needs of employers and working people. Working people are unable or cannot afford to give up jobs or move house to become full-time or even part-time campus-based students again.

### Jobs are changing

While countris like Canada and Norway will remain dependent on primary resource industries for their economic well-being, the sources of employment are rapidly changing, due to increased mechanization, the need to diversify to 'value-added' secondary industry (e.g.

furniture, paper), and the growth of new industries and services not directly dependent on the primary resource industries, such as communications, information technology, financial services and international trading.

Most of the new jobs are either in service industries, in companies employing less than 20 people, or require highly skilled specialists in the larger, resource-based industries, each 'new' employee often replacing many existing staff. Many of the new jobs are on a part-time or contract basis, with at least two-thirds of the new jobs going to women, and a majority of new jobs are relatively low-paid [8]. Nevertheless, nearly half the new jobs created require graduates or people with the equivalent of 17 years full-time education [9].

The traditional picture of work as a lifetime commitment to a particular trade or institution, with a secure pension at the end, applies to an increasingly smaller proportion of the population. In particular, secure middle management jobs of a general kind, requiring little or no professional or technical expertise, are disappearing rapidly. A very small proportion of the youngsters leaving school will find employment in the traditional resource-based industries as unskilled or semi-skilled workers; the majority of those already unemployed, and a good proportion of those already working in large companies or in primary-resource industries, need to be re-trained in the next few years.

The most significant development is that many of the new jobs will require a much higher level of skill than the jobs they are replacing, especially in management and resource based industries; people will retain existing jobs only if they are re-trained to higher standards; even for the majority of new jobs that will be low-paid and require generally low skill levels, training or re-training will be necessary, especially in basic skills, just in order to keep the job.

With respect to the skills needed in the workforce, these have been well defined by the Conference Board of Canada [10]:

- Good communication skills (reading/writing/speaking/listening)
- Ability to learn independently
- Social skills: ethics; positive attitudes; responsibility
- Teamwork
- Ability to adapt to changing circumstances
- Thinking skills: problem-solving; critical/logical/numerical
- Knowledge navigation: where to get/how to process information.

## Learning in the 21st century

Modern learning theory sees learning as an individual quest for meaning and relevance. Once learning moves beyond the recall of facts, principles or correct procedures, and into the area of creativity, problem-solving, analysis, or evaluation (the very skills needed in the work-place in a knowledge-based economy), learners need inter-personal communication, the opportunity to question, challenge and discuss. Learning is as much a social as an individual activity. However, for someone working in a small company, the nearest person with similar interests and expertise may be somewhere on the other side of the country, particularly in leading-edge technologies.

Learners will interact with their desk-top or portable workstations in a variety of ways, determined by the nature of the learning task, and their preferred style of learning in the work situation. These preferred styles will vary considerably, both within a single person, depending on the task, and, for the same task, between different individuals.

The learning context will need to encompass the following:

- Working alone, interacting with learning material (which may be available locally or remotely)
- Working collaboratively (and in an equal relationship) with fellow workers at different remote sites, either synchronously or asynchronously: both these modes are likely to be multimedia
- As an 'apprentice' or 'student', working with a more experienced worker, supervisor, or instructor
- As an instructor, supervisor or more experienced colleague for other less experienced colleagues.

The same persons may find themselves in each of these roles within a single working day. Learners will also need to be able to work from home, or from a work-site, or while in transit. They will need the following:

- Access to information (searching, downloading) from multiple sources in multiple formats
- Selection, storage and re-ordering/re-creation of information
- Direct communication with instructors, colleagues, and other learners
- Incorporation of accessed/re-worked material into work documents
- Sharing and manipulation of information/documents/projects with others.

Learners will need to access, combine, create and transmit audio, video, text, and data as necessary. If we take this as the design requirement, there is then a need to build systems that support this form of learning, both for formal and informal learning.

## New models of teaching

A number of factors are leading many Canadian post-secondary institutions to experiment with new information technologies for teaching. There is pressure from governments for greater efficiency, requiring institutions to take more students, while at the same time reducing funding. Another influence is the use by governments of earmarked funds for innovation (funds often established by holding back a proportion of 'regular' funding).

Another factor is the increase in student fees, leading to more and more students becoming part-time, in order to work their way through university. For instance, almost half the students in the universities, and two-thirds of the college students, in British Columbia now are part-time. Also, the trend towards life-long learning and the need for re-education and training for people already in the workforce is leading to a changing student population, with many more older students, working and with families, returning to post-secondary education (or in some cases never leaving it). These students need greater flexibility in the provision of learning, to fit it around their already busy and demanding lives.

It is not surprising then that many institutions are now turning almost in desperation to multimedia technologies as one possible solution to their increasingly pressing problems. It is from these often prototype developments that we will see some of the newer models of teaching and learning developing that will meet the needs of the changing adult learning market.

For instance, at the University of British Columbia, almost $4 million of its operating grant has been held back over the last two years by the government for an innovation fund for the university. The university has used approximately 50 % of this for investment in technology infrastructure, such as fibre optic cabling across the campus, computer networks in buildings, computer labs, networked servers, and video-conferencing facilities, and the remaining 50 % for technology applications. Almost all the application money has been used for projects (in each of the 12 faculties) using either World Wide Web or CD-ROM technologies.

This has led to a great deal of innovation across the 50 or so projects that have been funded in this way, and some important lessons have also been learned. Also, some lessons learned in other contexts, such as the use of technology for distance education, have also proved just as relevant for on-campus use of technology. I will describe briefly some of the lessons learned and some principles to apply when creating multimedia courses and products.

Two-way video-conferencing, using either compressed or full motion television, has been the major new technology used for delivery in many universities and colleges across North America. One of the most technologically advanced systems of video-conferencing operates between the University of Calgary and the University of Alberta. Video-conferencing has been slow to take off at UBC, but in 1995/96 one fourth year undergraduate plant sciences course was delivered in this mode, interestingly with the teaching originating from a community college, the University College of the Fraser Valley, because there were insufficient students at UBC in this specialist area (temperate fruit management) to justify a local teacher. Because of the excellent teaching technique and careful advance preparation of the instructor (Tom Baumann), this has been a very successful course. Video-conferencing has the advantage, from an instructor perspective, of not requiring a radically different approach from regular classroom instruction, and appears quick and easy to mount. However, unit costs are higher than regular classroom teaching, it does need considerably more preparation time, and students still need to be at a fixed place at a fixed time.

The biggest explosion in teaching technology in the last couple of years at UBC has been the WorldWideWeb (the Web), due to the development of relatively user-friendly hypercard technology such as Netscape. This enables ‘creators’ of materials to store primarily text and graphics on ‘screens’ that provide links to any other ‘screens’ located anywhere on the Web. Thus, by merely clicking on a highlighted or coloured section of text, a link can be made to another screen on another computer anywhere in the world.

The main use of the Web to date has been for accessing (and downloading) information. However, a number of institutions have started designing courses using Web technology. For instance, at UBC several courses were designed in 1995 using Web software and local servers for on-campus students. The first of UBC’s distance education courses using Web software is in Continuing Studies, which began offering a course ‘Mastering Cyberspace’, primarily aimed at people who want to use the Web for business purposes. In January 1997 UBC will deliver several Web-based credit courses to students off-campus.

Netscape software lends itself particularly to subject areas where there is a need for extensive colour illustration in still graphic form. Thus one of the most successful applications at UBC has been in Geology 202, where the combination of a structured approach to teaching with students able to access UBC-generated databases of graphics such as rock slides and rock formations, together with on-line access to other geology Web sites across the world, has considerably enhanced the flexibility of access for students.

At this stage there has been little evaluation of the use of the Web for the direct delivery of distance education courses. The UBC use is primarily that of information transmission, with some self-testing through multiple choice questions and in one case simulations. However, at the time of writing (November, 1996) Web software lacks the interactive flexibility of dedicated computer conferencing technology such as CoSy or First Class, although Hypertext provides a basic conferencing facility. Protocols also have to be established to ensure that only those who have paid their fees can access either the content or the interactive part of the course.

The main constraint of using the Web for direct teaching, once one goes off-campus, is the speed (or rather the slowness) at which pages can be accessed or downloaded. It is one thing to make material available on campus over high-speed networks and high-end modems; it is another to deliver a substantial amount of course materials over public telephone networks, through low-speed modems to the kind of computers that students are likely to have at home. We will be monitoring this aspect quite carefully. It may in many cases be better to provide the materials on a CD-ROM, with only updates being made available via the Web.

## Computer-based multimedia

There has been a rapid development in recent years of computer-based learning, due to technological developments both in the computers themselves, through faster processing, greater storage capacity and ‘embedded’ software that enables the integration of graphics, sound and moving visuals from external sources, and in the development of ‘peripheral’ equipment, such as CD-ROM and videodiscs. This has led to the development of computer-based multimedia materials (defined as textual data, sound, graphics and moving visuals integrated into a single computer platform).

Computers have for a long time been used for drill and practice. However, the combination of sound output, in the form of a digitized human voice and musical tones, recognition and analysis of human voice input, and feedback of results, has enabled the UBC Music department to apply off-the-shelf commercial software for the teaching of music. Students are asked to recognize either sheet music or tones generated by the computer and match that with their own singing input.

Off-the-shelf software, such as Supercard, can also be used for constructing teaching materials, making it much easier for instructors to develop materials for a particular context. There have been a wide number of projects at UBC in this area. Mark Broudo and colleagues in the Faculty of Medicine have developed teaching materials from scratch to assist students develop skills in the area of cardiovascular measurement, using animation, integrated full video and sound, and text, with multiple choice-type questions providing feedback. The material is structured in modules, with students able to access the material when they need it.

Brian Holl, a specialist in turf grass management at UBC, has developed a 'virtual' office and laboratory to allow students to diagnose and treat turf disease. Students can click on a number of 'tools' in the office and laboratory to access information. In addition, there is a virtual workbook that allows students to enter their own diagnoses and treatments, which is automatically transmitted to the instructor for checking. The interface also includes links to the World-WideWeb, and e-mail and messaging capabilities.

One of the more exciting uses of multimedia is the development of expert systems that allow the user to test hypotheses and simulate different conditions and see the outcome. One such module developed by Dr. Hamish Kimmins at UBC allows users to test different approaches to forestry management. The module shows the relationship between different forestry practices in terms of revenue yield, sustainability, bio-diversity and the aesthetic features of the landscape, and shows the impact of a particular decision over the various time periods of five, ten and forty years.

The increased user-friendliness of multimedia development tools enables even the learners themselves to create their own instructional materials. Liz Hammond-Karreemaa, a college instructor at Malaspina College on Vancouver Island, has developed a multimedia package on killer whales, based on local wildlife resources, in such a way that learners can create their own reports from the materials she has assembled.

There are several lessons to be learned from these experiences. With the exception of the video-conferencing example, the construction of learning materials frees the instructor from the need for direct 'real-time' delivery of the teaching material. Once created it can be used any time, anywhere by the learners. The examples also progressively move away from using the technology just for information transmission. There is some simple feedback and testing of students, and some provide skills development, but some of the examples, particularly the turf grass and forestry management examples, go further and develop problem-solving techniques which students can practice. Brian Holl's and Liz Hammond-Kaarreemaa's approaches require students to develop research skills. Some of the examples also enable students to provide open-ended responses using natural language, and all provide learners with much greater control over their learning, but within a clearly defined and structured learning environment. Such approaches are particularly valuable for adult learners in the new learning context.

## New models

However, these examples by no means exhaust the range of new teaching models needed. These examples still reflect the early stages of a new paradigm for learning, rather like Max Sennett's Keystone Cops were merely a necessary step towards Jurassic Park.

UBC has not for instance moved yet into the area of on-line collaborative learning, using computer mediated communications such as listserves, computer conferencing systems such as FirstClass (used extensively at the Open Learning Agency in BC), or the Virtual University model, based on integrating new tools with Web software, being developed at Simon Fraser University. These models encourage learners to work together from different sites and asynchronously on common projects, to construct new knowledge.

One interesting use of the Web is the design of courses around material publicly available on the Web, where students are guided or encouraged to seek information through the Web, and incorporate it into assignments. Some courses at the Open Learning Agency in British Columbia are planning to use this strategy.

These technologies now enable us to consider new approaches to teaching and learning that meet the needs already defined. For instance, it is now possible to offer students truly international courses, with faculty and other students drawn from across the world. Millions of dollars are spent by many countries in sending students to Canadian universities and colleges for extensive periods. The technology now allows students to come for shorter periods and study the rest of the program at home. This will allow many more students to benefit from such international programs. The benefits to Canadians of being able to make contacts with and understand the business practices and culture of different countries, and the different perspectives brought to common problems, are obvious.

Thus, one interesting use of the Web has been for networking post-graduate students in different specialist areas. For instance, the School of Architecture at UBC, together with Schools of Architecture at the University of Sydney in Australia, the University of Hong Kong, MIT, and several other universities around the world, have been using the Web to allow graduate students to present and critique each others' design projects.

## Resource-based tutoring

Another model is aimed at students seeking accreditation within a particular subject area who already have a good foundation, but who are working towards a more advanced level of study and a personally relevant area of expertise. In this model, the learner is put in touch with a tutor with specialist expertise who can guide the learner to sources of information and pre-prepared multimedia learning materials relevant to their interests. In this model, the tutor helps the learner navigate remote databases, or institutional libraries, which contain the multimedia instructional materials needed by the learner, sets and evaluates relevant learning tasks such as project work, and puts the learner in contact with other learners and experts with similar interests. This model is not very different from learner-centred teaching practised in British primary schools, except that it operates at a distance via telecommunications.

## Just-in-time training in the workplace

It is not difficult to build a convincing portrait of learning at the work-place. We can envisage a computer software designer or television animation artist, called Wayne, probably working from home, needing information on a certain technique or approach, or advice on how best to create a certain effect. From previous experience and contacts, or on the advice of a colleague, he has the name of someone half-way across the country (Sue).

From his work-station, Wayne calls Sue, talks about the problem, and Sue loads up some software which she 'shares' with Wayne via the network. Wayne asks a few questions, tries a couple of things on-line while Sue watches and comments, then downloads the software. Sue and Wayne are both registered with an educational institution that has been set up to enable the exchange of commercially sensitive material for learning purposes. Wayne's work-station has automatically displayed the cost per minute of consulting Sue, and the cost of rights for downloading the software. However, Wayne was also able to give Sue some information, and this is charged back to Sue's account. Wayne now not only has the software he needs, but also can contact Sue (on a chargeable basis) any time he has a problem with the software. The learning context has been established. Note it is fragmented, on demand, and charged at cost.

Lastly, the whole question of delivery of learning has been implicit in the discussion of new models of teaching. Adults need flexibility. They have families, and work commitments around which they have to fit their learning. This means that learning should as far as possible be accessible at any time and at any place. This means making use of delivery to the home, to local learning centres, such as the Community Skills Centres being established in small towns in BC, in the workplace, and into other institutions.

One project with an innovative method of delivery in British Columbia is SkillPlan. This project was developed as a result of a partnership with construction industry unions. The unions found that their members, many of whom were doing contract work at different sites, and often had some spare time between jobs, were needing to up-grade their basic literacy, numeracy and communication skills. The Open Learning Agency identified a computer managed learning system developed by the Jostens Corporation in the USA that provided adult basic education courses aimed at adults who have not completed high school graduation. Workers who need to improve their reading and writing skills can 'drop in' at the Agency's local centres, and use the system when it suits them. The system keeps track of each individual's progress, and enables learners to carry on where they left off the last time they were able to drop in.

Many other new curriculum models can be suggested (see [11], for instance). The challenge for educators and trainers in a world where information is multiplying so fast that even specialists in a particular field cannot keep pace is to ensure that learners have the learning skills and the preparation to go beyond accessing and navigating information to making sense of that information, and applying it in ways that are relevant to their lives and their work; in other words to move beyond information to knowledge. This means being able to construct new knowledge, by finding new ways to do things, based on knowledge already acquired, and to communicate that to others.

Many would argue that this is exactly what a traditional liberal arts education develops in learners. Employers on the other hand argue that workers are not coming to them with the necessary skills, and students should be trained to be more job specific [6]. There is not necessarily a contradiction here. It can be seen from the examples given that good teaching approaches can develop both good generic skills and be applied at the same time.

However, it is important to note that problem-solving and decision-making approaches such as those found in the turf and forestry management examples depend on expert systems, in other words knowledge bases developed from research, which are then applied to a particular problem. Secondly, in a world where jobs change for most people every five years, it is extremely dangerous to train for just the skills large companies say are needed here and now. The new jobs are less and less with large industrial or resource-based companies, and much more with the small entrepreneur. These need skills that allow for adaptation to changing conditions, not narrowly focused skills that may become redundant in a few years.

What is required then is a teaching and learning environment that more closely integrates basic research, navigation and understanding of information, application of knowledge, and skills development.

## The challenge for public institutions

Daryl Le Grew, the Vice-President (Academic) at Deakin University, Australia, has pointed out that many post-secondary institutions "are moving to reconstruct their infrastructure, redesign policy and realign external relationships to gain comparative advantage in the Information Superhighway environment". He argues [12] that there is a transformation taking place (a 'paradigm shift') in post-secondary education, characterized by Table 1.

*Table 1*

| Industrial society | | Information society |
|---|---|---|
| technology peripheral | to | multimedia central |
| once-only education | to | lifelong learning |
| fixed curriculum | to | flexible/open curriculum |
| institutional focus | to | learner focus |
| self-contained | to | partnerships |
| local focus | to | global networking |

In particular, he argues that the new technological environment "opens access to study across sectoral, disciplinary and cultural boundaries", which "will quickly erode traditional ideas of the course of study": selective access, sequenced and carefully integrated content, and level-based progress rules that are pre-determined by the institution. On the contrary, he argues, "curricula will be increasingly disassembled, modularized and customized to suit a wide range of clients requiring flexible delivery ... What constitutes a course will be increasingly negotiated between provider institutions, students and client groups."

If he is correct, this will require some major changes in the organization of post-secondary institutions.

## Who's in charge? Managing multimedia projects

The most common procedure adopted by faculty when embarking on multimedia projects is to develop a proposal, usually around a particular technology or software (e.g. video-conferencing or Netscape). Once funding is received, faculty order equipment and software, and find some willing, interested and computer-skilled post-graduate student to help with the development of the computer-based material. This I call the Lone Ranger approach, with the post-grad as Tonto.

There have been several advantages in this approach. First, it has brought a lot of faculty into exploring the use of new technology who would not otherwise have done so. Secondly, by choosing a cheap and (apparently) easy approach, faculty are able to make the most of materials already prepared, such as lecture notes and student handouts, which are then converted into multimedia materials. Most important of all, faculty themselves retain control of the project, and learn, usually the hard way, that there is more to multimedia design than they had anticipated. In fact, the experience in general is that faculty become excited by the potential, underestimate the work and problems they eventually have to face, and finally recognize the need for more help.

Another approach, and one used extensively in the private sector, is to develop project teams to create multimedia materials. Thus, as well as faculty, there would be an instructional designer, who will help with choosing the most appropriate technologies, with structuring the material and defining the teaching strategies and learning activities to be deployed in the multimedia materials, recommend student assessment strategies, and design the piloting and evaluation of the product.

Secondly, it is important to construct a 'screen' environment that allows the designers to maximize the learning features of high quality multimedia materials. This means designing an interface so that learners can interact in a variety of ways with the learning materials. This requires an interface designer to work with the subject expert and instructional designer. There is also need for someone with specialized multimedia graphics design skills to make screens look professional.

Someone is also needed who has the skills to obtain video and audio recordings, and the ability to edit and convert these recordings into digital format, for incorporation in the learning materials. And someone is needed who can develop a working script, integrate all these different elements into a well-edited and well-constructed final format, and who can choose appropriate software to facilitate the various production processes.

Lastly, each project will need a manager. The project manager sets up meetings, breaks up the design and development process into discrete stages with estimated amount of work and sets deadlines for each piece of work, monitors work flow and deadlines, manages the budget, and works on delivery and student support. The project manager may also handle liaison with external contractors and publishers, and marketing activities.

### The importance of teamwork

Some people will be able to combine more than one role. However, each role needs a high level of expertise. Teamwork, and a recognition by each member of the team of their own limitations, and the contribution that other members of the team can make, are critical to success.

Project management and a team of experienced specialists will initially seem like an expensive way to produce material, but in the end, it is almost always more cost-effective than just ploughing on with a multimedia project, and learning as one goes. In particular, it can reduce the time spent by faculty in mastering skills that they do not necessarily need, thus freeing them up for other activities. A good project team will also substantially reduce the time needed to complete the project, compared with a faculty member and a research student soldiering on alone. Lastly, if a higher quality product is produced, there are more possibilities of cost recovery from other applications than the original 'targeted' use.

Faculty often criticise multimedia development as too expensive or too demanding of faculty time. It is also very challenging, requiring faculty to try methods and technologies with which they are not familiar or comfortable. These are all valid concerns. Multimedia teaching will be more expensive, time-consuming and threatening if it is merely added on to all the other duties of faculty, within an organizational environment that has not been modified to support such activities. Just as automation required major changes in industrial manufacturing methods, so too is there a need to restructure universities and colleges to enable the benefits of the new technologies to be realised.

## Institutional change

Consequently, a number of issues need to be addressed. Most universities and colleges are aware of the need to put in a comprehensive technology infrastructure on campus. However, probably the most important step to be taken is to provide support to the people who will be most affected by technological innovation: faculty and students.

### Human resource development

Bluntly, faculty need training, not just in how to use the technology, but more importantly, in understanding how learning takes place, and how to design teaching approaches based on that knowledge. Without this fundamental understanding of the teaching and learning process, it is almost impossible to design high quality multimedia learning experiences.

There are at least three practical steps management can take in this regard. The first is to organize regular workshops on teaching practice and the use of technology (which in some institutions will mean creating or strengthening faculty development departments). The second is to provide rewards, in terms of tenure and promotion criteria, for successful, innovative teaching. Thirdly, while workshops are important, there is a need for more comprehensive and systematic courses or programs aimed at teachers of higher education. These are minimum requirements. An even more radical step would be to require successful completion of a higher education teaching qualification for tenure appointments; unfortunately such courses, if they exist at all, are not available in a manner that makes it practical for most faculty, i.e. part-time and at a distance, even if faculty associations could be persuaded into accepting such a policy.

### The convergence of on-campus and distance teaching

However, while such strategies are important, they do not necessarily provide any solution to faculty overload. This has to come from re-organizing the way that teaching is provided. One of the impacts of technological innovation on campuses is the convergence of on-campus and off-campus or distance teaching. Once materials are developed for on-campus students, they can, if designed with this in mind, be just as easily available to off-campus learners. Also, many more learners can access the same material, once it is created. Thus, the use of technology can allow for more students to be accommodated for the same number of faculty, with scope for re-allocation of resources to free up faculty for the development of teaching materials.

Furthermore, is a student registered as full-time who opts to take most of the course from home a distance student or an on-campus student? Does it matter? The introduction of multimedia courses opens up questions about the relevance of residential and prior qualifications for entrance; if space is not a limitation, why restrict students who want access? What becomes clear is that once courses are created in ways that allow for open and flexible learning, accessible anywhere and at any time, careful consideration needs to be given as to who needs access to a campus, and for what reasons.

## Student access to technology

There are though two large assumptions being made about the use of multimedia. The first is that students will have access to computers, Internet, CD-ROM players, etc. Student access to computers is increasing, but there is also a need for a clear policy to help students access the necessary technology being used for teaching and learning. While many students now arriving in universities already have their own computers (about 40 %), many do not. In any case, there is a need for common standards; multimedia materials require medium- or high-range personal computers and fast networks. These are often not available off-campus or in students' homes.

Again, there are several strategies that can be adopted. Institutions can negotiate leasing arrangements with suppliers, so students can pay a modest rental fee with the option for low-cost purchase at the end of the leasing period. A college can ensure there are ports on campus to allow students to plug in their own computers (much cheaper than providing computer labs). Capital funds for buildings (and car parks) can be re-allocated to support student's off-campus access to courses, thereby reducing the demand for campus facilities. Institutions can form consortia to block-buy long-distance Internet access throughout a province or state for students (the Open Learning Agency in British Columbia has recently negotiated such a deal, allowing students local call access to the Internet and OLA's services from most parts of the province). Governments may even install or buy leased network facilities for educational use, as in New Brunswick, Canada.

## Comparative costs of multimedia and conventional education

A more fundamental issue is the change in cost structures resulting from the development of multimedia courses. In the conventional higher education model, costs have tended to increase with student numbers, or quality drops. In other words, if the student/teacher ratio is kept constant, more teachers are needed. If more teachers are not recruited, class sizes increase, interaction with the teacher drops, and hence quality declines. We have seen over the past 10 years in many countries access to higher education being increased by increasing the student/teacher ratio, or by the hiring of young Teaching Assistants scarcely more than a couple of years ahead of the students they are teaching.

However, the cost structures for pre-prepared multimedia materials are quite different. They cost a good deal of money up-front to create, but once created, they can be used by as many students as necessary with minimal increases in costs. This becomes even more pronounced when the life of the course materials are taken into account.

Original multimedia materials created from scratch have a higher 'starting' or fixed cost than classroom teaching, but after production, the only additional costs are the cost of making and distributing compact discs (assuming that students have their own computer and CD-ROM player). Classroom or lecture hall teaching, however, increases roughly in proportion to the number of students. In fact, costs increase in steps, depending on the assumption about maximum class or group size before the level of teacher/student interaction, and hence the quality of the teaching, is considered to drop. Thus, as student numbers increase, extra sessions or classes have to be opened, and additional teachers or instructors found. Figure 1 shows the relationship between the costs of classroom teaching and the costs of pre-prepared multimedia.

Most universities and colleges have absorbed extra numbers of students in recent years by either increasing class size, or by using more and more low-paid and inexperienced teaching assistants (or both); in other words, the quality of teaching has been reduced.

## Quality comparisons between conventional and multimedia teaching

The second assumption is that the quality of interaction with pre-prepared multimedia materials is the same as between individual students and a teacher. This in fact is not the case. Well-designed multi-

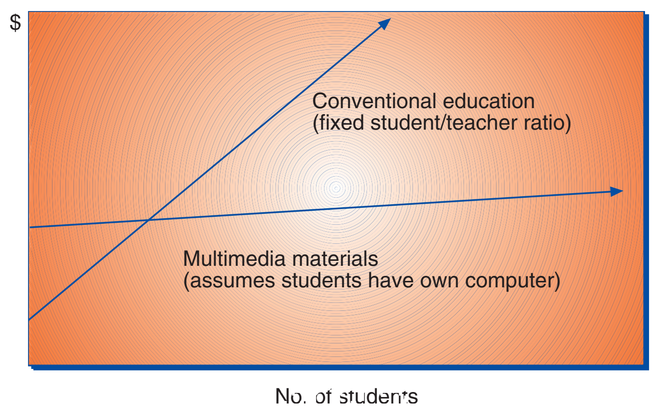


*Figure 1  Conventional classroom teaching vs. Multimedia materials*

media materials can both present information and provide a large amount of the interaction and feedback previously provided by teachers. This frees up the time for the teacher then to concentrate just on those areas where person-to-person interaction is critical. However, computers are not smart enough to anticipate all the questions, misunderstandings, and more importantly, original and creative outputs that students can generate. Thus, there is still the need for some form of provision, not only for student/teacher interaction, but even more importantly for interaction amongst students. This can be provided either in the traditional face-to-face small group seminars, or 'on-line' and at a distance by using e-mail or computer.

Basically, with multimedia, the teaching falls into two parts: presentation and interrogation of information, some feedback, and some skills development through the use of interactive, pre-prepared multimedia materials; and counselling, student guidance, knowledge building, argument and creative thinking, hypothesis development and testing, inter-personal skills development, and group work through either on-line or face-to-face group contacts. The aim is to use the most valuable and costly resource – that of the teacher – more efficiently, by allowing teachers to concentrate their time with students on what they can do best, namely encouraging and responding to the great variety of contributions that students make to the learning process.

## Comparing cost and quality

Figure 2 not only indicates the cost of providing on-line student/teacher and student/student interaction (via computer conferencing – arrow C), but the cumulative cost of multimedia materials plus computer conferencing (arrow D – see [13] for a methodology for costing educational technologies).

It can be seen in this model that for smaller numbers of students, conventional classroom teaching is likely to be less costly than multimedia and computer conferencing combined. However, as numbers increase the new media become increasingly more cost-effective.

## The need for cost-benefit analysis

It must be stressed that this is a hypothetical model. There is a great lack of hard data on the actual costs, not only of the new media, but even of conventional teaching in post-secondary education. Thus we do not know (a) if the model will hold in real-life, or (b) even if it does, where the critical point 'y' is, i.e. the number of students where the new media become more cost-effective. What is needed is at least some cost-benefit analyses of the actual applications of these new technologies in post-secondary education. There is no guarantee that these new technologies will be more cost-effective. Nevertheless, it can be seen that, in theory at any rate, the new multimedia technologies offer the hope of maintaining or increasing the quality of teaching as student numbers increase, at relatively less cost than conventional classroom methods.

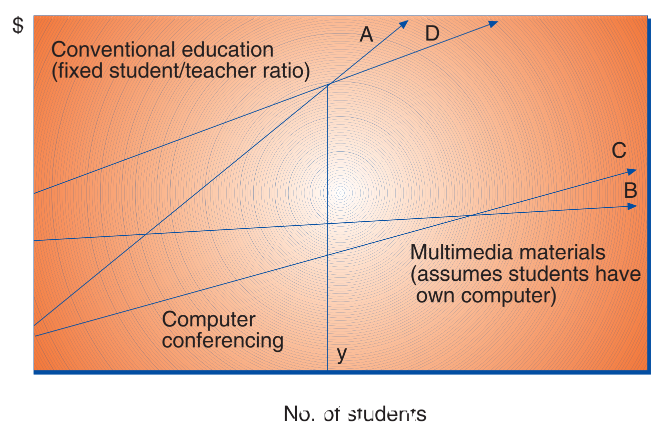


*Figure 2 Conventional classroom teaching vs. Multimedia materials combined with computer conferencing*

## Conclusions

It is more than unfortunate that at a time when there is a need for major changes in the structure and operation of the post-secondary education system, governments across Canada are threatening reductions in resources. This is unfortunate for two reasons. Now is not the time to reduce activity in adult education. There is a major new market, those in the work-force, and students coming from high schools need new approaches too. Nor is there any clear evidence that the application of new technologies and methods of teaching will save money; indeed they are likely to cost more, and there is certainly a substantial cost of change. The second reason is that the threat of cuts is likely to lead to defensiveness and a retreat to 'the good old days'.

At the same time, many of the new activities in adult learning do not need to be directly funded by the state. People who are working and in good jobs, and employers who want to keep ahead of the competition, get direct benefits from re-education and re-training. We are likely to see then increasing entrepreneurship from the public sector, and increasing competition with the private training sector. Indeed, competition generally is likely to increase, as the provincial and national borders of education are powerless to stop educational offerings through electronic networks. For instance, there are four out-of-province MBAs available at a distance in BC already. The main threat though to the public sector institutions will come not from out-of-province universities and colleges, but the large multinational media organizations, who see adult learning as a major new business for them.

Lastly, it is easy to get hung up on the technology, which is exciting, challenging and not without major risks and hazards. However, technology is not the issue. There is more than enough technology available already for us to teach in more or less any way we like. The issue is the changing needs of adult learners, and the need to find new ways of teaching and learning that will prepare them for the uncertainties of the 21st century.

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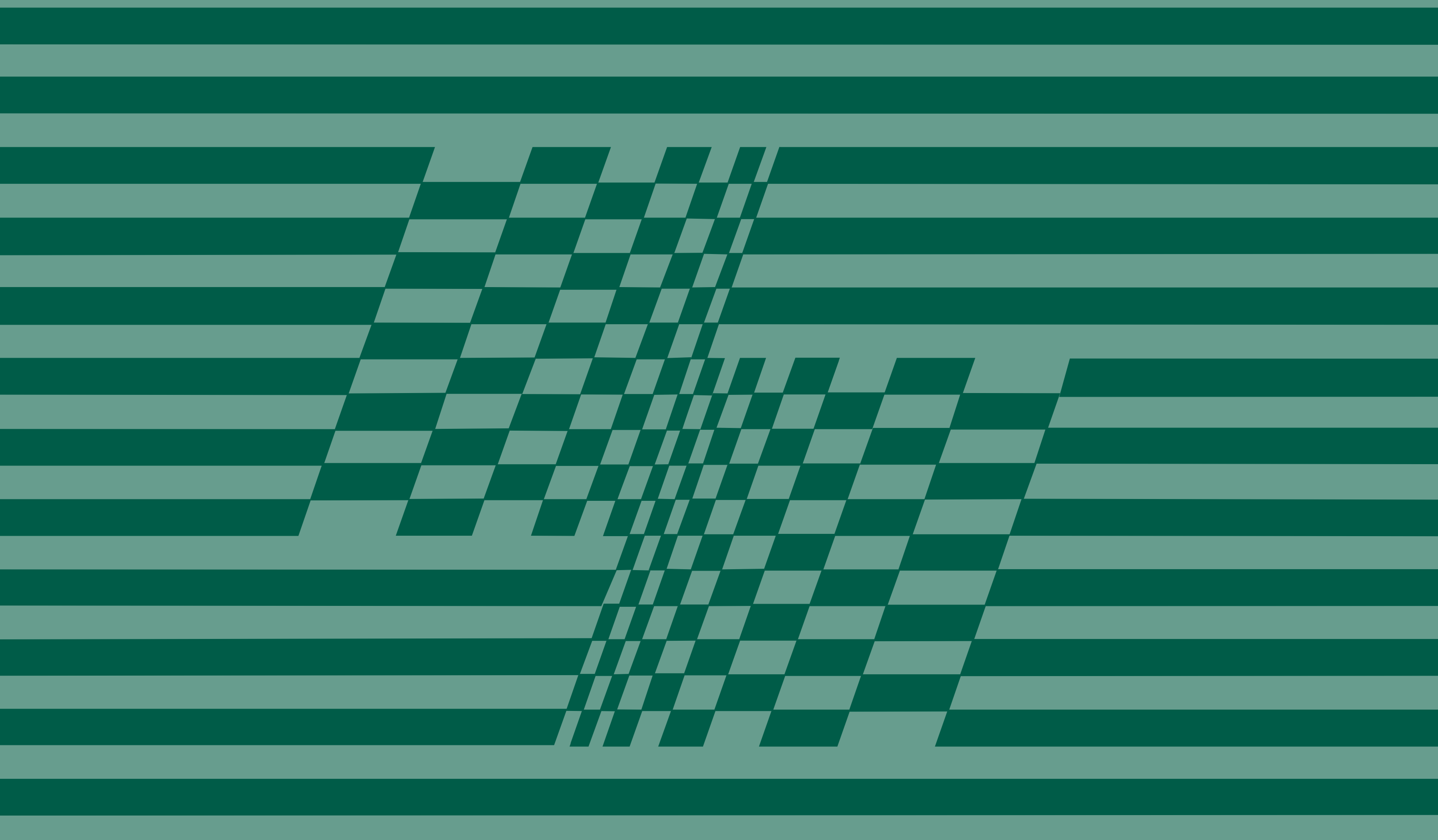
# Special



# Protocols for multimedia multiparty conferencing – a presentation of the ITU-T T.120 series recommendations

BY TROND ULSETH

## 1 Introduction

Among telecommunications people the term conferencing has been associated with audio conferencing, that is audio only, or video conferencing, that is audio and moving image.

The term conferencing is also used by data communication people. Data conferences may be synchronous, that is real-time conferences, or asynchronous, that is messages are sent to the other participants of the conference.

The introduction of ISDN and multimedia communication have led to a need to add data communication functionality (e.g. text or graphics) to audio and video conferencing. In the same way people would like to add audio and moving images to data conferences.

Thus, the term **multimedia conferencing** is introduced. Furthermore, there is a need for **multiparty** multimedia conferences. The ITU-T T.120 series recommendations are defining the data communication service for use in a multipoint multimedia conferencing environment.

This article presents an overview of the existing and planned ITU-T recommendations, and highlights some technological and market trends.

## 2 The basic principles

### 2.1 Area of applications

The ITU-T T.120 series of recommendations primarily addresses multiparty conferencing.

The initial application was audiographic conferencing, i.e. speech and data/graphics. The introduction of video coding algorithms enabling the transmission of moving images both on the ISDN and recently on the PSTN, led to an expansion of the application area. The recommendations now address multimedia conferencing, i.e. simultaneous transmission of speech, video and data/graphics.

Single medium subsets (data conference or audio only conference) are of course possible.

To set up a multiparty conference an MCU (Multipoint Control Unit) is used as described in Figure 1. Point-to-point connections are established between each conference participant and the MCU. The protocols can also be used in point-to-point communications between two users, however, some of the protocols are addressing multiparty functionalities.

The protocols also cover conference scenarios where two or more MCUs are used to establish the conference as described in Figure 1.

The protocols are designed to set up and control multimedia conferences. The functions and protocols defined are free from platform or network dependence. The present versions are addressing the data part of a multimedia conference and the conference control, while the audio and moving image parts of the multimedia conference need to be predefined similar to the present video conference service offered by a number of service providers.

The following types of conferences can be described:

- Data conference*
- Audio conference
- Audiographic conference (i.e. audio and data/graphics)*
- Video conference (i.e. audio and moving image)
- Multimedia conference (i.e. audio, moving image and data/graphics)*.

The T.120 protocols can offer control functionalities, e.g. chairman control, to all these types of conferences, and in addition offer data communication functions to those types indicated by an asterix.

### 2.2 Structure

The T.120 protocols can be separated into three groups as described in Figure 2. These groups are:

- Network related protocols
- Protocols addressing multipoint communication service and conference control
- Application protocols.

#### 2.2.1 Network related protocols

ITU-T Recommendation T.123 specifies the network related protocols. Protocol stacks are defined for:

- ISDN.
  This protocol stack is based on an MLP data channel established by the audio-visual framing and in-band signalling system defined in ITU-T Recommendation H.221. All terminals that are conforming to ITU-T Recommendation H.320 support this in-band signalling system.
- Line-switched data networks (X.21).
  The MLP channel shall be established by the audio-visual framing and in-band signalling system defined in ITU-T Recommendation H.221.

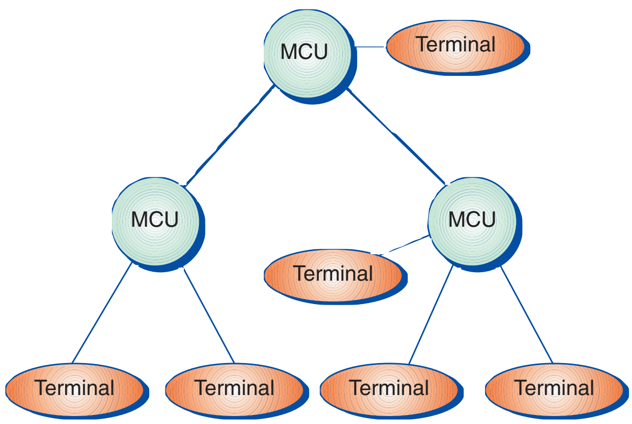



*Figure 1 A conference set-up using three MCUs*

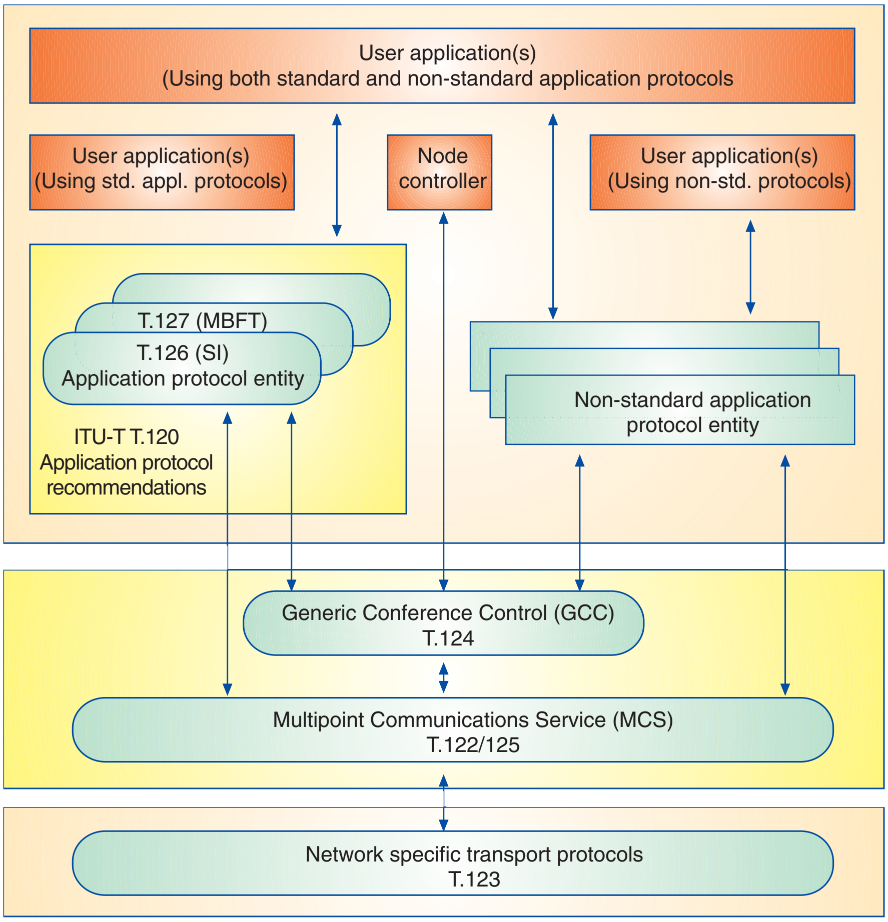



*Figure 2 Structure of the T.120-series protocols*

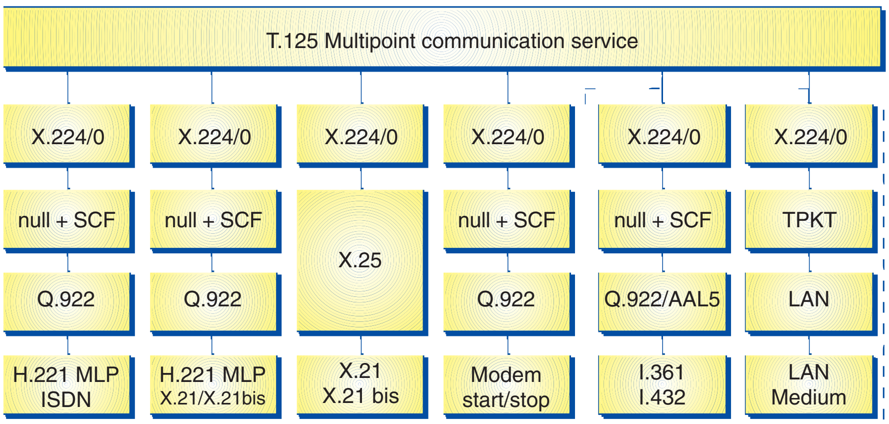



*Figure 3 Protocol stacks defined in ITU-T Recommendation T.123*

- Packet-switched data networks (X.25).
- The analogue telephone network (PSTN) via modems.
- Other networks or leased lines where audio-visual framing and in-band signalling system defined in ITU-T Recommendation H.221 is used.
- ATM-based networks (B-ISDN).
- Local Area Networks.

The protocol stacks covered by this recommendation are described in Figure 3.

The protocol stacks for ATM-based networks and LAN are in the 1996 version of the recommendation.

By using these protocols conferences between users attached to different networks can be set up. These aspects are further elaborated in Section 2.4.

It is worth noting that the standardised protocol stack for ISDN communication requires use of the framing and in-band signalling system defined in ITU-T Recommendation H.221. The 1996 version of ITU-T Recommendation T.123 describes some alternative profiles,

- Based on ITU-T Recommendation Q.922 (i.e. without the MLP data channel)
- Based on the telematic protocols defined in ITU-T Recommendation T.90
- Based on start/stop characters as defined in ITU-T Recommendation V.120.

None of these alternatives are fully standardised in the Recommendation. Furthermore, there is no procedure to identify the profile used apart from the procedures described in the referenced recommendations.

Multimedia applications will normally use the H.221 framing and in-band signalling and will thus have no problems. But there is a problem for both data conferences and applications where there is no simultaneous audio and moving image communication.

### 2.2.2 Protocols for multipoint communication and conference control

The Multipoint Communication Service is described in ITU-T Recommendation T.122, and the associated protocols are defined in ITU-T Recommendation T.125.

ITU-T Recommendation T.124 (Generic Conference Control – GCC) provides a set of services for setting up and managing the multipoint conference. It provides access control, chair control functionalities and control of priorities for the data communication between the participants in the conference. Four levels of priority are defined; the highest level is reserved for the conference control based on GCC.

### 2.2.3 Applications

So far, two applications are standardised:

- Still Image (ITU-T Recommendation T.126).
  The Recommendation includes JPEG encoded colour still images, JBIG encoded black/white still images and facsimile group 3/4. Five profiles are defined. Procedures for creating drawings and the control of pointers in a multipoint environment are defined,
- Multipoint Binary File Transfer (ITU-T Recommendation T.127).
  The Recommendation defines procedures for file distribution and file retrieval. Multiple files can be transferred simultaneously to a number of addresses that can be defined for each file.

There will be few application recommendations among the ITU-T T.120 series of recommendations. The objective is to standardise the principles for the communication between non-standard applications and the standardised protocols for the service. ITU-T Recommendation T.121 describes a model for application protocols. The recommendation is presented in Section 2.3.

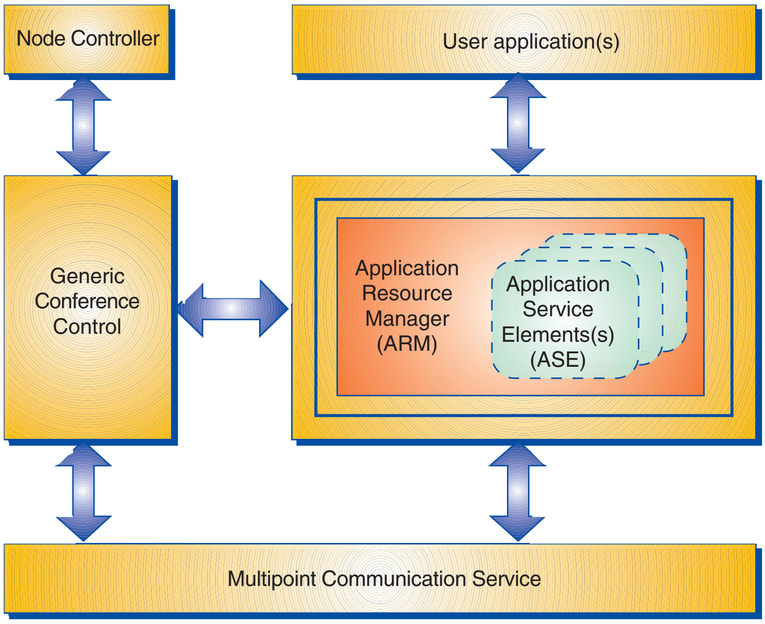



*Figure 4 The Generic Application Template Model*

## 2.3 Model for application protocols

To assist application developers ITU-T Recommendation T.121 Generic Application Template (GAT) presents a generic model for T.120-conforming applications.

Figure 4 describes the principle of the generic model.

The model consists of two functionally distinct parts:

- The Application Resource Manager (ARM) which is responsible for managing GCC and MCS resources
- The Application Service Element (ASE) which provides application-protocol-specific functionality.

All standardised application protocols are based on this model. It is recommended to use this model when developing non-standard applications.

The use of this model ensures that all non-standard applications have equal structure. It will simplify the communication between non-standard applications developed by several companies, but it cannot guarantee the communication between these applications; the guarantee can only be achieved by standardising the applications.

## 2.4 Network independence

The T.120 series recommendations support a broad range of transport options, including the Public Switched Telephone Network (PSTN), Integrated Switched Digital Networks (ISDN), or Local Area Networks. Conferences might be set up between terminals of diverse capability, on multiple different networks and across administrations. An example is described in Figure 5.

Apart from the ITU-T standardised protocol stacks, DataBeam offers solutions for communication on Novell Netware IPX networks and on TCP/IP networks (e.g. Internet or Intranet) as described in Figure 6. The scenario described in Figure 5 can therefore be extended to include Novell networks and TCP/IP based networks. Since the version of ITU-T Recommendation T.123 approved at WTSC was completed by ITU-T SG 8, ITU-T has decided to accept normative references to IETF documents (i.e. RFCs). The next version of T.123 will therefore include a protocol stack for TCP/IP.

The network bandwidth restriction may create problems. The bandwidth of an ISDN B-channel is 64 kbit/s, while the bandwidth when using standardised modems for the PSTN is restricted to maximum 33.6 kbit/s when using the recently approved extension to ITU-T Recommendation V.34. However, the modem bitrate depends on the quality of the connection; it might be lower. On Local Area Networks the delay may create problems for real-time communication.

As stated previously the present versions of the recommendations focus on data communication and conference control. Bandwidth variations or delay introduces no serious problems for that part of a conference, but the impact on the audio and moving image parts of a multimedia conference may be dramatic. Furthermore, different video coding algorithms may create problems, transcoding between different video coding algorithms might be expensive and introduces a significant increase to the delay of the connection.

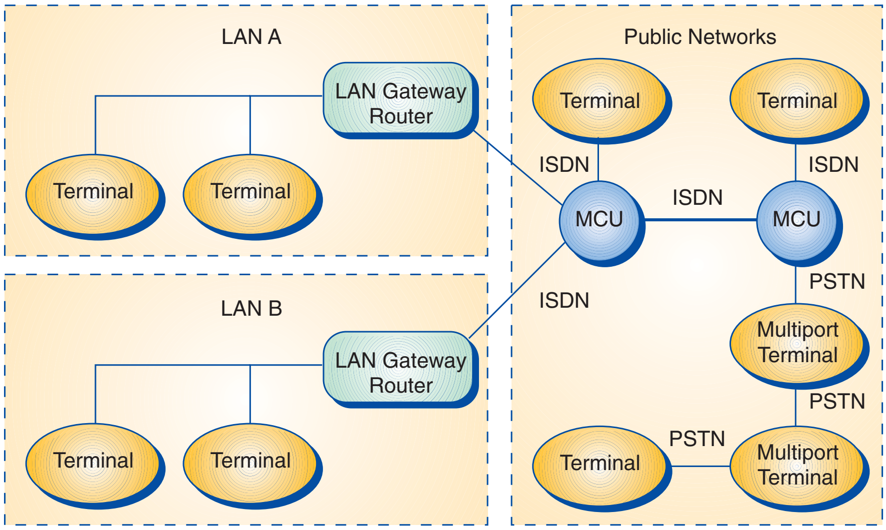



*Figure 5  Example of a mixed-network conference topology*

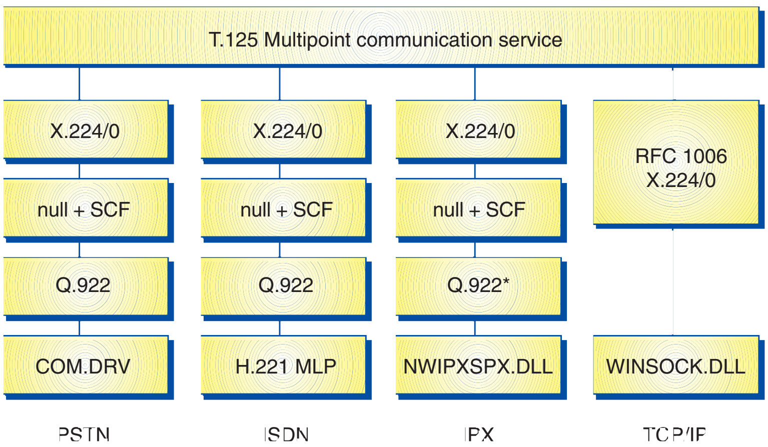



*Figure 6  Protocol stacks supported by DataBeam*

## 2.5 T.120 implementor's guide

Even though all possible effort has been made to avoid errors and/or phrases that can be interpreted incorrectly, such problems can hardly be avoided. ITU-T has no procedures for correcting errors in an approved document; a new edition has to be prepared.

The approval process of a new edition takes some time. For the benefit of the users ITU-T has issued an 'Implementor's Guide for the ITU-T T.120 Recommendation Series Data Protocols for Multimedia Conferencing'. This document is a compilation of reported defects. It is a 'living' document freely available. The document resolves defects in the following categories:

- Editorial errors
- Technical errors such as omissions or inconsistencies
- Ambiguities.

In addition, the document may include explanatory text found necessary as a result of interpretation difficulties apparent from the defect reports.

The document does not address proposed additions, deletions or modifications to the recommendations that are not strictly related to implementation difficulties in the above categories.

As already mentioned this is a living document. The latest version can be obtained at IMTC's ftp-site at the address

ftp://ftp.imtc-files.org/imtc-site/IMPGUIDE

or ITU-T's Web-site

http://www.itu.ch/itudoc/itu-t/com8/implgd.html.

Usually, new versions are available on the IMTC ftp-site earlier than on the ITU-T Web-site.

# 3 Market actors and products available

## 3.1 Participants in the standardisation activities

North-American companies have been the major contributors to the standardisation of the T.120 protocols. Mr. C.J. Starkey, Vice President of DataBeam and co-founder of this company, has been a key person and was rapporteur for the question addressing the T.120 protocols in CCITT (now ITU-T) for 6 years until the middle of 1993.

Other major contributors have been AT&T, Bellcore, BJ Communications, BT (British Telecom), France Telecom, PictureTel, PolyCom and VideoServer. Other contributors are Intel, BNR (Nortel), ConferTech, Multilink and VTEL. MicroSoft has been participating in 1996.

Apart from BT and France Telecom, European companies have been less active. GPT Video Systems has attended most of the meetings addressing the T.120 protocols. Other European companies attending some of the meetings are Teles, KPN (Dutch PTT) and Austrian PTT. Other European network operators as well as Japanese and South Korean companies have been present at a few meetings.

IMTC (The International Multimedia Teleconferencing Consortium, Inc.) is an important actor that is founded to facilitate and promote the creation and adoption of international standards for Multipoint Document and Video Teleconferencing, specifically the ITU T.120 and H.320 standards suites. The work on supporting the T.120 series recommendations was initiated by CATS (The Consortium for Audiographics Teleconferencing Standards, Inc.). In 1994 CATS and MCCOI (The Multimedia Communications Community of Interest) were merged to form IMTC.

Most of the CATS members were North-American companies, while the membership of MCCOI was based on both North-American and European companies. Telenor was a member of MCCOI, and is now a member of IMTC.

In December 1995, IMTC merged with PCWG (the Personal Conferencing Work Group), and the major network operators, suppliers of video conferencing equipment as well as companies like MicroSoft and Intel are now participating in the work of IMTC.

It is worth noting that, unlike other fora, IMTC is no alternative to the standards organisations, the fundamental goal is to bring all organisations involved in the development of multimedia teleconferencing products and services together to help create and promote the adoption of the required standards.

## 3.2 DataBeam

### 3.2.1 Introduction

DataBeam is one of the active companies in the work on the ITU-T T.120-series recommendations. Co-founder and Vice President of DataBeam, Mr. C.J. Starkey, was rapporteur for the work in CCITT, and is currently president of the IMTC.

DataBeam has established agreements with several partners on joint activities. Examples are:

- Agreement with MCI to deliver new real-time services for multi-point collaboration via the Internet
- Relationship with Cisco on new Internet server with conferencing capabilities
- Agreement with MicroSoft to facilitate the development and deployment of real-time multi-point data applications in corporate Intranets and the global Internet
- Strategic co-operation between Cisco, MCI, MicroSoft and Sun on development and marketing of neT.120
- Agreement with AT&T Paradyne and Multilink on development and marketing of technology for multiparty audiographic conferencing.

The products offered by DataBeam are:

- CCTS (Collaborative Computing Toolkit Series), a development tool
- FarSite, a software product
- neT.120 Conference server, a data conferencing server.

### 3.2.2 CCTS

CCTS is an integrated set of software development tools based on the T.120 standards. It is organised in 6 modules which corresponds to one or several T.120-series recommendations.

A toolkit on application sharing has been launched, but is now withdrawn, probably because ITU-T now is working on a recommendation on application sharing (T.SHARE).

The modules are:

- Multi-Point Communications Application Toolkit (MCAT). MCAT is the basis module which provides a general-purpose facility for establishing, servicing and managing the simultaneous delivery of data between multiple users connected via LAN, WAN, and dial-up networks. MCAT is based on the ITU-T Recommendation T.122/125 and T.123.
- Generic Conference Control Application Toolkit (GCCAT). This module offers facilities for establishing and managing meetings, as well as controlling the communications resources required by the conference applications.
- Node Controller Toolkit (NCT). This module streamlines the establishment and management of conference connections. NCT furnishes a generic standard for an undefined portion of the T.120 infrastructure.
- Session Manager Toolkit (SMT). This module offers a flexible abstraction of the session management functions common to all T.120-based applications. SMT is based on ITU-T Recommendation T.121, and secures a standardised communication between the applications.
- Shared Whiteboard Application Toolkit (SWAT). This module allows developers to rapidly add powerful T.126 compliant document conferencing or whiteboarding functions to their applications. SWAT is based on ITU-T Recommendation T.126,
- File Transfer Application Toolkit (FTAT). This module offers a simple way to embed multi-point background file transfer functions into an application. FAFT is based on ITU-T Recommendation T.127.

CCTS can be considered as an implementation of the principles described in ITU-T Recommendation T.121, and is probably the only commercial available tool for development of T.120-applications.

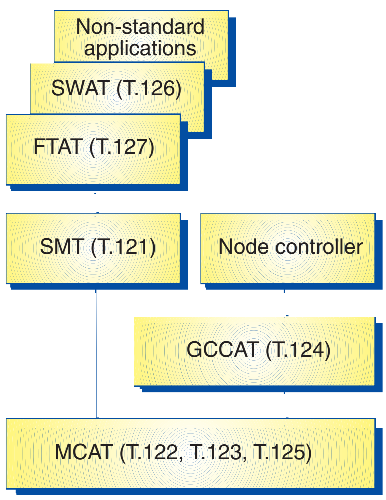



*Figure 7  CCTS modules*

### 3.2.3 FarSite

FarSite is a software which offers the tools needed for remote collaboration based on the T.120 protocols. FarSite provides both application sharing and shared whiteboarding, in point-to-point connections and in a multipoint conference.

Multipoint Binary File Transfer conforming to ITU-T Recommendation T.127 is offered. The whiteboarding function in the present version (FarSite 3.0) is probably not fully conforming to ITU-T Recommendation T.126, although this is the objective of DataBeam.

FarSite is available as a separate product and is included in several multimedia conferencing terminals and systems.

### 3.2.4 neT.120

The neT.120 Conference Server is a data conferencing server based on T.120 technology. It can be connected to the networks identified in Figure 6, that is ISDN, PSTN, IPX-based networks (Novell) and TCP/IP-based networks (Internet and Intranet). However, the present marketing of neT.120 indicates that DataBeam strategic decision is to offer products for data conferencing on Internet and Intranet. The agreement with Cisco, MicroSoft and Sun clearly documents this decision.

A software-only server, the neT.120 Conference Server leverages existing web browsers and desktop applications. The minimum requirement for participating in a neT.120 based conference is an Internet browser such as MicroSoft Internet Explorer, Netscape's Navigator or NSCA Mosaic.

By using terminals conforming to the T.120-series recommendations more functionalities can be offered.

## 3.3 Suppliers of T.120-based products

In the past standardisation has not been given high priority by computer and software manufacturers. Usually, the market forces, strategic alliances, etc. have been used to establish de facto standards. In the development of video conferencing terminals several suppliers have developed alternatives to the standardised solutions. However, the last year a trend to choose standardised solutions can be observed. Examples are:

- Intel ProShare 2.0 which conforms to ITU-T Recommendation H.320, and offers T.120 functionality. Although not officially confirmed, Intel will probably use MicroSoft developed data conferencing functionalities. Intel's development will be restricted to the audio and video part. Co-operation between Intel and VideoServer is established, and the VideoServer MCU is compatible with Intel ProShare 2.0.
- Apple's video conferencing system, QuickTime is also conforming to ITU-T Recommendation H.320. Apple has a licence agreement with DataBeam, and plans to introduce QuickTime with T.120 functionality in 1996. The licence agreement with DataBeam allows the QuickTime users to develop T.120-based applications without an extra licensing agreement with DataBeam.
- MicroSoft has indicated that support of T.120 protocols will be a part of the successor of Windows 95, and that the T.120 protocols will be used in other MicroSoft products (e.g. MicroSoft NetMeeting). MicroSoft and DataBeam have signed an agreement on development of T.120 application for use on Internet.
- PictureTel, one of the major suppliers of video conferencing equipment, is active in the ITU-T work on the T.120 recommendations. PictureTel is also active in the interoperability testing events organised by IMTC (Event 120).
- The major supplier of video conferencing MCUs, VideoServer, is actively participating in the ITU-T work on the T.120 recommendation, and offers some T.120 functionality in software version 5 for their MCUs.

# 4 Trends

## 4.1 Market trends

No doubt the T.120 protocols will be a success. Several observations supporting this statement can be made:

a) Important market actors such as MicroSoft and Intel are now actively participating in the standardisation work, and are actively promoting these protocols.

b) Computer Supported Co-operative Work, teleworking and multiparty multimedia conferencing have become important strategic elements for a number of companies.

Another aspect is the introduction of the T.120 protocols in the Internet environment. So far, real-time multiparty video conferences can be set up by using MBONE, a virtual network using IP multicast on Internet. The information is distributed to all hosts who have expressed interest in becoming a member of a certain multicast group. Like the present version of Internet, there is no Quality of Service guarantee. By the use of the Time To Live (TTL) value the distribution of the information can be restricted.

The introduction of neT.120 is the first step towards multimedia conferences on the Internet that include a well-defined group of participants. New functions such as chairman control can be offered. Extensions to the present IP protocols which offer guaranteed bandwidth are available, and the Internet Engineering Task Force is working on a new version of the Internet Protocol (IPv6) which can guarantee Quality of Service. When the new version of IP is implemented, world-wide multimedia conferences offering functionalities and Quality of Service similar to those offered on public networks, can be set up. This service will at the beginning be introduced on corporate networks (Intranets). Multimedia conferences set up on Intranets where some participants may be attached via public networks will be an important market segment.

From a technology point of view multimedia conferencing including moving images is the most exciting application. From the users' point of view audiographic conferencing and data conferencing might be more interesting on the short term. Today, video conferences where the quality of the moving image is acceptable for professional use requires connections set up via ISDN or networks offering higher bitrates. Audiographic conferences or data conferences can be set up on PSTN, Internet or a combination of PSTN and Internet (e.g. the audio connection on the PSTN, the data connection on the Internet). The required investment in terminal equipment will usually be low, a telephone, a modem and a PC are required. New modem standards offering simultaneous transmission of voice and data on a single telephone line may also be an alternative.

Another important trend is the evolution from the business market to the domestic market. In the future multiparty games might be an interesting market segment.

## 4.2 Network platforms

As already described standardised protocol stacks for public telecommunications networks (PSTN and ISDN) and for public data networks are available. Protocol stacks for LANs and TCP/IP networks are also available.

ITU-T is currently working on a recommendation on audio-visual terminals on LANs without a guaranteed Quality of Service (Recommendation H.323).

A recommendation on videophones attached to the PSTN is approved by ITU-T (Recommendation H.324). However, the size of the screen as well as the audio and video quality are probably not acceptable for business users. Real-time videotelephony on PSTN or Internet has for the time being several shortcomings, due to time delay as well as available bandwidth. Today, the only realistic network platform for multimedia communication where moving images are included, is the ISDN. It is possible to set up conferences where both audio, moving images and data are transported on two ISDN B-channels, i.e. 128 kbit/s. For more demanding applications the bandwidth can be increased to e.g. 384 kbit/s (6 B-channels).

Both data conferences and audiographic conferences can be set up on the ISDN. However, the standardised protocol stack for ISDN communication is based on the in-band signalling system specified for audio-visual communication. Data conferencing on the ISDN not using this in-band signalling system is therefore a problem for the time being.

These considerations lead to the following scenarios:

1. **Multimedia on the ISDN**
   This scenario is requiring video conferencing terminals, usually a PC, with T.120 software. Another option is a desktop videophone or a video conferencing terminal with a PC interface. Some videophones are equipped with a PC interface, but few support the necessary function on the data link layer to enable T.120 communication.
2. **Audiographic conferences**
   This scenario may be based on ISDN communication. There is a standard specifying a wideband (7 kHz bandwidth) ISDN telephone where up to 14.4 kbit/s can be reserved for data communication. The in-band signalling system specified in ITU-T Recommendation H.221 is used. The terminal must be equipped with an interface to a PC, similar to that of desktop videophones.

   A more realistic short term scenario is to set up two PSTN connections, one for audio, the other for data. A telephone may be used for the audio communication; usually a hands-free solution is preferred. An alternative might be a headset.
3. **Data conferences**
   This scenario will be based on PSTN or Internet communication.

Combinations are of course possible. One alternative is to use Internet for the data part of a multimedia or audiographic conference.

Where guaranteed Quality of Service can be offered Internet/Intranet is a realistic alternative for multimedia conferences too.

## 4.3 Interoperability testing

Experiences gained by the introduction of new protocols such as facsimile and videophony indicate that the risks for misinterpretations of the requirement of the recommendations, errors in the recommendations or shortcomings of the recommendations are significant. There is always a need for a verification of a standard or recommendation, as well as a need for verifying that equipment produced by different manufacturers is able to interwork.

IMTC is addressing these issues. An interoperability testing event called Event 120 is organised by IMTC. The first event was held in Santa Clara, California, 25–27 March 1996. 25 manufacturers participated. Approximately 6,000 test sequences were conducted, covering equipment connected to ISDN, PSTN, LAN and Internet.

A second session was held in Gaithersburg, Maryland 18–20 September 1996. At this session 3,000 test sequences were performed.

It is claimed that 95 % of these tests were successful. Although these results are promising, it is worth pointing out a few favourable conditions:

- One is the leading role of DataBeam. Most of the implementation was based on the DataBeam products or DataBeam's development toolkit. When software or development toolkit from other suppliers is available, the situation could be worse.
- Another is that the tests were predefined. It is therefore likely that attempts have been made to keep clear of problem areas.

The initiative to start Event-120, however, is positive, and an important condition for interoperability between terminal equipment produced by different manufacturers.

In Europe, EV (European Videoconferencing); an organisation where European network operators are participating (among these Telenor), has carried out both interoperability testing and conformance testing of H.320 terminals.

## 4.4 Standardisation

### 4.4.1 Applications

As already stated, there will be few recommendations on applications among the ITU-T T.120 series of recommendations. Some proposals for application recommendations have been forwarded. One of these is to expand to T.190 series recommendations on Co-operative Document Handling (CDH) to include multiparty scenarios. A proposal for organisation of the work is described in Figure 8.

Work in ITU-T SG 8 on XAPI (Extended Applications Programmable Interface) has so far been addressing point-to-point CDH. The extension to a general use in a T.120-environment is now considered.

Other applications related issues are security and encryption in an T.120 environment.

The most important proposal, to develop a recommendation on application sharing in a T.120 conference (T.SHARE), is presented by MicroSoft, PictureTel and PolyCom. The proposal is supported by a number of other North-American companies. The proposal is based on technology used in MicroSoft NetMeeting and PictureTel LiveShare Plus.

The principles of this recommendation are described in Figure 9.

The application runs on a host. The screen information is transmitted to the other participants of the conference. The other participants can control the application by using mouse and keyboard. Windows is not required. However, if Windows is used, all participants may switch between applications as if the applications were running on their PC. The only restriction is that information from the clipboard of other PCs than the host cannot be copied into the application(s).

The transmission of the screen information and control information will use traditional T.120 channels, and full T.120 functionality is available.

T.SHARE will in principle specify two protocols:

- The main protocol is the protocol which will be maintained and further processed
- In an annex a protocol which secures compatibility with MicroSoft NetMeeting and PictureTel LiveShare will be specified. This protocol will not be maintained, and will be withdrawn after a period to be defined (e.g. three years).

Several observations can be made on this proposal:

a) It is proposed to standardise a new application, a logical evolution to secure interoperability between applications, but in conflict with the argument that applications are a subject for competition, not standardisation.

b) One of the sources of the proposal is MicroSoft, a company which is large enough to establish de facto standards.

c) It is proposed to standardise principles which are already used in Internet products. This is an indication that in certain areas standards designed for traditional telecommunications applications will also be used in products designed for Internet. In other words, the communication between traditional telecommunications networks and Internet will be simplified.

d) The proposal, supported by a number of North-American companies, is to some extent in conflict with the decision made by ITU-T SG 8 to develop CDH protocols for multiparty conferences.

e) Intel has accepted that a protocol which is not compatible with their application sharing protocol, is standardised. Furthermore, Intel has declared that there will not be further revision of the present application sharing software, the new software will be based on T.SHARE.

f) An underlying question is – should protocols covering all relevant scenarios be standardised, or should attempts be made to standardise protocols which are simpler and which are functioning although they may not cover all possible scenarios.

By tradition the Internet environment has prepared their own standards, RFCs. However, some standards developed by ISO or ITU-T on algorithms for coding of audio and moving image have been used. There is also a trend to remove the border between RFCs and formal standards developed by ITU-T and other standardisation organisations.

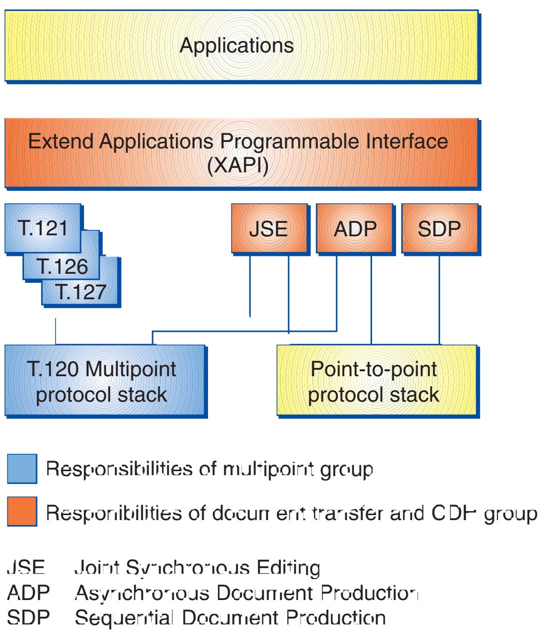



*Figure 8 Proposal for organisation of the work on CDH*

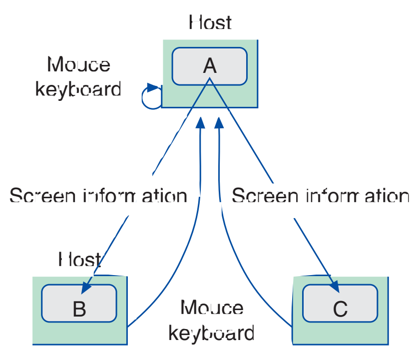



*Figure 9 Principles of T.SHARE*

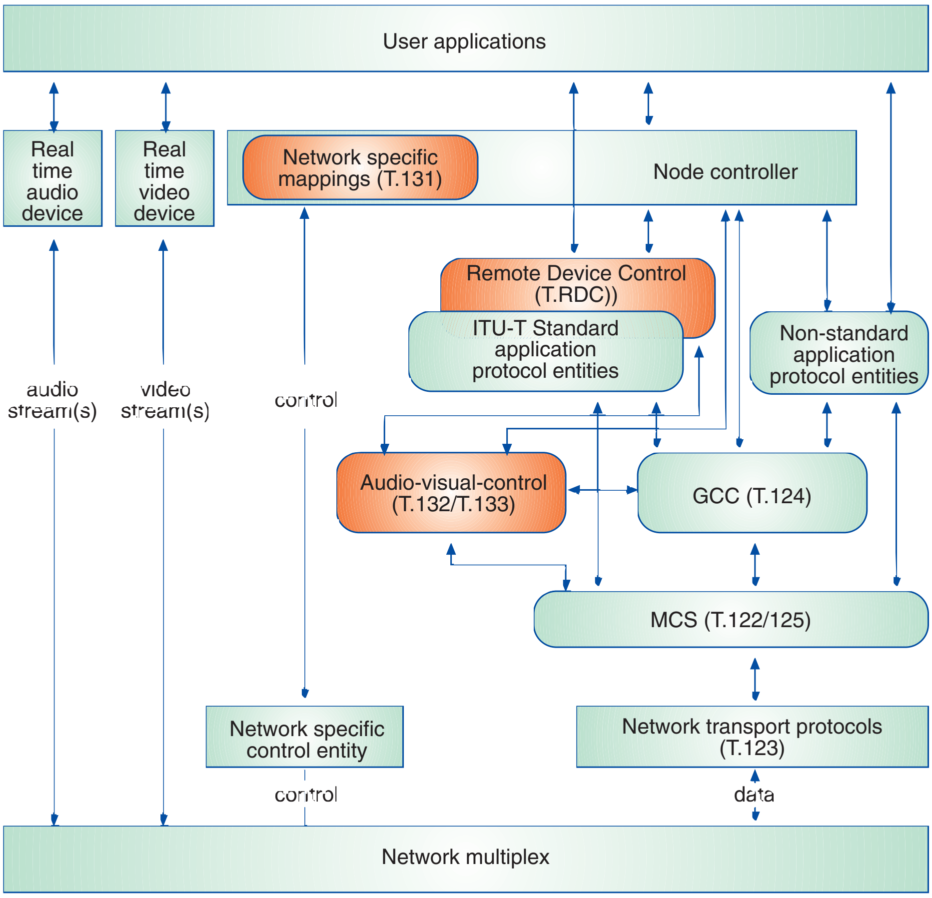



*Figure 10 Relations between the T.120 series recommendations and the planned T.130 series recommendations*

### 4.4.2 Network interworking and applications interworking

Network interworking is usually no problem for data conferences and for audiographic conferences where two separate connections are set up. The present standards for multiparty video conferences are based on the condition that all participants who receive the moving image have to have the same video coding algorithm, and to transmit/receive the coding image, audio and data at the same speed. In most cases these participants are connected to the same network. However, gateways do exist between LANs and ISDN which support the principles of the ITU-T H.320 standard, and thus offer the user a possibility to participate in a multiparty conference from a terminal on the local network. Participants may also be connected to the MCU via leased lines. These conferences where the video coding algorithm and the transmission speed are identical are identified as homogenous conferences.

Conferences where the participants are connected to different networks (ISDN, Internet, ATM, etc.), different video coding algorithms are used, and where also graphics and audio might use different coding algorithms, are described as heterogeneous conferences.

Standards addressing these issues are on the way. Initially, a single recommendation identified as T.AVC was planned. Now the objective is to prepare a set of recommendations identified as the ITU-T T.130 series. The structure of Figure 2 can be extended as indicated in Figure 10.

The number of recommendations in the T.130 series is not yet fixed. There will be an introductory recommendation, T.130. There is work on

- T.132 – Audio Video Control: Infrastructure Management
- T.133 – Audio Video Control: Service Management.

Drafts are available. It is planned to approve these recommendations at study group level in 1997. However, there are still a number of complex, unsolved issues; the plan may fail.

A network related recommendation, T.131 – Protocol for Network Specific Mapping of Real Time Audio Video Elements, is planned to be approved in 1998.

One of the issues discussed is whether control of remote devices (cameras, microphones, VCRs, etc.) should be an integral part of the already planned recommendations, or be a separate recommendation (T.RDC).

Most of the functionalities specified in the T.130 series are based on the use of an MCU or a server. Scenarios where the in-band signalling is based on ITU-T Recommendation H.221 (equipment connected to ISDN or leased lines), or ITU-T Recommendation H.245 (PSTN, ATM or LAN) will be covered.

A control protocol for network interworking will be defined. Control mechanisms for transcoding (e.g. between H.261 and MPEG) as well as mechanisms enabling the user to specify and control Quality of Service, will be prepared.

Whether T.131 and T.132 should be merged or not is another issue. A decision to merge these recommendations will probably result in a delay.

ITU-T recommendation T.133 will cover

- Video switching
- Video processing (e.g. Continuous Presence)
- Mixing of audio information
- Identification of audio and video sources
- Chairman control.

An example is described in Figure 11. A Continuous Presence function presents images from several sites (e.g. five sites). One of the images is larger than the others. Additional information (video, documents, etc.) can also be presented.

The present Telenor video conference service (Telenor Møtepunktet®) offers a Continuous Presence function where images from four sites are presented on one screen. However, when the new recommendations are in force more flexibility can be offered. Some of the functions overlap with functions specified in the T.120 series recommendations. One solution is to extend ITU-T Recommendation T.124 to cover T.130-based functionalities.

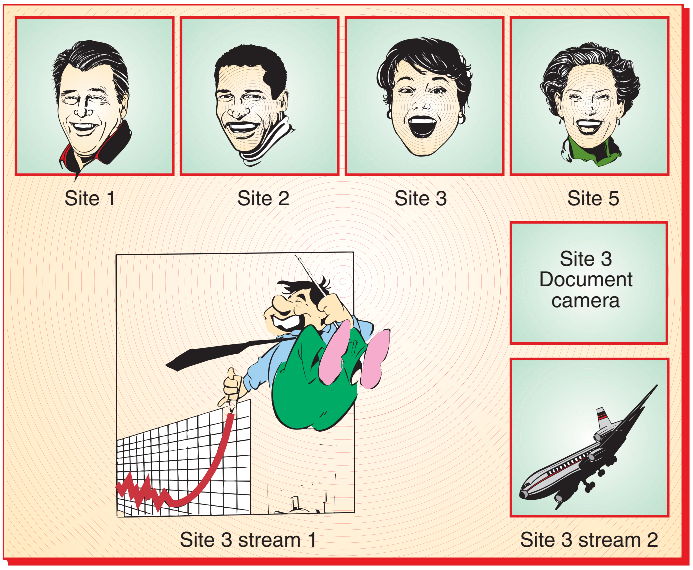



*Figure 11 A Continuous Presence presentation*

## 5 Closing remarks

The importance of standards can be illustrated by the success of the facsimile. Prior to the creation of the facsimile standards, a facsimile machine could only communicate with other machines made by the same manufacturer. The consequence was a few, expensive machines on the market. Today, people take it for granted that when they send a fax, it will work no matter what brand of machines are sending and receiving. The price of a fax machine has reached a level where it is interesting to home users as well as business users.

In much the same way, the T.120 series of standards defines a means to communicate multimedia across various networks. As companies develop software products based on these standards, they will be able to communicate with each other. The T.120 series of standards are also creating a bridge between several networks, PSTN, ISDN, Internet/Intranet, ATM and LAN. The T.120 series standards will be an important element in the multimedia applications that will be developed in the coming years.

# Charging of ATM services

BY RAGNAR ANDREASSEN, ØYVIND BREIVIK, EINAR EDVARDSEN, THOR ESKEDAL, NINA KLOSTER, OLAV ØSTERBØ

## 1 Introduction

Developing the ATM networking concept to its current state of maturity has for several years been a major effort in research and standardisation. In that process, most important aspects of the concept have been studied thoroughly and in depth.

Charging and billing are traditionally operator internal responsibilities. For this reason, and perhaps also for other reasons related to the competitive nature of the topic, the charging and billing aspects of ATM have received less attention than other operational issues. Now that large scale commercial deployment is imminent, achieving insight into charging and billing of ATM services is of vital importance for both customers and operators. Generating such understanding over a broad range of questions related to charging and billing of ATM services constituted the main motivation for forming the European ACTS project CA$hMAN. The project consists of several European companies, including Telenor R&D and Ericsson from Norway.

To develop a good and sound billing system many aspects concerning both operators and customers have to be taken into account. For a network operator it will be essential to achieve customer satisfaction and good network utilisation, for thereby to increase the revenue. This means that a network operator has to put requirements on how the charging scheme should operate and be implemented. Below is mentioned some of these requirements [7]:

- Cost-recovery (the pricing should reflect the network cost for an average over a range of services and customers)
- The total billing system should be cost effective and technically feasible to implement
- The pricing structure should be understandable by customers and salespersons
- Pricing should be flexible – ability to tailor to customer and market segments
- Provide economic incentive to upgrade network sufficiently to provide good QoS
- Encourage responsible use of network by customer.

For the customer the main goal is service satisfaction. Even as the operator puts requirements on the charging schemes, the customer will put requirements regarding charging aspects of the services offered. These could be:

- Clear, predictable and traceable call charges
- Comparison with competitors' prices possible
- Clear relationship between cost and service delivered
- Possibility to trade quality against cost.

This article will give an overview of some different methods of charging/pricing of ATM services. Since our work on these issues was initiated by the CA$hMAN project, we will link general thoughts and considerations about pricing policies for ATM to the work undertaken by the project.

To give a short summary of the article, some introductory remarks regarding the special features of ATM relevant to charging follows this introduction. Thereafter follows a short presentation of the CA$hMAN project. In Chapter 2, some methods for ATM charging is presented, from the most simple solutions to more sophisticated ones. The chapter is summed up by introducing the special charging algorithms the CA$hMAN project has decided to investigate in more depth. In Chapter 3 is outlined a general discussion about the billing system as a complete system for charging ATM services. The discussion covers which components in the network would be involved in billing issues, how different services could be reflected in the billing system, and considerations about the reliability of a total billing system. In Chapter 4 we again turn the focus to the work undertaken in the CA$hMAN project, where investigation of different charging algorithms through user experiments are stressed. The chapter describes the experiment platform used, what questions we try to answer by conducting experiments, and the results we have achieved so far in the project. In Chapter 5 some consequences for the network operators are discussed, and finally Chapter 6 gives some concluding remarks and some ideas of future work to be done.

### 1.1 Some aspects of ATM relevant to charging

From the initial idealistic ideas of creating a simple and universal system for asynchronous transfer, ATM [8] has developed into a highly sophisticated networking concept. Although being perhaps *the* most universal standardised networking concept developed until now, the intended simplicity vanished a long time ago. It should not be surprising then that the sophistication of the networking concept may also imply sophisticated charging. The purpose of this section is to identify and outline aspects of ATM that may have bearing on questions related to charging.

In ATM, fixed size units are switched based on the principle of virtual connections. Being asynchronous, the switching and transfer rely on statistical sharing of network resources. Virtual connections and statistical sharing of resources are as such old concepts, but a quite revolutionary property of ATM is that these concepts are combined with contractual guarantees on service qualities. This observation has several far-reaching implications, one of them being that the network operator must closely watch ingress traffic, and if necessary impose traffic filtering on the traffic entering the network in order to be able to fulfil the contractual obligations.

When a customer sends a service request for a new connection to the network, a proposal is at the same time made for a traffic contract. There is no guarantee that the network will actually accept the proposal, guarantees apply only after the contract is made. The process of evaluating such service requests is denoted Connection Admission Control (CAC). A possibility (at least theoretically, this is not standardised) may be that the customer at the same time requests one of several possible tariffs for the service (see Section 2.4.1). Other elements of the contract proposed will be the type of service to be used for the connection, i.e. the ATM Transfer Capability (ATC), and the parameters of the policing mechanism (Usage Parameter Control (UPC) parameters).

The UPC functions and the transfer capabilities are defined in [2]. The transfer capabilities relate to what kind of resources must be allocated in the network to provide a service of a certain kind. The type of policing functions to be used is also closely related to the choice of ATC. Using ITU-terminology (ATM-forum have their own definitions, also with slightly differing semantics), four ATCs are defined: Deterministic BitRate (DBR), Statistical BitRate (SBR), Available BitRate (ABR) and ATM Block Transfer (ABT). In the CA$hMAN project, only the first three of these have so far been considered.

For the DBR ATC, network resources must be allocated to sustain sources sending at a continuous peak rate. Accordingly, the UPC parameters are only related to the peak rate of the offered traffic, i.e. restricted to the two parameters defining the peak rate policing: Peak Cell Rate (PCR) and Cell Delay Variation Tolerance (CDVT).

For sources that may not need the same amount of resources allocated, but still require quality guarantees, the SBR ATC is defined. For such connections, the traffic contract will basically contain the two peak rate parameters, and two additional parameters related to the foreseen burst level variability of the source, named Intrinsic Burst Tolerance (IBT) and Sustainable Cell Rate (SCR). The choices made on IBT and SCR will influence the amount of resources that must be allocated in the network.

The last ATC considered in the CA$hMAN project is the ABR ATC, which is basically a 'best effort' service defined with feedback rate-control mechanisms. The ATC is defined with a Minimum Cell Rate (MCR), denoting a guaranteed lower bound on available capacity for the source, a Peak Cell Rate, and an Allowed Cell Rate (ACR) that will vary dynamically between the peak rate and the minimum rate, reflecting the 'best effort' component of the service.

Other quality parameters that may be agreed for a connection in a traffic contract, 'orthogonal' to the 'service plane' spanned by the ATCs, may be related to loss probabilities and delay properties of transmitted traffic, and the 'priority level' of the traffic. All these parameters will influence the amount of resources that must be allocated in the network to provide a service, and may thus also be possible discriminators in pricing schemes based on resource usage.

### 1.2 The CA$hMAN project

The ACTS project CA$hMAN(Charging and Accounting Schemes in Multi-Service ATM Networks), is a consortium consisting of companies from several European countries. Network operators, hardware manufacturers, universities and software developers are all co-working to solve different tasks relating to charging of ATM services. Since some underlying strategies of charging are operator confidential, charging schemes are not an issue for recommendations. The main goal is, as stated in the CA$hMAN project summary for 1996, to *"study, develop, implement, verify and compare charging and accounting schemes for ATM networks"*. The outcome of the project will, however, expectedly impact on standardisation for the structure of accounting models, on the TMN architecture related to accounting management and requirements on the processing and monitoring capabilities to support the charging mechanisms. To do this, experiments and field trials with real users are highly prioritised, and the use of ATM National Hosts for conducting them has been stressed. SUPERNET in Norway, TRIBUNE in the Netherlands and EXPERT in Switzerland are all research networks which the CA$hMAN project hope to be able to take advantage of. The CA$hMAN project deals with charging strategies at the ATM level.

The CA$hMAN consortium consists of skilled people both within teletraffic theory for developing charging algorithms, and within exploration of how charging impacts on network management architectures. Experienced hardware constructors are also part of the CA$hMAN team to build prototype equipment able to support different charging algorithms. Hence, the consortium consists of people with many different skills, who together form a group that is able to evaluate the charging schemes from different angles.

## 2 Charging algorithms for ATM

Generally, there may be a rather broad range of possible charging algorithms for ATM depending on the parameters and the measurements they depend on. The simplest one is obviously the flat rate, e.g. the subscriber pays a fixed amount per month. This simple algorithm gives no incentive to use the network resources in a particular way. Contrary to the flat rate pricing scheme, which is independent of the actual use, one reasonable principle is that the charge in a reasonable way should reflect the actual resources a connection occupies in the network. Such schemes are commonly denoted usage based charging (UBC). There may be some different ways of achieving this. The UPC function (with parameters negotiated at call set-up) will upper bound the traffic conveyed by the network over a connection. One possibility could be to charge by algorithms derived from the traffic contract and the time duration. Another possibility, which is investigated in CA$hMAN, is to charge according to some traffic measurements. In CA$hMAN these measurements are obtained by introducing the important notion of effective bandwidth, which reflects the actual usage of network resources. Some important properties and implications of effective bandwidth is mentioned in Appendix I.

The different possible charging schemes may be listed according to the issues mentioned above starting with the simplest ones. We must, however, not forget that the different ATCs may be charged according to schemes which may result from other considerations than pure traffic aspects. As an example it seems reasonable that ABR services will be charged lower than DBR or VBR (for the same traffic volume) because of the lack of guaranteed bandwidth.

Another important issue is the implementability of the charging schemes. If the extra cost for implementing a complex charging scheme is very high the benefit in terms of better performance is of less value.

In the following some general aspects of some possible and relevant charging schemes will be briefly discussed. In Figure 1 is illustrated how charge and mean rate relate for some of these schemes.

### 2.1 Algorithms based on flat rate

As illustrated in Figure 1a), this charge is only based on a flat rate (e.g. per month). It will mainly depend on the type of access link chosen including the bitrate. There may, however, also be other parameters defining classes of subscribers. It may be worth mentioning that although the charge is independent of the characteristic of a particular connection, both UPC and CAC are applicable to guarantee the QoS.

The flat rate does not give any incentives to use the network resources in some particular way, the charge is independent of the number of connections, the traffic characteristic, and the time duration. Although this charging scheme is simple, the subscribers will benefit from the fact that they always will be able to predict the cost of their communication services.

Flat rate policies are inherently applicable to the Permanent Virtual Channel (PVC) services that are now being offered. These services form direct rivals to the traditional flat rate leased line services with the asset of offering more flexible capacity agreements. With the advent of Switched Virtual Channel (SVC) services more elaborate schemes may be introduced.

## 2.2 Algorithms based on traffic contract and call duration

For DBR and SBR services the contract parameters play an important role for the traffic management. For DBR the relevant parameters are PCR and CDVT and for SBR the parameters are PCR, CDVT, SCR and IBT. From these parameters it is possible to calculate an equivalent capacity and the charge could be proportional to that capacity multiplied by the call duration. For a given set of such policing parameters, the charging algorithm is still insensitive to traffic volume, and Figure 1a) applies also to this kind of charging.

The main drawback with a charging scheme based only on traffic contract is that the users must pay for an assumed amount of traffic, whether it is used or not. So this scheme gives no reduction in the charge if the traffic sent is substantially lower than the traffic contract. On the other hand, this scheme gives a strong incentive to choose a contract that closely matches the generated traffic.

## 2.3 Algorithms based on traffic volume

A purely volume based charging scheme is illustrated in Figure 1b). The main objective to charge according to traffic measurements is that users should pay an amount that somehow reflects their real usage of network resources. To obtain this goal different measurements are possible, ranging from plain cell counts to sophisticated estimations of different traffic parameters.

The main objection against only using measurements for charging in ATM networks is that this type of algorithms are independent of the traffic contract. This means that users have no incentive to choose a traffic contract that tightly matches the source characteristics. It is likely that the CAC procedure to a great extent will depend on the contract parameters, so for the ATCs bounded by some CAC algorithm (mainly DBR and SBR), the requested resources at call set-up should somehow be reflected in the charge. For the ABR services the situation is different, where apart from the minimum guaranteed cell rate (MCR), the ABR users may share the unoccupied resources in the network. So for ABR the traffic beyond the MCR could well be charged according to only traffic measurements such as cell count.

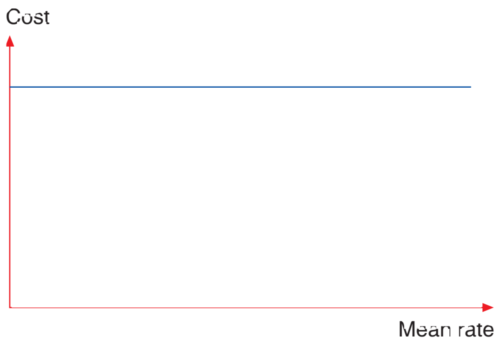



Figure 1a Volume insensitive algorithms

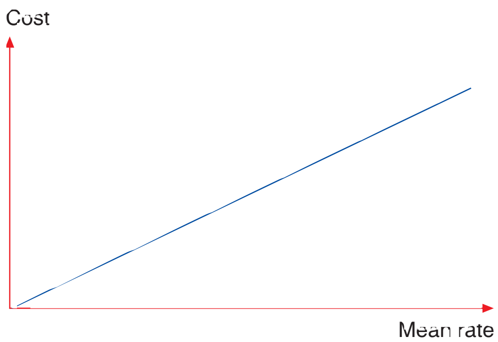



Figure 1b Volume-based algorithm

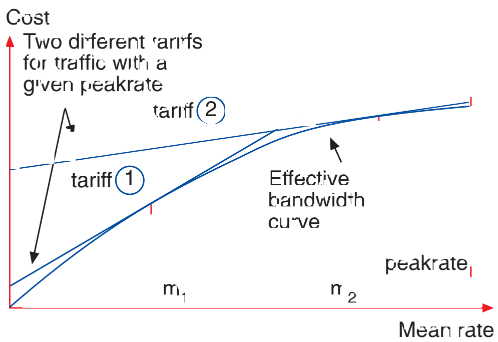



Figure 1c Kelly's charging algorithm

*Figure 1 The effective bandwidth and charge as a function of the mean bitrate for some different charging schemes*

## 2.4 Algorithms based on traffic contract, call duration and traffic volume

As mentioned above it is likely that a satisfactory charging scheme for ATM will contain all the three aspects mentioned above. One part of the algorithm will be a flat rate independent of the traffic sent into the network. In addition, there will be a traffic dependent charge based on both traffic measurements, call duration and traffic contract parameters. It is also possible that other traffic parameters (which are not part of the traffic contract for the different ATCs), such as an estimated mean rate, will be a part of the charging scheme. Such approaches, based on the concept of effective bandwidth, have been investigated in the CA$hMAN project where two charging schemes are implemented in the testbeds. These are *Kelly's charging algorithm* and the *Two tax-band algorithm*, both described below.

### 2.4.1 Kelly's charging algorithm

This algorithm is based on cell count and time duration plus a possible extra set-up charge. The cost of a connection is then given by the formula:

$$COST = C_T T + C_V V + C_A$$

where $T$ is the time duration and $C_T$ is the charge per time unit, $V$ is the traffic volume and $C_V$ is the charge per volume of traffic carried, and $C_A$ is a fixed charge per call. The tariffs $C_T$, $C_V$ and $C_A$ will depend on the traffic contract parameters negotiated at call set-up, but they could also depend on other traffic parameters, for instance an estimate of the actual mean cell rate of a connection. One possible choice of the parameters is derived by Kelly [1] and is given in Appendix I. For this particular choice of parameters the tariff will encourage the users to give the best estimate of the mean rate $m$ to get the cheapest charge. How tariff and mean rates relate in the Kelly charging algorithm scheme is illustrated in Figure 1c): Users submitting traffic with mean rate close to $m_1$ should prefer Tariff 1 to Tariff 2.

The charging scheme above may also be a good choice for ABR services. The essence in this approach is that the traffic up to MCR is charged at a flat rate per time unit, and the volume above the MCR is given a rate per volume which should be less than the corresponding rate per volume for DBR and SBR traffic. Anyhow, the result will give a charging function which is on the same form as above, but the tariff parameters $C_T$, $C_V$ and $C_A$ must be chosen differently for ABR services.

### 2.4.2 The two tax-band charging scheme

A charging scheme based on Kelly's algorithm will only depend on the duration of a connection $T$ and the volume $V$. This means that two connections with the same duration and volume will be charged equally, so there will be no extra charge for burstiness by applying this formula. For example, an on/off source with different burst length will be charged the same if it has the same peak and mean rate, in spite of the fact that the source with the longer bursts will be more difficult for the network to carry.

One way to take burst length into account is to implement some kind of burst detection by sorting the traffic flow into two categories – one for high intensity and another for low intensity. Then, by charging the first category higher than the other one, we are able to better identify and charge bursty traffic according to resource usage.

The above charging scheme is implemented by defining a small measuring interval $t$, over which we measure the number of cells carried $V_t$, and classify the interval of being of type I or II according to $V_t \leq K$ or $V_t \geq K$ where $K$ is a constant depending on the interval $t$. Then the two tax-band charging formula takes the form:

$$COST = C_{T1}T1 + C_{T2}T2 + C_{V1}V1 + C_{V2}V2 + C_A$$

where $T1$ and $T2$ are the total duration of intervals of type I and II; ($T1 + T2 = T$). Similarly, $V1$ and $V2$ are the total volumes of cell generated in type I and II; ($V1 + V2 = V$). The value of $K$ is chosen to be less than $ht$ (which is the volume generated by the peak rate $h$ in the measuring interval of length $t$, and one possible choice is to set $K = 1/2ht$). The tariffs $C_{T1}$, $C_{T2}$, $C_{V1}$, $C_{V2}$ and $C_A$ may be given as functions of the contract parameters, but also additional parameters may be included. One set of tariffs may be obtained by a similar procedure as for Kelly's algorithm; however, the expressions get more involved and it also requires that the users must specify their estimate of the mean values in each tax-band and also an estimate of the portion of time in each tax-band.

### 2.4.3 The CA$hMAN approach to usage based charging

Charging and tariffs are not present only to collect money from the customers, but can also be actively used to derive information suitable to optimise the network utilisation. For instance, by tailoring the tariffs to the choice of traffic contract parameters, the users are encouraged to choose tariff and contract parameters that matches his traffic profile (see Section 2.2). Without such a linkage, the users do not have incentives to give adequate suggestions for contract parameters. By making reasonably good choices, both parties may profit. The users by having lower bills, and the network operator by using the information to optimise network utilisation. However, contract parameters only define the upper limits for the traffic a customer is allowed to send, and do not reflect the traffic he actually will send. An idea worth following, is therefore to investigate whether it is possible to derive more information from the users – information that can be used to further increase network utilisation. As pointed out in Section 2.4.1 the mean value of the traffic has been proposed to be such a useful parameter.

It is not obviously clear that a user is able to estimate the mean value of his intended traffic. But on the other hand, whatever knowledge the user posesses may be of value to the operator in optimising network utilisation. The user may also be motivated to improve his estimates if he receives the right incentives and he may learn by experience, possibly aided by suitable "intelligent" functions implemented in his communication equipment. The task to be solved is to implement a charging scheme that has the necessary incentives for a customer to provide the network operator with adequate information. The aforementioned algorithms (Section 2.4.1 and 2.4.2) have the needed properties that may encourage the user to give good estimates.

As indicated, there are many uncertainties present in the most advanced implementation of UBC, and there are a number of open issues to be investigated. For instance, we do not know

- Whether the potential gain to the network is large enough
- Whether we can load the customers with more 'duties than already done'
- Whether the incentives for the customers are large enough
- Whether the incentives can be presented in an understandable format
- Whether it is technically possible to predict mean rate estimates good enough to be used in CAC in order to increase network utilisation.

To answer these questions the CA$hMAN project has implemented an experimental platform with the most fundamental functionality included. The platform incorporates the minimum management functions and the capability to present on-line charging information to the user. The experiments are described in more detail in Chapter 4.

## 3 Aspects of billing support

In order to introduce and conduct any usage based charging scheme, a system that supports the operation and the management of the entire billing process is required. The billing system is a vital part of an operator's total network solution as it provides the means for securing revenue. The billing system is also essential in the handling of the customer care relation, e.g. traceability and logging of charging events are important in defence of customer dissatisfaction with possible subsequent invoice complaints. Operators strive to meet customer demands. New requirements on billing options are important to satisfy as the bill forms an important interface between the operator and the customer. With the introduction of new services, one such customer requirement could be a preference to receive one consolidated bill that covers the whole range of used services. Furthermore, marketing analysis (e.g. who are the big spenders and what services are they using?) and tariffing forecasting tasks (e.g. modelling of the revenue distribution of introducing new tariffs) may be alleviated by means of functions of the billing system.

A complete and comprehensive billing system is not yet available for ATM. From a commercial point of view the technology is relatively new, and a flat rate policy has initially been adopted – a flat rate charging scheme does not necessarily require an extensive and complicated billing system. With the introduction of more sophisticated charging schemes a more elaborate system is required. Increased competition resulting from the deregulation of the telecommunication market may create a driving force for the development and deployment of more sophisticated charging methods. A system that supports such deployments may represent an important competitive edge towards capturing market segments and new customers.

In general and in brief, the billing process in a telecommunications system may involve

- Measuring the usage of offered and utilised services
- Collecting and transferring the measured usage to an appropriate tariff system for charge calculations
- Associating calculated charges to the rightful customers, and
- Forwarding charges to an invoice system for subsequent payment processing that eventually turns into revenue.

This process is also applicable to ATM. The following sections discuss some of the functionalities and components required at different phases of the billing process relating to usage based charging schemes for ATM.

### 3.1 Components for realising usage based charging of ATM-Services

An ATM network comprises a set of interconnected switches that route the ATM traffic streams to their various destinations. ATM bearer services are offered to the customers at the fringes of the network; with access points that are typically attached to small edge switches. Within the core of the network a smaller set of high capacity backbone switches allow traffic to be concentrated and aim to assure reliable transport and interconnectivity across the network.

The provisioning and control of ATM bearer services as well as the management of the ATM network infrastructure require a set of support systems. The functions that are required may be classified into two categories: those that address the operations of the network and those that address the related business process. The former category is often termed the Operations Support System (OSS); the latter the Business Support System (BSS). The classification of these functions target two of the main areas of concern for the operator in the context of service provisioning and customer care, namely, how to automate the handling of the technology in question (e.g., fault management and configuration management) and how to automate parts of the business process (e.g., customer handling, tariffing and invoice processing, marketing analysis applications).

A total billing solution for an ATM network must be based upon the usage measurement functions provided by the network elements. It must also be integrated with the OSS for surveillance and configuration management and with the BSS for post-processing and tariffing purposes. Some central problems that will be encountered in assembling such a system are addressed below and outlines of possible solutions are discussed.

To handle billing, among the features that are required is a system that collects the usage data from the network elements and which adapts and relays the collected information to the post-processing systems contained within the BSS domain. Such a billing accessory is essential in interfacing the diverse usage measurement capabilities of the network elements. The measurements and the subsequent data generation (DG) of billing information is performed at the switches. For each active ATM connection, billing data is associated with and represented in Call Detail Records (CDR). These are accumulated in files, foreseen to be at 15 minutes or hourly intervals. One of the tasks of the billing auxiliary server alluded to is to collect these files from the switches at regular intervals. Connectivity to and from the billing server with the network elements is therefore required – a virtual billing network takes form, as depicted in Figure 2. The server must be able to collect different file and CDR formats and handle different decoding rules to conduct the function on a possible plethora of different switches contained within the network. A proprietary solution, coupled to a specific vendor switch element, will not do. As ATM networks evolve, both in size and complexity, and as new and unforeseen technology is introduced, novel switch billing capabilities will undoubtedly enter the picture. In this context, the billing server adaptability is paramount. It must be able to handle the variations and the mixtures of old and new network equipment in a flexible manner. The alternative, replacement or even alterations of billing components, as new switch technologies are introduced, is unquestionably an expensive and arduous option. Adaptability is also important in the context of interfacing the BSS. Existing operators that already offer other services (e.g. telephony) have their own post-processing system that has been exhaustedly exercised and well-carved to meet the particular needs of the operator. Integration with the existing post-processing system may very well be desired. The implication is that the

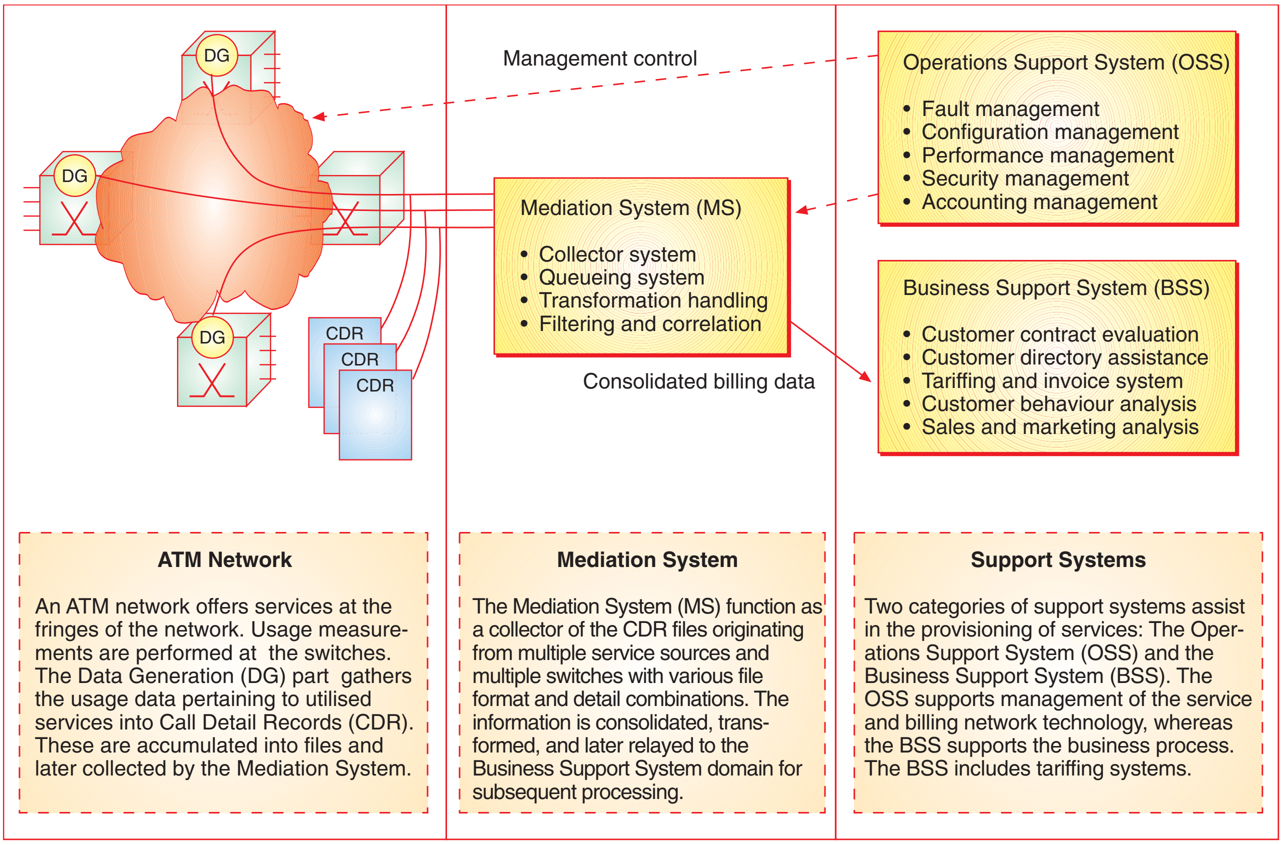



*Figure 2 A Billing System*

billing server must transform or convert the collected CDRs to a format and use encoding rules that are appropriate for the particular system. There are numerous such post-processing systems available and the billing server must therefore be able to offer a generic solution to this mediation function.

## 3.2 The bandwidth diversity aspect

ATM is a broadband technology, promising high capacity transmission services. Collecting the measured usage of these services pose a challenge to the capacity and to the storage capabilities of the entire billing system. The traditional telephony call is typically of short duration, in the order of minutes. The main unit of usage measurement is the time period in which a call occupies network resources. In addition to the usual time zones and distance tariffs, this time period historically forms the basis for usage based charging in telephony. The story may be more complicated for ATM.

In ATM, the granularity of the measurement unit for a volume based charging scheme[1] – the cell – is next to infinitesimal compared to the bandwidth that is available for use. ATM permanent virtual connections, which are normally held for a long duration, often months at a time, will soon exhaust the switch accumulators that keep track of the volume usage if such a volume based charging scheme is deployed. There is a need to relieve the switches and drain the accumulators at regular intervals. The billing server cannot simply collect the desired CDR once at the time a connection is released, which could be the case in plain telephony systems. Instead, partial complete CDRs must be collected regularly (e.g. every 15 minutes or at hourly intervals) until the connection is taken down. Additional and to some extent superfluous CDRs will therefore be generated; and at some intermediate stage an assemble function must be introduced to merge the related, although partial CDRs.

With the advent of switched virtual connections a new twist of the capacity problem takes form. The duration of switched virtual connections are found at the other end of the time scale to permanent virtual connections. It may be envisaged that switched virtual connections will have holding times that span periods of perhaps a few seconds instead of months. Noting that the frequency of the CDR generation for these types of connections has an inverse proportion to the small duration, it becomes apparent that the number of CDRs that need to be collected will put a serious workload on the billing system. The scene is troublesome but not entirely unmanageable. By means of network planning, peak hour predictions, and by estimation of the customer arrival process a certain upper threshold on the busy hour call attempts may be approximated. Clearly, the billing

[1] *Measured volume may be one of the components in a usage based charging scheme.*

system must be designed to sustain this threshold rate. Furthermore, it must cope with exceptional conditions. That is, events that cause the threshold to be exceeded. Such conditions cannot be excluded since an estimate of the threshold is just that, an estimate; and there will be variances and uncertainties bound to it. On the average, however, the frequency of CDR generation should be below the threshold as peak hours is not the norm. Processing overload conditions may be effectively controlled by means of buffering and queuing mechanisms: During overload conditions CDR files are placed in a queue and during idle times those that have been waiting are served. This mechanism forms a trade-off between capacity and buffer storage at the expense of delay in the billing processing.

## 3.3 The heterogeneous service aspect

Unlike telephony, ATM offers various bearer services with dissimilar characteristics and quality assurance. The different services give rise to different needs concerning the location of the usage measurements and consequently the CDR generation for a connection. It is also very much dependent on the charging policy of the operator. Take for instance the case of charging, based upon usage, for a VBR service. One approach is to measure the traffic that enters the network, i.e. at the ingress. Since ATM connections are bi-directional, and may even be asymmetrical with respect to bandwidth requirements, two measurement points must be considered, one at each entry into the network, as depicted in Figure 3a. This will produce two distinct and distributed CDRs, one for each direction, that must be collected, correlated, and assembled to enable the details of the bi-directional connection to be associated with a billed party. Why not measure the usage at one point only so that just one CDR is created, thus avoiding the need to perform the additional processing? This *could* lead to an inconsistent charging policy: charging based upon what enters the network for one direction and charging based upon what exits the network for the other direction seems like an odd course to take. Suppose that the two sources involved in a connection transmit identical traffic. By measuring the two streams at one point only (see Figure 3b), one may end up with a bizarre situation in which the two charges will differ (since cells may be lost due to congestion and the measured usage will therefore be dissimilar for the two directions). Measurements for a VBR service should therefore be distributed, and either take place at ingress or at egress of the network depending on an entry or an exit charging practice. A more elaborate policy might be devised to differentiate the charge for cells of different cell loss priorities. Cells that are tagged at the entry of the network (and hence are given lower priority than those that are not) are not assured deliverance to the destination in case of network congestion. One policy is to charge only for those cells that are delivered. Measuring only at the ingress (after the UPC function) is insufficient in this case. In such a scheme one may require that all four measurement combinations be taken into account (see Figure 3c). For the VBR service category, low priority cells are treated in a best effort service fashion. There is also a separate service category for best effort traffic, namely UBR, that treats all cells with the lowest priority. Given that all cells are treated equally, it is only required to measure at the two egress points to handle a scheme that aims to charge for the delivered volume. There are still other cases. If one considers multicast services the number of CDRs that must be collected proliferates. And that is not the end of the story. There is also the case of performing measurements

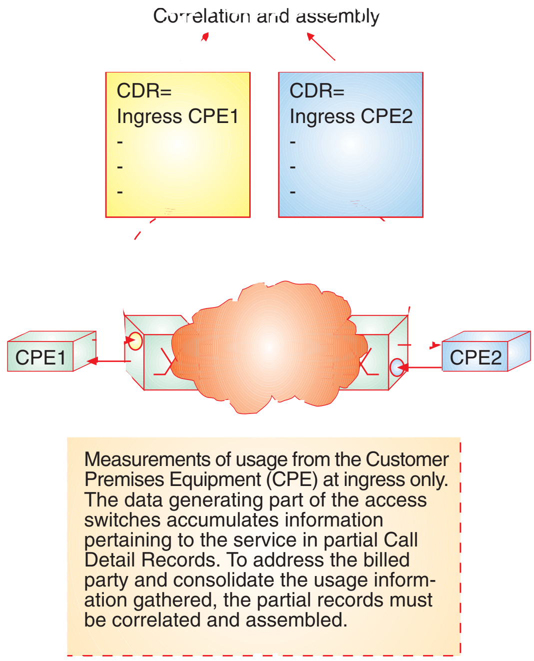



Figure 3a Usage measurements at ingress only, two locations

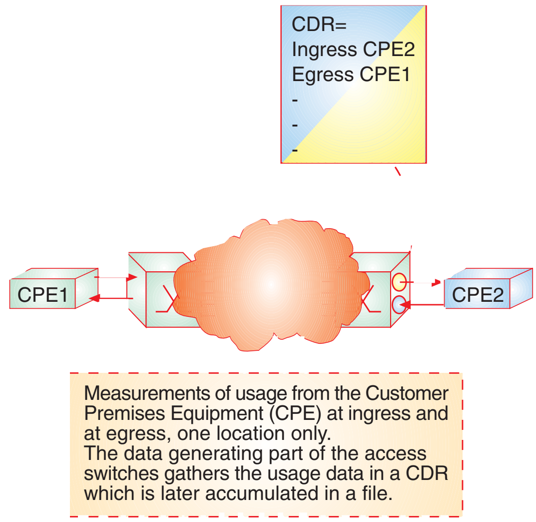



Figure 3b Usage measurements at ingress and egress traffic, at one location only

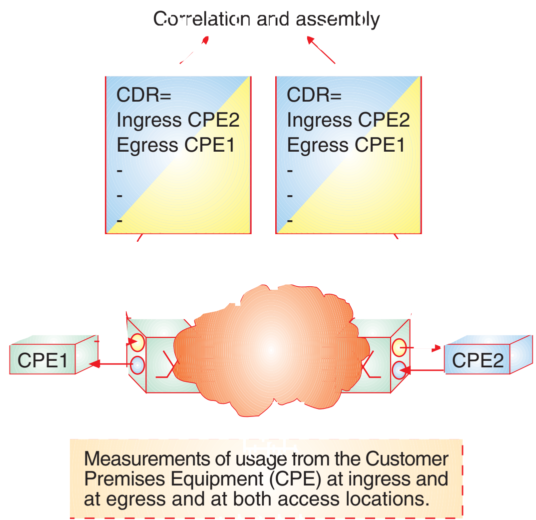



Figure 3c Usage measurements at two locations, both ingress and egress and at two locations

at the interface between operators for traffic that is in transit. There is a variety of possibilities with various degree of sophistication; and they all consume capacity of the billing system. It is important, however, that the billing system does not constrain the choice of charging policy. Ideally, there should be support for all combinations by enabling the desired and appropriate configuration to be set from the Accounting Management function of the OSS.

### 3.4 Reliability aspects

The reliability of such a system is vital: if the billing system malfunctions, the operator will be unable to collect payments from the customers for services offered and carried. The reliability does not merely depend on the mediation functions and the BSS but, since it depends on the virtual billing network, also on the ATM network. For instance, one can easily imagine a scenario in which one of the network links goes down. If such a broken link was used to carry billing information streams, from one or more switches, the function of the billing system is disrupted. There are various technology solutions to this one scenario, among them is protection switching. In a network with protection switching, nodes that detect severe link failures will re-route the traffic using other available links. But suppose then that the billing mediation function breaks down and that there are no backup solutions. What policy should the operator pursue? One could argue that, since the operator cannot get paid for the traffic being carried, the result should be revocation of the services, until the billing system is operational again. The alternative is to offer the services free of charge in the recovery period. The latter might seem like the most obvious policy, but there is a pitfall: customers might grow suspicious of the operator's billing system; and the very last thing an operator wants is breeding customers that question the operator's invoice functions. These customers will soon enough shun the particular operator and move their business to other providers[2]. Fault situations are not the only events that may endanger the operational state of the system. For instance, bringing new functionality or equipment into service must be performed in such a way as not to jeopardise the ongoing billing process. The key issue is that once a billing system is established and made operational it must remain operational, lest the operator faces the possibility of loss of revenue and customer dissatisfaction. The depicted scenarios aim to stress the importance of reliability and reliability on all components introduced to handle billing functions.

As is the case for any new technology system reliability cannot be guaranteed until initial unforeseen problems have been eradicated. ATM is a relatively new technology and ATM networks have yet to be exhaustively exercised in commercial environments. With heavy investments in the introduction of novel services using new ATM technology, a provider must clearly avoid dissatisfied customers. New ATM services may promise new revenue and more customers, but if the billing system is unreliable or even unpredictable both revenue and customers will be lost. Reliability is crucial in any telecommunication system component, but perhaps even more so in the context of billing. The novelty of the ATM technology makes this a difficult area.

[2] *Billing is the main source for customer dissatisfaction. Often as much as 50 % of customer complaints stem from billing functions.*

### 3.5 Charging and billing of composite services

The discussion so far has been confined to ATM in isolation. Taking a wider perspective, tomorrow's broadband networks will offer other and more intelligent services (e.g. Frame Relay and ATM Interworking, LAN Emulation, Video Conferencing, Shared Multimedia Applications, Voice over ATM, and so on), in addition to the pure ATM access and transmission functionality. The networks will also reach out and extend into other related technologies (e.g. residential broadband access). Indeed, ATM might very well become the common transport technology that other services and higher layer protocols will make use of, but these latter will be charged differently. The introduction of these value added services will require additional system components, such as access devices, application servers, gateways, and interworking units, that may have their own charging capabilities. A tremendous challenge is to integrate these components in a common billing system framework.

### 3.6 Perspective

A system to support billing is complex and expensive. The situation is no different for ATM. This chapter has given a brief overview of some of the issues that must be considered in constructing a billing system for usage based charging of ATM services. There are other topics that are closely related and to some extent coupled to the billing domain that have not been brought forward. One such topic is fraud detection, another is customer subscription handling. Security mechanisms is yet another important subject. Billing spans across many complicated areas. Billing systems, in the context of ATM, are still immature and a lot remains to be explored. This is the crux of the problem, and yet, it is what makes it so important. There may be good commercial opportunities in this field for early vendors of ATM charging and billing systems.

## 4 Experiments in CA$hMAN

In Chapters 2 and 3 we have discussed different charging methods and considerations which have to be taken into account in constructing a billing system based on the ATM technology. Constructing a total billing system is a major undertaking. Within the CA$hMAN project limits only pieces of such a billing system would be implemented. The aim of the project, as stated earlier, is to implement different charging schemes and investigate their feasibility through conducting user experiments. By doing this the projects gain experience of the implementation costs involved by implementing different charging schemes, how it effects the hardware construction and network utility and how users react to different charging policies. In this chapter we summarise what kind of experiments have been conducted in the first round of the project, what our goals for the experiments were, and the results obtained within the first project year. A brief overview of the experimental platform is also given to describe the experimental environment.

### 4.1 Background

In the CA$hMAN approach the charge of a call is due to time and volume usage based on a given traffic contract. By using the experimental platform developed, the user has an opportunity to also offer an estimate of the mean bitrate of traffic to be generated. This mean rate estimate actually constitutes a choice of tariff for the call to be made, so within one set of traffic contract parameters, the user may choose among many mean rates, i.e. different tariffs. A typical call can go like this: The user decides what kind of traffic the call will generate onto the network and chooses a tariff that he thinks will give him the lowest charge. If the user has chosen an expensive tariff, he should be able to renegotiate the choice of tariff. This gives the user the ability to influence on the charge for every call by selecting tariffs based on e.g. QoS limits, bearer capability, contract parameters, bandwidth, CDV restrictions, etc. Since the user earlier did not have this opportunity, the proposed charging concept introduces many questions of how a user understands the new concept and how he reacts to it.

In the user experiments, we wish to examine user behaviour and the possibilities an operator has to influence the user in order to achieve good network utilisation. Some of the questions we try to answer regarding user behaviour are:

- How does the user understand the relation between a tariff and the traffic he is going to send/receive? What does the user know about traffic characteristics, i.e. usage of bandwidth?
- How does the user understand the relation between time duration cost versus cost per volume of data? Is it cheaper to send an amount of data with short time duration and high bandwidth, or vice versa?
- Does the proposed charging scheme give the user a strong incentive to choose a tariff that gives the network an optimal utilisation?
- How willing is the user to trade quality against cost?

As pointed out earlier we also want to investigate the implications the charging system has on network utilisation, and how the charging algorithms and billing management system operate as a billing architecture. Questions we try to answer in these experiments are:

- What cost reductions can be gained by influencing the traffic process, i.e. shaping?
- How well does the proposed charging algorithm reflect the cost of network resources?
- What knowledge have we gained regarding implementation issues of the experiment platform?
- How well does the charging algorithm reflect the network cost of different traffic characteristics?

Both types of experiments are vital to carry out. The experiments regarding network utilisation and architecture can, and should be, conducted in a controlled environment. These experiments have therefore been carried out within a laboratory environment. The user trials, however, are more difficult to conduct. To get good and sound results many "ordinary" none-ATM knowledgeable people should be experiment users, and their choice of tariff should affect the payment of a service. Today, this is difficult to achieve. Also the user behaviour experiments have therefore taken place inside a laboratory environment. One possible way to conduct real user trials is to make use of ATM National Host networks. Both in Norway, Switzerland and the Netherlands testbeds have been installed with the ability to connect to the National Host networks. The aim would be to interconnect a group of experimental users at each site, who are willing to take part in the trials. Vital conditions for carrying out these user trials are that participating network operators are willing to allow these kinds of trials on their networks, and that representative and willing customers may be found for experiments.

## 4.2 The CA$hMAN charging experimental platform

An important idea in the formulation of the CA$hMAN project was the requirement to validate the implementation feasibility of the theoretical charging models developed in the project. Among the evaluation criteria for any charging model, the technical implications with regard to charging management will be an important factor. Making prototyping of the charging management systems will also make possible the investigations of user behaviour and user acceptance. General sources of information for the system described in this section are [9] and [10].

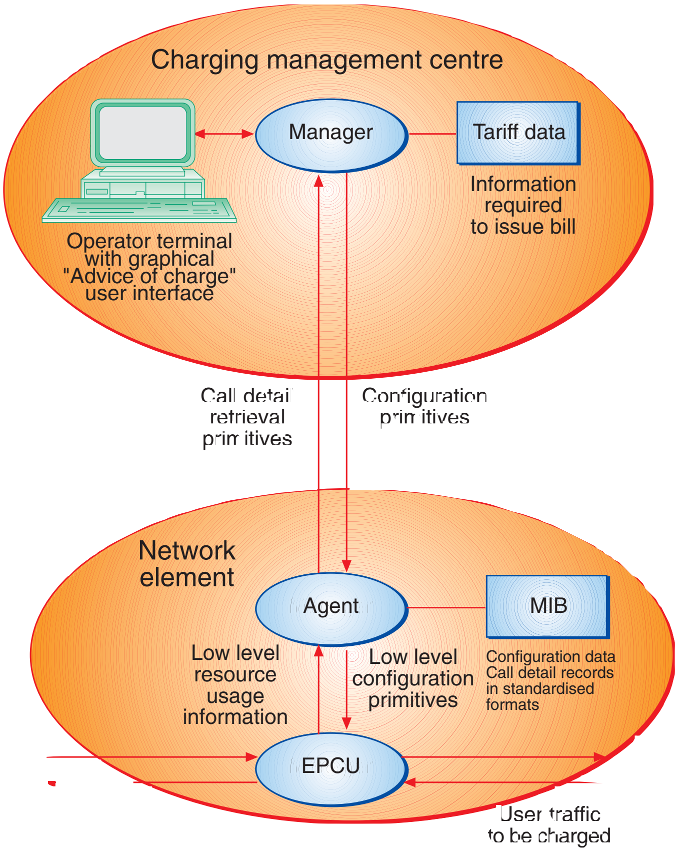



*Figure 4 The CA$hMAN charging management system*

Motivated by the above, a substantial effort has been made in the project to realise prototype charging management systems. The functional structure of this system is shown in Figure 4.

Describing the system 'bottom up', the user generated traffic enters the 'Ericsson Policing and Charging Unit' (EPCU). This unit carries out the 'low level' operations involved in the charging. For the simplest charging algorithm, these functions amount to cell counting and time measurements. Such measurement functionality would be a natural part of a switch in a real system, but in the CA$hMAN project the functional entity is realised in a separate piece of equipment developed from the general Ericsson exchange terminal unit ET-34 (see photograph in Figure 5). For the 34 Mbit link rates used for the transmission through the EPCU, implementing the time critical charging operations by general off-the-shelf processors is sufficient to fulfil real-time requirements. The EPCU essentially consists of two exchange terminals linked together through a specialised backplane. By combining two exchange terminals, the EPCU thus forms a bi-directional integral 'low-level' charging device.

Management systems work on abstract data models representing the network, so an abstract model of the charging unit is constructed and realised as a 'Management Information Base' (MIB). A set of primitives are defined, operating on this base. These may typically be defined as 'Set()' and 'Get()' operations on the elements of the base. The 'Agent' receives these primitives from the 'Network management centre', and must ensure that the state of the MIB is consistent with the actual state of the EPCU. To this end, a specialised 'low level' control interface is defined between the Agent and the EPCU. As the Agent is implemented on a general purpose computing platform, separate from the EPCU, it may be described as a 'proxy' agent. For reasons of simplicity, consistency and dependability, a preferred solution would have been to integrate the two.

Overall control of the charging system is executed from the 'Charging management centre' via the operator terminal. From the operator terminal, it is possible to configure charging and policing parameters for a connection, choose between charging algorithms and select tariff profiles. A 'Manager' is responsible for maintaining the tariff data base, and to handle the communication with the proxy agent. In the CA$hMAN implementation, the operator terminal is equipped with functionality to perform continuous advice of charge, and also graphically display running billing information for a connection. As the complete management system is implemented in a Unix environment running the X-protocol, the operator terminal may be displayed on any X-server, e.g. also the X-server on which the user application is located and executed. In this way, the user may get the running charging information displayed, simulating an 'advice of charge' service. In the development of the project, a more realistic advice of charge service based on user/network signalling is under consideration.

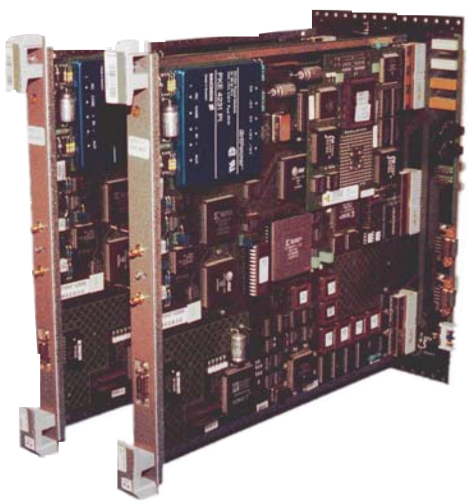


*Figure 5 The EPCU (Ericsson Policing and Charging Unit)*

The above described management network is of course a simplification of a realistic charging management network. As pointed out previously, there will be a large number of charging agents to be controlled, charging information for a single bi-directional connection will be generated at different locations and must be assembled consistently, and the configurations of charging and policing parameters for connections must be consistent. The diversity of services offered in ATM networks will thus give new challenges for management network designers. Not the least of these challenges will be the dimensioning and traffic handling in the charging management network itself! Even so, the efforts made in the project have contributed towards demonstrating the feasibility of constructing a management model for usage based charging, and also shown that the single prototype components required to implement the charging model may be realised within the limits of a moderately sized project team.

## 4.3 Experiment results

Results from the first round of experiments in the CA$hMAN project are documented in [11]. In these experiments the simple charging scheme by F. Kelly was evaluated against a backdrop of general and more detailed questions as stated in Section 4.1. The questions addressed the following areas of study:

- Properties of the scheme in relation to implementation
- Relation of the scheme with network operation
- Perception of the charging by user and customer.

Within all three areas useful information has been gathered.

In relation to the first and second bullet, developing and experimenting with the tools provided a number of insights into implementation issues. Some of the issues evaluated were

- Speed of calculation and transfer between hardware and software components
- Implementation complexity within hardware and software
- Construction design of a user friendly graphical user interface.

How the charging scheme reflects network operation and utilisation has been investigated by simulation with real traffic traces. Different experiments involving shaping and multiplexing of connections have been carried out, which verify the theoretical calculations. An interesting result is the reduction of charge caused by shaping, thus demonstrating that the chosen charging algorithms provide an incentive for users to improve characteristics of submitted traffic.

Regarding the third bullet above, many interesting results were attained. The users participating were non-project colleagues willing to run the CSCW (Computer Supported Co-operative Work) application Isabel and give us feedback regarding their understanding and feelings about the CA$hMAN approach to charging ATM services. The main results from these experiments were

- A user has a strong desire to adopt his traffic characteristics to suit the charge he is willing to pay, e.g. by means of shaping.
- A user prefers tariff choices explained by words in an understandable way, instead of mathematical figures.
- Some services are more difficult to predict than others as to what would be the best tariff choice.
- A user needs some knowledge of the traffic characteristics of the application he is running.

In the next round of experiments the project will continue to examine many of the same issues taking into account different charging schemes, more elaborate network management for the billing system and also more automation regarding advice to the customer about choice of tariffs.

## 5 Consequences for the network operator

Charging policy is one of the most important tools available for a network operator to control the utilisation of network investments. Tariffs may be used to differentiate between customers. For instance, if he wants to attract the big market of household customers, he creates a tariff that matches their situation as regards price profiles. High volume users or service providers will have other demands, and must be approached by other tariffs. We do not intend to give answers as regards what price level or tariff structure should be used in special cases. The main factor that establishes prices and tariffs, is the market.

The choice of charging policy depends upon a number of factors. For instance:

- Tariffs offered by other competitors
- The present utilisation of the network
- A general wish to attract/exclude special kinds of usage
- Coverage of investments and network maintenance
- The run for even higher profit
- Improve utilisation of network resources
- Avoid cannibalisation
- Protection against resellers
- Network stability
- Network flexibility
- Cost of implementing and running billing/charging systems.

The charging algorithms mentioned in Chapter 2 influence the above factors in various ways. Maybe none of them match the complete set of requirements a network operator may have. There is, however, a fundamental difference between flat rate charging (FRC) and the other charging schemes. While FRC does not require any measurements or logging functionality, all the others do. This leads to a dilemma. If one believes that the advantages of the FRC's simple scheme more than compensates for missing properties (Chapter 4.1), one may decide to build a network without charging functionality. However, charging policy depends on the market situation. What one actor does, influences immediately on the others. Consequently, to be able to respond to changing market impulses, one has to be prepared for shifting views of charging. This means that one has to make a choice flexible enough to respond to each demand from the market. If first excluded, it may be impossible to implement usage sensitive charging schemes at a later stage, due to technical limitations.

If the technical infrastructure for a complete billing system must be implemented whatever the choice of charging policy might be, then the main difference between FRC and the other schemes is much less apparent.

## 6 Concluding remarks and future work

Charging and accounting in ATM networks is a challenging and important field. A goal is to obtain a stable and well performed network, both from the user's and from the network operator's perspective. To achieve such a goal it is necessary to gain experience both from theory and experiments. In the CA$hMAN project these objectives are strongly focused. The results obtained so far supports the idea of usage based charging (UBC). Two schemes have been implemented in the laboratory testbeds justifying that UBC may well be introduced in a commercial ATM network. Due to the lack of paying experimental users the effect on the revenue for the network operators and on the network performance is difficult to predict, however, we believe that both the customers and the network operators can benefit from charging based on UBC.

Still, there are open and yet unsolved questions to be addressed. One example is how to charge the ABR services. Another area of interest is the question of making some advice of tariffs for the users. The network may possibly guide the user to obtain the best tariffs depending on his traffic profile, and thus raise the question of renegotiating of traffic contract and tariffs for ongoing connections.

The questions raised above, which are important both from the operator's and customer's perspective, are among the issues that will be examined in the future CA$hMAN work.

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## Appendix I. Effective bandwidth

Because ATM allows statistical multiplexing the network resources may be divided between the connections (users) in a statistical manner. This means that each connection on average needs less capacity than the peak rate; on the other hand, an allocation after mean rates will be too optimistic (in almost every case, also for CBR sources). The concept was introduced by Hui [3] for bufferless multiplexing, and further elaborated by Gibbens and Hunt [4], Guerin et al. [5] and Courcoubetis and Weber [6] to also cover multiplexers with finite buffers.

The idea of *effective bandwidth* is to assign a measure of resource usage which adequately represents the trade-off between sources of different types, taking account of their varying characteristics and also the requirements on QoS.

Based on mathematics, the effective bandwidth is defined through the arrival process of a source. If $X(t)$ represents the work generated by a source (i.e. the volume of bits arrived) in an interval of length $t$ we define the transform

$$\alpha(z,t) = 1 / zt \log E[e^{zX(t)}]$$

The transform above has some nice features which are important in practical use. First of all, the effective bandwidth defined above is linear, which means that the effective bandwidth of a sum of two or more independent cell streams is the sum of the effective bandwidth of each individual stream. Secondly, the effective bandwidth lies between the mean and the peak arrival rate of a source (up to the time $t$). The time parameter $t$ and space parameter $z$ are left undefined in the definition above and will be decided upon by the resource parameters such as capacity, buffer space and scheduling policy. To see this we refer to the following important result concerning the cell loss $L(c,b)$ on a link of capacity $c$ using a cell buffer of length $b$ [6].

Let

$$\alpha_T(z,t) = \sum_i \alpha_i(z,t)$$

be the sum of the total effective bandwidth on the link. Then the cell loss is approximated by the following expression:

$$\log L(c,b) \approx \sup_t \inf_z [zt\,\alpha_T(z,t) - z(ct+b)]$$

Let $z^*,t^*$ be an extremating pair in the expression above, then a QoS demand that the cell loss is below $e^{-\gamma}$ will limit the effective bandwidth in the following simple way:

$$\alpha_T(z^*,t^*) \le c^* = c + 1 / t^* (b - \gamma/z^*)$$

Stated in words: The sum of the effective bandwidths must be below an equivalent link capacity.

Although the expression seems to be linear in the sum of the effective bandwidths the relation is not quite easy to use as a CAC algorithm, since one needs to re-calculate a new pair of $z^*,t^*$ for each new call arrival.

Another fundamental issue is the problem of estimating $\alpha_T(z,t)$ for real traffic sources. One possible solution could be to make an on-line estimate of the effective bandwidth from the formula above. This needs a large number of calculations of exponential terms and seems for the time being not to be realistic. Another possibility which may seem to be appropriate is to estimate the effective bandwidth by considering the worst case traffic obtained from the traffic contract. Assuming negligible CDV these parameters are PCR for DBR type traffic, and PCR, SCR and IBT for SBR type traffic. The main drawback with this approach is that there might be a large difference between the contract and the actual use of network resources for a source.

To reflect the actual usage Kelly has proposed to apply a simple on/off model to estimate the effective bandwidth. We let $h$ be the peak rate and $m$ the mean rate of an on/off type source. Then the effective bandwidth will read:

$$\alpha(m,h) = 1/s \log[1 + m/h(e^{sh} - 1)]$$

where $s = zt$.

The nice thing with this simple formula is that it is easy to estimate the effective bandwidth by counting cells, and thereby estimating the mean *m*. (We assume that the peak rate *h* is known.) This gives rise to the famous Kelly's charging formula [1].

### Kelly's charging algorithm

Consider a SIR source and suppose that the mean value is stochastic and given by a variable *M* with expectation *m*, then Kelly has shown that the effective bandwidth formula above remains unchanged (where *m* is now interpreted as the mean of the stochastic variable *M*). Suppose that the network at call set-up requires the user to announce a mean value *m* and then charges the connection of an amount $f(m,M)$ where *M* is the measured mean rate for the connection. In [1] it is shown that the best choice of the tariff is to take the tangent of the curve $\alpha(M,h)$ at the point $M = m$. By this assumption one gets the following tariff:

$$f(m,M) = a(m) + b(m)M$$

where

$$b(m,h) = e^{sh} - 1 / s[h + m(e^{sh} - 1)]$$

and $a(m,h) = \alpha(m,h) - mb(m,h)$.

## List of abbreviations

| | |
|---|---|
| ABR | Available Bit Rate |
| ACR | Allowed Cell Rate |
| ACTS | Advanced Communications Technologies and Services |
| ATC | ATM Transfer Capabilities |
| ATM | Asynchronous Transfer Mode |
| BSS | Business Support System |
| CAC | Connection Admission Control |
| CBR | Constant Bit Rate |
| CDR | Call Detail Records |
| CDV | Cell Delay Variation |
| CDVT | Cell Delay Variation Tolerance |
| CSCW | Computer Supported Co-operative Work |
| DBR | Deterministic Bit Rate |
| DG | Data Generation |
| EPCU | Ericsson Policing and Charging Unit |
| IBT | Intrinsic Burst Tolerance |
| LAN | Local Area Network |
| MCR | Minimum Cell Rate |
| OSS | Operations Support System |
| PCR | Peak Cell Rate |
| PVC | Permanent Virtual Channel |
| QoS | Quality of Service |
| SBR | Statistical Bit Rate |
| SCR | Sustainable Cell Rate |
| SVC | Switched Virtual Channel |
| UBC | Usage Based Charging |
| UBR | Unspecified Bit Rate |
| UPC | Usage Parameter Control |
| VBR | Variable Bit Rate |
| VCI | Virtual Channel Identifier |
| VPI | Virtual Path Identifier |

# The frequency assignment algorithm used in the mobile network planning tool MOBINETT

BY RALPH LORENTZEN

## 1 Introduction

Telenor Research and Development is developing the EDP-based mobile network planning tool MOBINETT. Based on input data concerning traffic, field strength, interference, candidate base stations, available frequencies and cost data, MOBINETT proposes which base stations should be established and which frequencies should be assigned to which base stations. The objective is to minimize total cost. MOBINETT contains a frequency allocation module based on integer programming. In this paper the integer programming model and the corresponding solution algorithm are described.

The input to the frequency allocation module is a set of admissible frequencies (which need not be contiguous) and a given set of base stations where each base station must have assigned to it a required number of frequencies. For each base station certain frequencies may be preset and certain frequencies may be excluded. In addition, a compatibility matrix is given, which for each pair of base stations indicates to what extent they interfere. Based on this input the frequency allocation module in MOBINETT tries to allocate frequencies to base stations such that the frequency requirements are satisfied and the total interference is minimized. The frequencies are partitioned into groups. To the greatest possible extent frequency groups rather than individual frequencies should be allocated to the base stations.

The admissible frequencies have the form $K_0 + K_1 \times f$ where $K_0$ and $K_1$ are constants and $f$ is an integer. We shall refer to the individual frequencies by their integer $f$.

For certain base stations certain frequencies or frequency groups may be preset. Furthermore, for certain base stations not all frequencies or frequency groups may be admissible.

## 2 Notation and basic concepts

The following notation is used:

- $F$ Number of admissible frequencies
- $f$ Subscript denoting frequency
- $g$ Subscript denoting frequency group
- $A_g$ Number of frequencies in frequency group $g$
- $g(f)$ The frequency group which contains frequency $f$
- $B$ Number of base stations
- $b$ Subscript denoting base station
- $F_b$ Number of frequencies required on base station $b$
- $C$ Compatibility matrix with dimensions $B \times B$

The matrix $C$ is normally obtained from the output of a field strength prediction program. The elements $c_{bb'}$ of the matrix $C$ are either in the interval [0, 1] or equal to 2 or 3.

$c_{bb'} < 0.1$ indicates that the base stations $b$ and $b'$ do not interfere in practice.

$0.1 \le c_{bb'} < 1$ indicates that the base stations $b$ and $b'$ do interfere in the sense that ideally $b$ and $b'$ should not use the same frequency. If the same frequency is used on $b$ and $b'$ a penalty is incurred which increases with increasing $c_{bb'}$.

$c_{bb'} = 1$ indicates that if frequency $f$ is assigned to $b$ and frequency $f'$ is assigned to $b'$, then we must have $|f - f'| \ge 1$.

$c_{bb'} = 2$ indicates that if frequency $f$ is assigned to $b$ and frequency $f'$ is assigned to $b'$, then we must have $|f - f'| \ge 2$.

$c_{bb'} = 3$ occurs if and only if $b = b'$. It indicates that if both frequencies $f$ and $f'$ are allocated to $b$, then we must have $|f - f'| \ge 3$.

When $c_{bb'} = 1$ we say that $b$ and $b'$ *e-interfere*, and when $c_{bb'} = 2$ we say that $b$ and $b'$ *n-interfere*.

Based on the matrix $C$ we establish a series of undirected graphs, namely $GN$, $GE$ and $G1, G2, \ldots, G9$. The nodes in all these graphs represent the base stations. In $GN$ there is an edge between $b$ and $b'$ if and only if $b$ and $b'$ n-interfere. In $GE$ there is an edge between $b$ and $b'$ if and only if $b$ and $b'$ e-interfere. In $Gi$ there is an edge between $b$ and $b'$ if and only if $i / 10 \le c_{bb'} < (i + 1) / 10$.

In order to obtain a tight linear programming relaxation of the integer programming model we operate with *odd holes*, *EN-pairs* and *cliques*.

An odd hole with cardinality ≥ 5 in $GN$ is denoted by $HN$.
An odd hole with cardinality ≥ 5 in $GE$ which is not in $GN$ is denoted by $HE$.

An EN-pair $(E,N)$ consists of two sets of base stations $E$ and $N$ with $|E| > 1$ where all $b$ in $N$ n-interfere with all $b$ in $E \cup N$, and where the $b$-s in $E$ e-interfere with each other.

For an EN-pair $(E,N)$ we define $s(E,N)$ to be the subset of $N$ which results when we for all EN-pairs $(E',N')$ with $E' \cup N' \supset E \cup N$ remove from $N$ every $b$ in $N'$.

A clique in $GN$ is denoted by $CN$.

A clique in $GE$ which is not a clique in $GN$, and which cannot be written as $E \cup N$ where $(E,N)$ is an EN-pair, is denoted by $CE$.

A clique in $Gi$ is denoted by $Ci$.

## 3 The integer program

The frequency assignment problem is formulated as an integer program.

First we define the variables:

$$x_{bf} = \begin{cases} 1 & \text{if frequency } f \text{ is used on base station } b \\ 0 & \text{otherwise} \end{cases}$$

$$x_{bg} = \begin{cases} 1 & \text{if frequency group } g \text{ is used on base station } b \\ 0 & \text{otherwise} \end{cases}$$

$s_b$ frequency deficit on base station $b$

$$z_{f,Ci} = \begin{cases} 1 & \text{if the clique constraint associated with frequency } f \text{ and clique } Ci \text{ is violated} \\ 0 & \text{otherwise} \end{cases}$$

Then we formulate the constraints:

(1) $$\sum_f x_{bf} + \sum_g A_g x_{bg} + s_b = F_b$$

(2) $$x_{bf} + x_{b,f+1} + x_{b,f+2} + x_{b,g(f)} + x_{b,g(f+1)} + x_{b,g(f+2)} \le 1$$

(3) $$\sum_{b\in CE} x_{bf} + \sum_{b\in CE} x_{b,g(f)} \le 1$$

(4) $$\sum_{b\in CN} \left(x_{bf} + x_{b,f+1} + x_{b,g(f)} + x_{b,g(f+1)}\right) \le 1$$

(5) $$\sum_{b\in E} \left(x_{bf} + x_{b,g(f)}\right) + \sum_{b\in N} \left(x_{bf} + x_{b,g(f)} + x_{b,f+1} + x_{b,g(f+1)}\right) \le 1$$

for EN-pair *(E,N)* with $|N| > 1$

(6) $$\sum_{b\in E} \left(x_{bf} + x_{b,g(f)}\right) + \sum_{b\in N} \left(x_{bf} + x_{b,g(f)} + x_{b,f-1} + x_{b,g(f-1)}\right) \le 1$$

for EN-pair *(E,N)* with $|N| > 1$

(7) $$\sum_{b\in E\cup N} \left(x_{bf} + x_{b,g(f)}\right) + x_{b',f-1} + x_{b',g(f-1)} + x_{b',f+1} + x_{b',g(f+1)} \le 1$$

for all EN-pairs *(E,N)* and for all *b'* in *s(E,N)*

(8) $$\sum_{b\in HE} \left(x_{bf} + x_{b,g(f)}\right) \le \left(|HE| - 1\right)/2$$

(9) $$\sum_{b\in HN} \left(x_{bf} + x_{b,g(f)} + x_{b,f+1} + x_{b,g(f+1)}\right) \le \left(|HN| - 1\right)/2$$

(10) $$\sum_{b\in Ci} x_{bf} + \sum_{b\in Ci} x_{b,g(f)} - z_{f,Ci} \le 1$$

(11) $x_{bf} \ge 0$ and integer, $x_{bg} \ge 0$ and integer, $s_b \ge 0$, $z_{k,KL} \ge 0$.

$x_{bf}$ and $x_{bg}$ are only defined if *f* and *g* are admissible on *b*.

Finally, we state the objective function to be minimized:

(12) $$\min \sum_{b,f} c_{bf} x_{bf} + \sum_{b,g} c_{bg} x_{bg} + \sum_b c_b s_b + \sum_{f,Ci} c_{Ci} z_{f,Ci}$$

Here, the coefficients $c_{bf}$ and $c_{bg}$ are normally 0 initially. As will be seen, they may change during the solution process. The penalties $c_{Ci}$ are chosen to increase with increasing *i*, and the penalties $c_b$ are chosen to be large numbers.

For realistic cases the number of variables is reasonably small (~10 000), but the number of constraints can be quite large (> 150 000). We use a heuristic where we repeatedly need to solve the linear programming (LP) relaxation of the integer program. Most LP packages perform better solving the dual of such problems, i.e. linear programs with a reasonable number of constraints and a large number of variables. In the dualized problem it will be the dual variables which have to be integer. We therefore formulate the dual of the integer program and describe a heuristic to get a solution where the dual variables have integer values.

## 4 The dual of the integer program

The dual of the integer program can be formulated as follows:

minimize

(13) $$\sum_b F_b \pi_b + \sum_{b,f} \pi_{bf} + \sum_{f,CE} \pi_{f,CE} + \sum_{f,CN} \pi_{f,CN} + \sum_{f,(E,N)} \pi^1{}_{f,EN} + \sum_{f,(E,N)} \pi^2{}_{f,EN} + \sum_{f,(E,N),b'\in s(E,N)} \pi^1{}_{f,EN,b'} + \sum_{f,HE} \left[\left(|HE|-1\right)/2\right] \pi_{f,HE} + \sum_{f,HN} \left[\left(|HN|-1\right)/2\right] \pi_{f,HN}$$

subject to

(14) $$\pi_b + \pi_{bf} + \pi_{b,f-1} + \pi_{b,f-2} + \sum_{CE\ni b} \pi_{f,KL} + \sum_{CN\ni b} \pi_{f,KN} + \sum_{CN\ni b} \pi_{f-1,KN}$$
$$+ \sum_{\{(E,N);|N|>1,b\in L\}} \pi^1{}_{f,EN} + \sum_{\{(E,N);|N|>1,b\in N\}} \pi^1{}_{f,EN} + \sum_{\{(E,N);|N|>1,b\in N\}} \pi^1{}_{f-1,EN}$$
$$+ \sum_{\{(E,N);|N|>1,b\in L\}} \pi^2{}_{f,EN} + \sum_{\{(E,N);|N|>1,b\in N\}} \pi^2{}_{f,EN} + \sum_{\{(E,N);|N|>1,b\in N\}} \pi^2{}_{f+1,EN}$$
$$+ \sum_{\{(E,N),b';b\in E\cup N,b'\in s(E,N)\}} \pi^2{}_{f,EN,b'}$$
$$+ \sum_{HE\ni b} \pi_{f,HE} + \sum_{HN\ni b} \pi_{f,HN} + \sum_{HN\ni b} \pi_{f-1,HN}$$

$\ge -c_{bf}$ for *f* admissible on *b*

(15)
$$\begin{aligned} & A_g \pi_b + \sum_{f \in g} \pi_{bf} + \sum_{f \in g} \pi_{b,f-1} + \sum_{f \in g} \pi_{b,f-2} \\ & + \sum_{CE \ni b, f \in g} \pi_{f,CE} + \sum_{CN \ni b, f \in g} \pi_{f,CN} + \sum_{CN \ni b, f \in g} \pi_{f-1,CN} \\ & + \sum_{\{(E,N);|N|>1, b \in E\}, f \in g} \pi^1{}_{f,EN} + \sum_{\{(E,N);|N|>1, b \in N\}, f \in g} \pi^1{}_{f,EN} \\ & + \sum_{\{(E,N);|N|>1, b \in N\}, f \in g} \pi^1{}_{f-1,EN} + \sum_{\{(E,N);|N|>1, b \in E\}, f \in g} \pi^2{}_{f,EN} \\ & + \sum_{\{(E,N);|N|>1, b \in N\}, f \in g} \pi^2{}_{f,EN} + \sum_{\{(E,N);|N|>1, b \in N\}, f \in g} \pi^2{}_{f+1,EN} \\ & + \sum_{\{(E,N),b';b \in E \cup N, b' \in s(E,N)\}, f \in g} \pi^2{}_{f,EN,b'} \\ & + \sum_{HE \ni b, f \in g} \pi_{f,HL} + \sum_{HN \ni b, f \in g} \pi_{f,HN} + \sum_{HN \ni b, f \in g} \pi_{f-1,HN} \\ & \geq -c_{bg} \text{ for } g \text{ admissible on } b \end{aligned}$$

(16) $\pi_b \geq -c_b$

(17) $\pi_{f,CE} \leq c_{CE}$

(18) All $\pi$-s $\geq 0$ except $\pi_b$ which is unconstrained.

(19) The dual variables $x_{bf}$ and $x_{bg}$ corresponding to constraints (1) and (2) are required to be integer.

# 5 Solution method

## 5.1 General

The solution method is heuristic and solves the dual problem. The dual variables associated with the constraints (14) and (15) in the dual program correspond to the primal variables $x_{bf}$ and $x_{bg}$ respectively in the primal program. We repeatedly solve linear programming relaxations of the dual problem using dynamic variable generation and deletion where we successively fix one or more of relevant fractional dual variables to 1 or 0 until they all are integer.

First we generate data structures external to the linear program which hold all cliques in *GE*, *GN* and *Gi*, all EN-pairs and all odd holes up to a specified size. These data structures are used to dynamically identify variables which price out negatively relative to the current basic solution and thus can be added to the linear program. Variables corresponding to cliques, EN-pairs and odd holes which become non-basic during the solution process are deleted from the linear program.

Of course, the problems of generating all cliques, EN-pairs and odd holes are NP complete, but our graphs are sufficiently small to allow us to do this generation in reasonable time provided we restrict ourselves to odd holes of small size.

In the variable fixing phase we can choose between fixing only one or possibly more than one variable to an integer value after each solution of the LP relaxation.

## 5.2 Fixing one variable at a time

If we decide to fix one variable at a time, we proceed as follows: If there are fractional dual variables corresponding to type (15) constraints, we choose one with the highest fractional value and fix it temporarily to 1. If all these dual variables are already integer, we choose a fractional variable corresponding to a type (14) constraint with the highest fractional value and fix it temporarily to 1. If this fixing causes too many frequencies to be allocated to a base station, the variable is permanently fixed to 0. If not, and the fixing does not lead to an increased $\Sigma_b s_b$, the fixing is made permanent. Otherwise, we try a temporary fixing to 0. Then we fix the variable permanently to 1 or 0 such that we get the least possible increase of $\Sigma_b s_b$.

## 5.3 Fixing more than one variable at a time

If we allow for fixing more than one variable after each solution of the relaxed LP, we choose a threshold > 0.5 and proceed as follows:

First we sequence the fractional variables corresponding to type (15) constraints in descending order. Then, one by one, we fix them permanently to 1 if

- Their value is greater or equal to the threshold,
- The fixing, together with earlier fixings, does not allocate more frequencies than required to a base station.

Then we treat the fractional variables corresponding to type (14) constraints in the same way.

If no fractional variable exceeds the threshold, we fix one variable at a time as described in 5.2.

## 5.4 Fixing variables permanently

Fixing variables permanently is done, as explained below, by removing constraints from the problem.

If we want to fix permanently a fractional dual variable to 1 we first try to do this by deleting constraints from the problem.

We delete constraints of type (14) or (15) representing combinations of base stations and frequencies or frequency groups which are incompatible with the fixed combination. Furthermore, if fixing a variable to 1 implies that the frequency demand for the corresponding base station is satisfied using fixed variables only, all constraints of type (14) and (15) pertaining to this base station whose dual variable is not fixed are removed from the problem.

If we cannot find any constraints to delete, we change the right hand side element corresponding to the dual variable to $\infty$. (This corresponds to setting the cost coefficient of the corresponding primal variable in the primal problem to $-\infty$.)

If we want to fix permanently a fractional dual variable to 0 we simply remove the corresponding constraint from the problem.

### 5.5 Fixing variables temporarily

If we want to fix variables temporarily, we do not want to delete constraints which we later would have to recreate. Instead we implement temporary variable fixing by manipulating right hand sides.

If we want to fix temporarily a fractional dual variable to 1 we do this by changing the corresponding right hand side to $\infty$, and if we want to fix temporarily a fractional dual variable to 0 we do this by changing the corresponding right hand side to $-\infty$.

## 6 Use of GRASP

For the case where we fix one variable at a time only, we have incorporated an option to use GRASP (Greedy Randomized Adaptive Search Procedure) with parameter $\gamma$. In this case we save the solution of the LP relaxation we obtain before variable fixing starts. Starting from this solution we carry out $\gamma$ solution processes with variable fixing as described above. In each of these processes we choose the variable we want to fix temporarily to 1 randomly amongst the $n$ largest fractional dual variables, where $n$ is a parameter chosen by the user. This gives us in principle $\gamma$ distinct solutions to our problem, and we choose the best one.

## 7 Partitioning base stations into subsets

Even if the described heuristics are used to solve the frequency allocation problem, computer time may be prohibitive for large cases. We have therefore implemented an option for partitioning the base stations into subsets. The optimization is carried out and frequency allocations are fixed for the subsets one by one. We have to pay for this of course by a possible reduction in solution quality.

When we have solved the problem for some subsets, then the options for frequency allocations in the remaining subsets are reduced because of interference between base stations in subsets already treated with base stations in subsets not yet treated.

Ideally, we want to partition the base stations into subsets such that

- There is as little interference between subsets as possible
- The size of the subsets is such that the workload for the optimization is equally shared between the subsets.

The problem of minimizing interference between subsets of given sizes is a variant of the graph partitioning problem. We have implemented a simple heuristic for this problem where we start from a partition based on the sequential ordering of the base stations by the user and then exchange base stations between subsets until we obtain a local minimum.

Our method for choosing the subset sizes so that the optimization workload is evenly distributed is based on some very bold assumptions and approximations. One of the assumptions is that all frequencies are admissible for all base stations.

We introduce some additional notation:

| | |
|---|---|
| $n$ | number of n-interferences |
| $e$ | number of e-interferences |
| $r$ | average frequency requirement per base station |
| $B_i$ | number of base stations in subset $i$ |
| $s$ | number of subsets |

For a randomly selected base station the expected number of n-interferences is $2n/B$, and the expected number of e-interferences is $2e/B$. If the set of base stations is partitioned into subset 1 and subset 2 with $B_1$ and $B - B_1$ base stations respectively, the expected number of n-interferences between a particular base station in subset 2 with base stations in subset 1 is

(20) $N = (2n / B)B_1 / (B - 1) = 2nB_1 / (B(B - 1))$,

and the corresponding expected number of e-interferences is

(21) $N = (2e / B)B_1 / (B - 1) = 2eB_1 / (B(B - 1))$.

Assume now that all frequencies in subset 1 have been allocated. The question is what is the expected number of different frequencies which are allocated to the base stations which interfere with a particular base station in subset 2. We make the assumption that these frequencies are randomly distributed. Then the expected number of different frequencies which are allocated to base stations in subset 1 which n-interfere with a particular base station in subset 2 is

(22) $F(1 - (1 - 1 / F)^{Nr}) \approx Nr = 2nrB_1 / (B(B - 1))$.

(The approximation is reasonable only if $F$ is large compared to $Nr$, but we use it anyway.)

Correspondingly, the expected number of different frequencies which are allocated to base stations in subset 1 which e-interfere with a particular base station in subset 2 is

(23) $F(1 - (1 - 1 / F)^{Er}) \approx Er = 2erB_1 / (B(B - 1))$.

Thus, the number of possible allocations in subset 2 is reduced on the average by

(24) $[2(3n + e)r / (B(B - 1))]B_1(B - B_1)$.

Then we have the following:

Number of constraints in LP no 1:

(25) $B_1F$

Expected number of constraints in LP no 2:

(26) $B_2F - [2(3n + e)r / (B(B - 1))]B_1B_2$

Expected number of constraints in LP no 3:

(27) $B_3F - [2(3n + e)r / (B(B - 1))](B_1 + B_2)B_3$

Expected number of constraints in LP no 4:

(28) $B_4F - [2(3n + e)r / (B(B - 1))](B_1 + B_2 + B_3)B_4$

and so on.

These expressions are then set equal to each other.

We set

(29) $k = 2(3n + e)r / (FB(B - 1))$.

Then

(30) $B_2 \approx B_1 / (1 - kB_1)$

(31) $B_3 \approx B_1 / (1 - k(B_1 + B_2))$

(32) $B_4 \approx B_1 / (1 - k(B_1 + B_2 + B_3))$

...

(33) $B_s \approx B_1 / (1 - k(B_1 + ... + B_{s-1}))$.

Furthermore,

(34) $B_1 + ... + B_s = B$.

A set of $B_i$-s which satisfy (30) to (34) may be found by trial and error. However, in order to obtain a set of $B_i$-s which is somewhat more robust to deviations from our assumptions we use some rough approximations in order to obtain a framework where the subset sizes grow linearly.

From the above we see that

(35) $$B_{i+1} / B_i = \frac{1 - k(B_1 + \cdots + B_{i-1})}{1 - k(B_1 + \cdots + B_i)} \approx 1 + kB_i$$

(assuming that $k$ is small).

This gives

(36) $B_{i+1} - B_i \approx kB^2_i$.

We approximate the difference equation (36) by the differential equation

(37) $dB / di = kB^2$

with solution

(38) $$B_i = \frac{1}{1/C - ki} \approx C + kC^2 i.$$

Condition (34) gives

(39) $$C = \sqrt{\frac{1}{k^2(s+1)^2} + \frac{2B}{ks(s+1)}} - \frac{1}{k(s+1)}$$

Finally, the $B_i$-s found by (38) are rounded in a way which makes (34) hold true.

## 8 Concluding remarks and acknowledgement

At the time of writing the frequency allocation module is still being experimented with and has most probably not found its final form. It is expected that the module later will be incorporated in a graphical user interface.

The author wishes to thank H. Moseby for valuable assistance in setting up and implementing the frequency allocation module in MOBINETT.

# Status

International research and standardization activities in telecommunication

Editor: Endre Skolt

# Introduction

BY ENDRE SKOLT

In the status section of *Telektronikk* we have earlier presented standards work in ETSI and ITU, and research studies in EURESCOM, RACE and ACTS. In this issue of *Telektronikk* we take a look at the European Co-operation in the Field of Scientific and Technical Research (COST) programme and present three projects which have had Telenor participation.

COST involves projects in a large number of areas from agriculture and biotechnology to telecommunications. All projects under COST are pre-competitive and the COST telecommunications programme has since its introduction in 1971 operated as a European forum for development of new technology, co-ordination of basic research, and contributions to standardisation organisations. Today, there are 25 countries participating in COST projects, mostly EU member countries. COST is however not a EU body. In the telecommunications programme this year, more than 2000 scientists have joined, and compared with other international research programmes, university scientists represent a large part of the working force.

The most important study areas in COST include:

- Development and simulation of Networks, including Integrated Satellite/Terrestrial Networks
- Multimedia and Image Communications
- Radio systems
- Optical technologies: Systems, components and reliability
- Telecommunications facilities for disabled and elderly people
- User requirements in Telecommunications
- Speech Technology
- Software Verifications and Validation.

Telenor R&D has actively participated in COST projects addressing areas like speech technology, development of video coding technologies, telecommunications for disabled and elderly people, fundamentals of

mobile and satellite communication and fixed services terrestrial communication. In the following we present results from three projects that recently have terminated.

In the first paper, Mr. Per Helmersen reviews what has been achieved in the COST 219 project. COST 219 was set up in 1986 and ended September this year. The main objectives of the project have been to collect information about existing telecommunications devices appropriate for disabled and elderly people, to stimulate activities in this field, and to survey the practical needs of disabled people and evaluate the future possibilities of information technologies. Mr. Helmersen reports that telecom operators are starting to view the increasing number of elderly and disabled people as an important market. By meeting the needs of customers with reduced hearing, vision and mobility, telecommunication service providers may gain a competitive edge in the overall market.

In the second paper, Mr. Agne Nordbotten presents the achievements in COST 235, a project studying radiowave propagation effects on telecommunications system using frequencies in the higher microwave and millimetre bands. The growth in radio communications has made it necessary to use frequency resources in these bands both for satellite and terrestrial communication. More specifically, COST 235 has studied the propagation effects caused by the atmosphere (attenuation, scattering, depolarisation) and ground terrain effects (multipath, shielding, attenuation from trees etc.). Telenor R&D has been an active project partner, and chaired one of the three working groups.

The last paper gives a comprehensive description of the results from COST 231, "Evolution of land mobile radio communications". The project has been organised into three working groups with focus on the radio system aspects and technologies for third generation standards, channel characterisation at frequencies between 900 MHz and 3 GHz, and both system aspects and propagation at microwave and millimetre wave frequencies. The authors are Mr. Per Hj. Lehne and Mr. Rune H. Rækken.

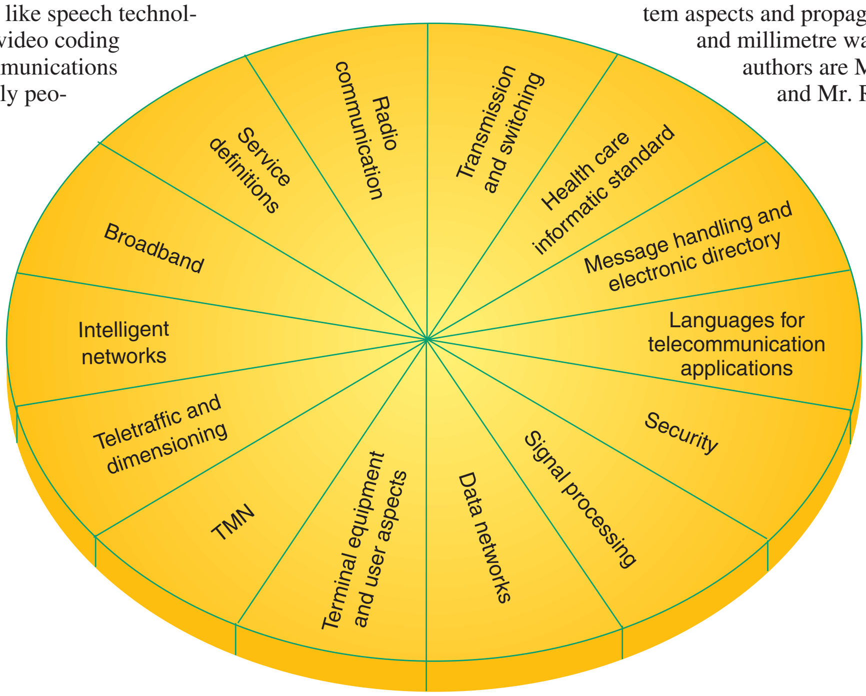


*Figure 1 Telecommunication areas*

# COST 219: Future telecommunications and teleinformatics facilities for disabled people and elderly

BY PER HELMERSEN

In Europe, there are about 100 million elderly people and 50 million who are disabled. In addition, there are those who suffer from dyslexia, learning difficulties or milder forms of intellectual impairment, as well as the 0.5 % of the population who are temporarily disabled through illness or accidents.[1] The prevalence of most forms of impairment increases considerably with age and so the disabled population grows disproportionately as life expectancy rises. Disabled and elderly people are a significant segment of the telecommunications market.

Access to telecommunications offers disabled users improved independence, mobility and quality of life. For many, it means the opportunity to work at their own pace and in their own homes. The telecommunications industry has made enormous progress over recent years. Unfortunately, more advanced equipment often makes greater demands of the user and so, people who are all too familiar with the many barriers of daily life can actually be further isolated and disenfranchised by technology with the potential to remove many of these barriers. Anyone who cannot use telecommunications services will find it hard to gather information, make reservations, maintain social contacts or even call emergency services. As an increasing number of services are being transformed into telecommunications or on-line services, the prospect of equal access for many of these user groups is threatened.

There are also intrinsic problems in the nature of new technology. As products are changing rapidly, shrinking in size and cramming more and more features into software, engineers have difficulty in getting inside the chip or software to make modifications while the product is being developed. A consequence of this is that existing devices for people who require special solutions and interfaces are obsolete, non-competitive and difficult to maintain. In addition to these technological constraints, cost and lack of awareness have also been important factors in the poor provision made for disabled user groups.

In order to ensure that the needs of disabled people were properly formulated and made available to the European telecommunications industry, regulatory authorities, research bodies, standardization organizations and others, the COST 219 project was set up. The project started in September 1986 and was terminated in its present form in September 1996. Two requests for extensions of the activity have been approved, making 219 one of the longest running COST projects. During the 1987–94 period the project received financial support from the European Community, DGXIII and DGV in order to make it possible for representatives from small industry, universities as well as invited experts on handicap problems to participate in the work of COST 219.

The COST 219 signatories[2] have co-operated in order to promote research into the field of telecommunications and teleinformatics with the aim of proposing solutions to problems related to the needs of disabled and elderly persons. The main objectives of the project have been to collect information about existing telecommunications and teleinformatics devices and services as well as ongoing research and development appropriate to disabled and elderly people, to stimulate activities in this field, to survey the practical needs of disabled people and to evaluate the future possibilities of information technology. Under the chairmanship of Jan Ekberg from the National R&D Centre for Welfare and Health in Finland, COST 219 has organized 30 meetings and seminars focusing on a wide range of subjects such as text telephony, picture communication, elderly and technology, smart cards and terminals, speech technology, telephones and hearing aids, legislation and standardization, databases, etc. Twenty-nine publications (including 3 books published by the Commission of the European Communities[3]) document 10 years of activity in the field.

The major activities of COST 219 have been carried out by various working groups. The composition and focus of these groups have changed during the 10 years the program has existed, reflecting not only social and technological change, but also the increasing maturity of COST 219. The following working groups were functioning in the final stages of the program:

- WG1 Standardization and Legislation (Chairperson: C. Stephanidis, GR)
- WG2 Videotelephony (Chairperson: Leonor Moniz Pereira, P)
- WG3 Access to Communication Technology (Chairperson: Bob Allen, Irl)
- WG4 Voice Communication (Chairperson: Patrick Roe, CH)
- WG5 Technology Trends (Chairperson: Diamantino Freitas, P)
- WG6 Text Communication (Chairperson: Kelvin Currie, UK)
- WG7 Information Transfer (Chairperson: John Gill, UK)

Organizations such as ETSI – especially HF2 – have frequently used COST 219 as the basis for their own work in this area. Furthermore, the information obtained has been collated and disseminated through publications and conferences across Europe and more recently in Eastern/Central Europe. Because of COST 219's activities it was possible to include issues related to disabled and elderly persons in RACE and to define a new program, TIDE. The overall result is that a forum has been established which is now internationally recognized as a reference point on matters concerning disability and telecommunications. One example of this recognition is the recent exposure solutions for disabled customers received at Telecom 95. As a direct result of COST 219's efforts an ITU stand at Telecom 95

[1] The forgotten millions. Access to telecommunications for people with disabilities. *DG XIII. Brussels, 1994.*

[2] *The MOU has been signed by Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Malta, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Croatia and Slovenia have started the procedures to sign. Active participation from EC, (TIDE office, RACE office and Helios) should also be mentioned, in addition to frequent collaboration with ETSI.*

[3] *Von Tetzchner, S (ed.). 1991.* Issues in telecommunication and disability. *Brussels, Office for Official Publications of the European Commission. ISBN 92-826-3128-1-.*

*Roe, P R W (ed.). 1995.* Telecommunications for all. *Brussels, Office for Official Publications of the European Commission.*

*Olesen, K G. 1992.* Survey of text telephones and relay services in Europe. *Brussels, Commission of the European Communities, Directorate-General, Information Technologies and Industries, and Telecommunications.*

was constructed as a smart home for elderly and disabled showing how telecommunications can be used to support independent living. This ITU/COST 219 stand was visited by over 10,000 attendees.

COST 219 was officially terminated in September 1996. A new COST Action has recently been approved, however, ensuring that information related to the needs of disabled and elderly persons will be made available also in the future. Signatories of the COST Action 219bis MOU (1996 – 2001) will carry out the following main tasks:

1) Analyze and propose new solutions intended (in order of priority) to:
   - make services generally accessible to all,
   - make services adaptable when they cannot be made generally accessible, or
   - offer special solutions to meet explicit problems
2) Support co-operation between technical specialists of telecommunications, teleinformatics, standardization, legislation and specialists working for elderly and disabled persons
3) Evaluate new technical solutions for providing telecommunication and teleinformatics services to elderly and disabled persons
4) Actively disseminate information to relevant actors
5) Promote appropriate research activities.

Modern telecommunications have the potential to open up society to people with disabilities. The market is large and economically attractive. It is obviously necessary and desirable that telecommunications should develop in a way which improves the services available to all. There is sometimes a mistaken assumption that this will come about as a direct and inevitable result of technical progress. The efforts of the COST 219 program have since 1986 demonstrated that an emphasis on standardization, legislation and European-wide coordination is essential. It has also become clear that a broad uptake of solutions is achievable only if equipment manufacturers and service providers can be convinced that there is a market and that many of the special requirements of elderly and disabled users will also benefit normal untrained users and subscribers.

Within a liberalized telecommunications environment Telenor and other PNOs will find themselves being drawn towards the provision of specialized services for the needs of persons with disabilities and the large greying population. This will be through realizing the commercial opportunity that these customers offer as well as in response to calls for regulatory action by groups representing these customers' interests. A third and perhaps equally important driving force will be the increasing recognition of the importance of design for all policies. "Accessibility and Universal Design Principles" have recently been approved and implemented by major US telecom operators such as Pacific Bell and NYNEX. These companies have realized that by meeting the needs of customers with reduced hearing, vision, mobility or information processing abilities they are also developing products and services which benefit all of their customers – not only those with specific and identifiable handicaps. In a market where ever-raging price wars make it increasingly difficult for customers to base their decisions solely on cost, factors such as ease of use and the availability of flexible solutions which can be adapted to meet specific needs and tastes may be the only factors differentiating one provider from the next. Carrying on in the tradition of COST 219, COST 219bis will continue to provide PNOs not only with insight into the needs of their many disabled customers and information on how to meet them, but also give those cognizant of the commercial advantages of universal design a clear market advantage and a flying start into the next century.

# COST 235: Radiowave propagation effects on next generation fixed-services telecommunication systems

BY AGNE NORDBOTTEN

## Introduction

The COST 235, which started in 1991, concluded its work through the arrangement of an International Symposium on Broadband and Millimetric Propagation Effects on Terrestrial Radio in October 1996. In that connection a report presenting the objectives of the work, the main contributions and results with conclusions, discussions and also recommendations for future work has been issued by the Commission of the European communities [1].

This paper gives a short summary of the objectives and results from the project with some focus on the contributions from Telenor R&D.

## COST 235

The growth in radio communication as well as the technological development now makes it both possible and necessary to start using the frequency resources of the higher microwave region and in the millimetric region for both satellite and terrestrial communication. It was the realisation of the fact that these future telecommunication systems would be strongly influenced by propagation effects from the atmosphere (attenuation, scattering, depolarisation) and ground terrain effects (multipath, shielding, attenuation from trees, etc.), as illustrated in Figure 1, which necessitated a thorough investigation into these phenomena in order to establish reliable and accurate prediction models, QoS and availability criteria for such systems. Since the project started, the use of radio communication has increased even faster than expected. During the same period algorithms for efficient coding of moving video have been developed and the standardisation of MPEG2 has resulted in possibilities for development of new services including interactivity creating a need for broadband access for public services.

Systems based on the use of millimetric waves will normally be low margin systems requiring very reliable prediction methods and efficient fading countermeasures to insure cost effective operation and efficient resource utilisation.

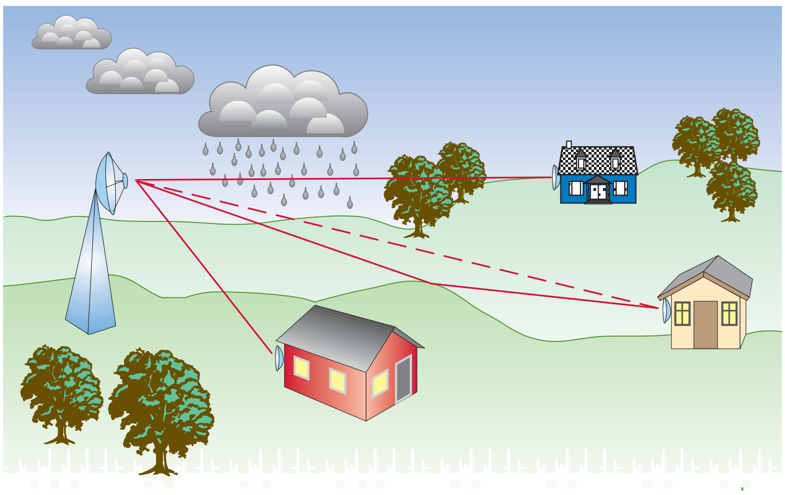

*Figure 1 Atmospheric and terrain influences on millimetric wave propagation*

The applicational background for the results from COST 235 thus turned out to be the very best at the end of the project and the timing for the project very good. In Europe, several larger projects based on the application of millimetric waves have been initiated under the Fifth Framework Program of the EU.

The work in COST 235 on these problem areas was organised in three working groups on

- Frequency selective fade effects focusing on channel modelling, diversity improvement, dual polarisation phenomena, multipath occurrence and performance and availability criteria (clear air effects) (WG1)
- Flat fade effects and millimetric wave considerations addressing the areas of gaseous absorption, the effects of hydrometeors and the influence of atmospheric turbulence (WG2)
- Site shielding and interference reduction strategies like the effects of urban environment on the radiowave propagation, terrain propagation models as well as antenna and systems aspects (WG3).

The project was led by Martin M.P. Hall, Rutherford Appleton Laboratory. Terje Tjelta, Telenor R&D, has been the chairman of Working Group 1 (WG1). Research groups from altogether 14 nations has participated in the project.

The work in the project started with a total of 28 technical questions which then were reduced to eleven areas for detailed consideration in the respective working groups.

## Main results from the project

Under WG1 the work has focused on Quality of Service and availability of systems in the microwave region. Improved prediction models have been developed and several contributions made to the standardisation process in ITU-R. Results from measurements on multipath occurrence in Norway have been correlated with meteorological data and a close relationship between the refractivity gradient obtained from meteorological data and multipath fading was found. It has been recommended that work in this area continues in another COST project.

A thorough investigation into the possibilities of different methods for diversity improvement has been undertaken, and from Norway it has been shown that there are great advantages in the form of equipment saving and space saving on the installation site in using angle diversity since this requires only one antenna per installation as illustrated in Figure 2, which shows the basic principles for angle and space diversity, respectively.

During the project period new transmission systems based on SDH have been installed by different operators. For such systems the error problems are different from previous systems, it is now a question of errored blocks rather than errored bits, and these problems have turned out to be somewhat complicated in handling. The relationship between block error and BER has been analysed, and a method has been described that makes it possible to convert old bit error measurements into block errors which can be evaluated according to G.826 parameters.

A model for dual polarisation of the radio channel has been developed considering the separate contributions from both antenna and propagation effects. Testing versus experimental

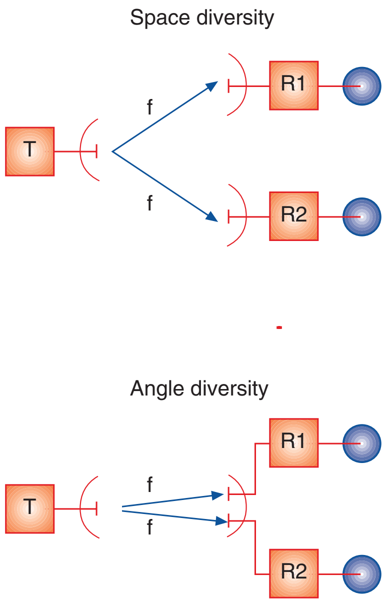


*Figure 2 Antenna installations for angle and space diversity*

data has been performed, and the conclusion is that use of dual polarisation in terrestrial microwave systems now is a mature technology, thus increasing the communication capacity of that part of the spectrum.

In the millimetric wave range the presence of hydrometeors has the strongest effect on signal attenuation. The models used so far for prediction of the effects of precipitation have been tested and evaluated at frequencies below 40 GHz, and there has actually been doubt about their validity in the higher frequency range. In this frequency range the contribution from scattering is important. Thus, the observed attenuation will not be determined by the rain intensity only, but also depend on drop size distribution, resulting in different attenuation levels from event to event and even within events depending on the variations in drop size distribution. For long term statistics these phenomena will be more or less averaged out, but when such averages are being used, large deviations must be expected for shorter or longer intervals depending on the details of such drop variations. Figure 3 illustrates how the drop size distribution can change during a rainfall. A knowledge of local meteorology may be required for reliable dimensioning of such systems, and development of adaptive fading countermeasures is required.

The effects of precipitation on millimetric wave propagation have been studied extensively in COST 235. A data base of attenuation measurements, coupled with rain rate data, has been collected from a number of links operated in Europe and a testing versus the different models proposed and in use has been conducted. The deviations between some of the models is noticeable and for Europe only 2–4 should be recommended. In this area it turns out that the models being used tend to underestimate the fading problem over shorter distances.

At Telenor R&D the focus has been on obtaining an understanding of phenomena which are typical for the Norwegian climate and measurements have been running at Kjeller since 1993. Kjeller is well suited for such measurements. There are normally several short and intense rainfalls with relatively large drops and rapid variations in drop size distribution in the summer season. During the period from September until November there will be both long-lasting rainfalls with smaller drops and more intense rainfalls in between. At the end of the period there may be some events with sleet/wet snow.

In spring there will be a long period with snow-covered terrain which represents the worst situation for reflection and multipath when the snow has recrystallised and gets wet.

It has been shown that the occurrence of sleet and hail has strong effects on the monthly distribution curves for the specific attenuation. Figure 4, which represents June 1993, illustrates this based on measurements over a 630 m long path at Kjeller. The total amount of precipitation for this month was 27 mm with one single hail event contributing 6.7 mm. The specific attenuation curves for 40 (solid lines) and 60 GHz (dashed lines), show that the hail event dominates totally for higher attenuation values.

Fading countermeasures are very important for the use of such systems.

Availability as a concept is much more complicated at millimetric frequencies than at lower frequencies. In a sectored distribution system (point-to-multipoint) the attenuation at a given time will vary quite a lot with direction due to the inhomogenity of rain. Availability, however, is defined in a specified direction and will of course statistically be very much the same in different directions, but availability will not be the same for a given instant of time in different directions. If for instance AGC is used as a fading countermeasure there will be a difference in systems performance depending on the criteria used. Use of the most faded direction for control gives the highest availability as well as strong signals in the unfaded directions which increases the interference problem in a cellular system. The difference between a point to point and a point-to-multipoint system with regard to fading countermeasures is obvious.

Another problem in this connection is that it would be of interest having some information on the dependency of the attenuation statistics during a day. It should not be at a minimum when the number of customers is the highest. Such information is lacking.

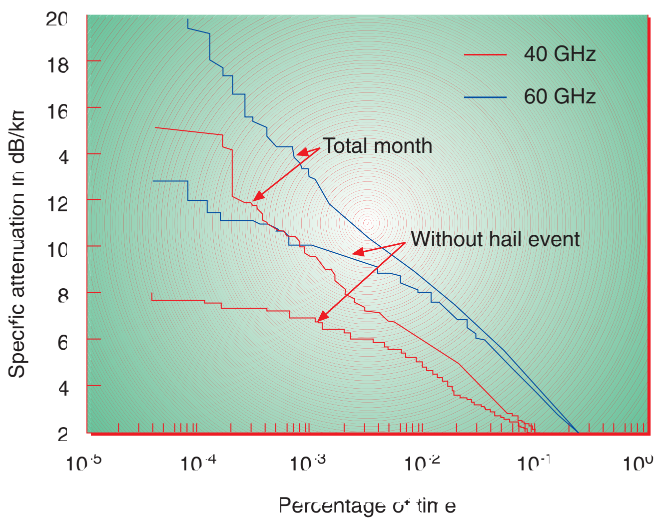


*Figure 3 Variation of drop size during rainfall (as measured with distrometer at Kjeller)*

Working Group 3 has analysed the effects of diffraction, scattering and terrain in detail, with a special focus on urban areas characterised by buildings, constructions and trees. The models developed contribute significantly to the prediction of diffraction, scatter and attenuation imposed by buildings and vegetation as well as to the understanding of terrain propagation effects and site shielding effects.

A prediction procedure aiming at estimating the effects of scattering on a radio connection has been described.

Both attenuation and scattering from groups of trees have been analysed and a model for estimating the attenuation as a function of vegetation depth has been recommended. A belt of vegetation of 4–6 m can easily result in more than 20 dB of signal attenuation. Vegetation thus represents a major problem for propagation of radio waves and in particular new systems for satellite communication and point-to-multipoint access systems and mobile communication in the millimetric wave area.

It has been shown that frequency reuse at millimetric frequencies will be reduced by the effect of scattering from buildings in urban areas. A method for calculating the effects of shielding on digital communication systems in the frequency range from 10 – 100 GHz has been implemented. The method can be used to evaluate the performance of communication systems in an urban area.

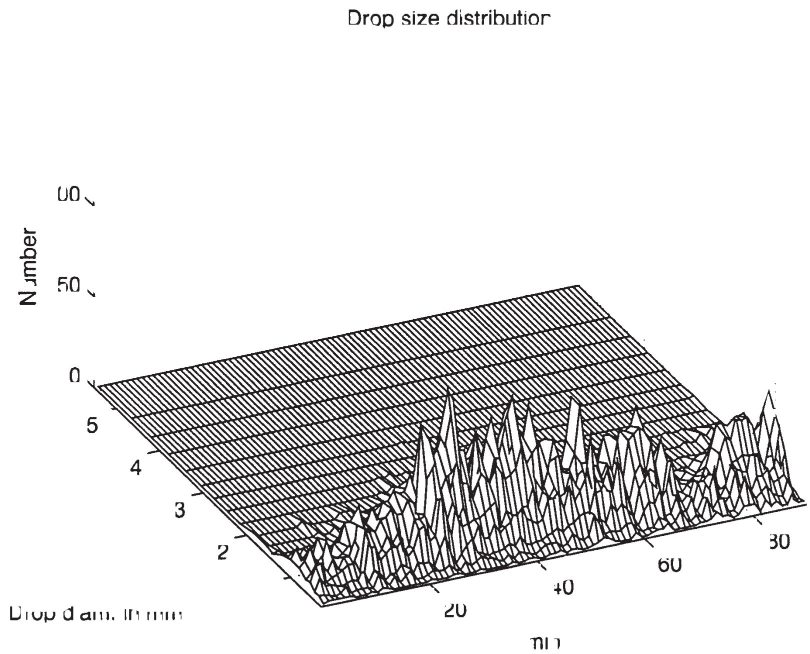


*Figure 4 Cumulative distribution of precipitation attenuation for June 1993 with and without hail event representing 25 % of the total precipitation*

## Concluding remarks

The work of COST 235 represents a valuable contribution to improved radio communication systems through improved prediction for the microwave frequency range to valuable contributions for design guidance of new systems in the millimetre wave range which will now be gradually more used for communication systems requiring high capacity channels. The information collected is of particular interest for different new ACTS projects focusing on communication and distribution using millimetric waves. For Telenor the participation in the ACTS project AC215 CRABS (Cellular Access to Broadband Services) with the main objective of developing and demonstrating a broadband interactive point-to-multipoint distribution system, was a result of contacts established in COST 235. Three of the nine partners in CRABS participated in COST 235.

COST 235 has also represented an opportunity for writing scientific articles and presenting conference papers. One university thesis was associated with the work at Telenor.

The work from COST 235 is partly continued in a new COST 253 project on Satellite Systems from Ku-band and above, and another project focusing on terrestrial systems is under consideration.

A well organised COST project represents an opportunity for international scientific work in co-operation within larger project areas. It represents possibilities for development and testing of new ideas which later evolves into systems work and applications as well as the possibility for establishing valuable contacts in other organisations. However, nothing is free and possibilities are created through the activity of the individual partner.

## Reference

1 COST 235. *Radiowave propagation effects on next-generation fixed-services terrestrial telecommunication systems.* Commission of the European Communities, 1996. (Final report EUR 16991 EN.)

# COST 231: Evolution of land mobile radio (including personal) communications

BY PER HJALMAR LEHNE AND RUNE HARALD RÆKKEN

## Introduction

The COST 231 project started on 6 April 1989, and was originally scheduled to expire in April 1993. To align the time scale of COST 231 with the time scales of interacting RACE projects, the COST action was then extended to 5 April 1996.

Chairman of the COST action was from the start Mr. Pietro Porzio Gusto from CSELT, Italy. In 1992, Mr. Eraldo Damosso, also CSELT, took over the chairmanship.

The objectives were, among others, to identify the characteristics of third generation mobile radio and personal communications systems currently under specification, and to provide design methods and coverage models for their implementation.

This included studies on digital transmission techniques and radiowave propagation in the UHF band. The aim was to establish prediction methods for attenuation and multipath effects in macro, micro- and indoor cells by modelling and simulation of the radio transmission channel.

Also, long-term studies have been carried out on radio based communications systems for broadband services (i.e. services requiring a capacity greater than that of the basic ISDN services). This involved studies on a large spectrum of new telecommunications technologies at millimetre wave and infrared bands.

Thus, COST 231 has covered a variety of land mobile aspects, mainly focusing on personal communications systems providing voice and data communications through small, cheap, hand portable radio terminals.

This article highlights some of the work performed and presented within COST 231. The article is however not exhaustive, due to the huge amount of work carried out within the COST action.

The main information source for this article is the COST 231 Final Report [1].

### Participation

At the end of the project, 20 signatory countries participated at the Management Committee meetings: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom. Usually, more than 80 people from about 70 participating organisations attended the meetings.

### Liaisons

During its period of existence the COST action had close relations with most RACE projects related to mobile and personal communications, with other COST actions and several international standardisation bodies (see Table 1). Additionally, there were liaisons with: UK Technical Party on Mobile Communications, UK LINK CDMA Project, and URSI (The International Union of Radio Science).

## Organisation of the work

The work was split into three main areas and organised in corresponding working groups:

- WG1 – Radio System Aspects
- WG2 – UHF Propagation
- WG3 – Broadband Applications.

WG1 had its focus on the system aspects and technologies for third generation standards. The objectives were to complement and evaluate the various RACE projects and to provide significant results to the standardisation bodies, especially on multiple access techniques (CDMA[1], TDMA[2], etc.) and new coding and modulation techniques.

1 *Code Division Multiple Access.*

2 *Time Division Multiple Access.*

*Table 1 COST 231 liaisons*

| | |
|---|---|
| **RACE projects** | |
| CODIT | R 2020 UMTS COde DIvision Testbed |
| MONET | R 2066 MObile NETworks |
| MBS | R 2067 Mobile Broadband System |
| MAVT | R 2072 Mobile Audio Visual Terminal |
| ATDMA | R 2084 Advanced TDMA Mobile Access |
| TSUNAMI | R 2108 Technology in Smart Antennas for UNiversal Advanced Mobile Infrastructure |
| **COST Actions** | |
| 227 | Integrated Space/Terrestrial Mobile Networks |
| 235 | Radiowave propagation effects on next-generation fixed-services terrestrial telecommunications systems |
| 244 | Biomedical Effects of Electromagnetic Fields |
| 245 | Active Phased Arrays and Array Fed Antennas |
| **ETSI TCs/STCs** | |
| SMG2 | Radio aspects of GSM / DCS1800 / UMTS |
| SMG5 | Universal Mobile Telecommunications System – UMTS |
| RES02 | Land Mobile (except GSM, UMTS, DECT) |
| RES03 | Cordless Communications, i.e. DECT, CT1/2 |
| RES10 | Radio LAN |
| **ITU-R** | |
| TG 8/1 | Recommendations on International Mobile Telecommunications – IMT-2000 (formerly FPLMTS) |
| SG 3 | Study group on Radiowave propagation |

WG2 studies were on the mobile channel characteristics at frequencies between 900 MHz and 3 GHz. Outdoor measurements and modelling (i.e. macro- and micro-cells) were given special attention. This included developing prediction methods where the influence of systems parameters like base station antenna height and directivity and site location and environment, were taken into account. The emphasis was gradually shifted towards outdoor short-range and indoor propagation and building penetration.

WG3 operated along a different axis, covering both system aspects and propagation at microwave and mm-wave frequencies. The main focus has been on high data rates (above 10 Mbit/s) short range communication in indoor environments. Both theoretical and experimental work has been carried out. Attention was also paid to system operation in outdoor environments, and to infrared communications. Particular reference has been given to ETSI's High Performance Radio Local Area Networks (HIPERLAN). Some attention has also been given to safety aspects for infrared and millimetre wave radiation.

## Main achievements

This chapter gives an overview of the main work and results of the research activities carried out within COST 231.

### Radio channel characterisation

Knowledge about the radio channel is crucial in mobile communications. A lot of effort has been put into understanding and describing the radio channel from different points of view. Attention has been increasingly focused on modelling the electrical field with respect to both the propagation delay and the incidence direction. Work has been put into defining the *field direction-delays-spread function* (FDDSF). The FDDSF characterises the disperse nature of the environment. Hence, both space- and time-dependence of the channel response can be developed.

The "radio environment" is not a well defined parameter. Basically, different propagation mechanisms will dominate in different environments. Therefore, categories of environments have been identified, each of them having characteristic propagation scenarios. Division and characterisation is given, both by cell type (i.e. macro-, micro- and pico cells) and area type (urban, suburban, rural, etc. for macro-cells). Still, environment variability is present within a given category, influencing on the radiowave propagation properties. To deal with this, three *sources of randomness* have been identified:

- The arrangement, the mean height and the electrical properties of buildings in an urban area
- The geometrical and electrical properties of the objects interacting with the electromagnetic field
- The receiver position and the factors leading to time variations.

A common feature for all these is that they can only be described to a certain level of accuracy. Hence, they contribute to making the FDDSF and channel response (CR) into stochastic variables.

The FDDSF is used to describe both the small scale / short term and large scale fluctuations of the channel.

A main goal for the work on channel characterisation and propagation measurements is to be able to model the channel for simulation purposes. Therefore, a lot of effort has been put into the channel measurement and modelling activity during the work of COST 231. Three different objectives have been aimed into:

- Long term area simulations, to evaluate signalling performance, coverage studies, cellular efficiency, and others.
- Narrowband system simulations, to consider transceiver performance. Examples in COST 231 are the evaluation of new modulation techniques and optimised transceiver architectures.
- Wideband system simulations, which is the most interesting case. This implies modelling the time disperse properties of the radio channel. The *tapped delay channel* has been frequently employed for this, with a large variety on complexity depending on the use. A two-path Rayleigh (or Rice) model has been employed in evaluating different modulation schemes and for DECT system evaluation. Also a 6 taps delay line channel emulator has been used.

### Channel sounding techniques

There are two classes of equipment for measuring propagation conditions of the mobile radio channel. Narrowband equipment transmits and receives CW (or a narrow frequency spectrum). This type of equipment is mainly used for path loss measurements. Wideband equipment – channel sounders – transmits a frequency spectrum above the coherence bandwidth of the radio channel, and is used for channel characterisation.

Channel sounders are often categorised into three main classes: pulse, pseudo-random sequence, and frequency sweep (chirp) sounders. The two latter use pulse compression techniques.

In a pulse channel sounder, a short RF-pulse is transmitted, and the received signal envelope is detected by the receiver. Only information about the received signal amplitude is obtained, it is thus not possible to get any information about the Doppler spectra. Unless very large transmitter power is used, the distance between transmitter and receiver is limited. In addition, this method is sensitive to interference from other services.

The signal used for sounding the channel by a pseudo-random sequence sounder, is the carrier modulated with a pseudo-random binary sequence. In the receiver a sliding correlator, a signal processor performing correlation or a channel matched filter, is used to estimate the channel impulse response. By using this technique it is possible to obtain a larger range between transmitter and receiver. If Doppler spectra are to be derived, frequency synchronisation between transmitter and receiver is needed.

The frequency sweep technique is well known from radar theory. Traditionally, a pulse compression filter in the receiver is matched to the transmitted wave form. The resolution of the measurement system is inversely proportional to the bandwidth of the frequency sweep, and the maximum measurable delay is proportional to the duration of the sweep. This measurement technique also makes it possible to obtain large ranges between transmitter and receiver even when moderate output power is used. In addition, the method is resistant to interference from other services, and gives good utilisation of the used measurement bandwidth.

### Propagation data analysis

The main outcome of the wideband propagation measurements is information about performance of given digital radio systems in a given multipath environment. Some radio systems have very simple air interfaces, and their quality of service are hence very vulnerable to interference and multipath propagation. Other radio systems have built in measures to compensate for the influence of multipath propagation, or even utilise the energy received from the direct (if any) as well as all the reflected signal components (multipath diversity).

When designing a radio system, or when choosing among different radio systems to be used in a given environment, it is therefore very important to have some measure of the influence of the propagation conditions on the radio system performance.

Impulse responses measured by a channel sounder can be further processed to give parameters indicating performance of different radio systems exposed to various propagation conditions. Important statistical parameters describing the channel impulse responses are:

- *Mean Delay (MD):* The first order moment of the IR; the power-weighted average of excess delays.
- *Delay Spread (DS):* The second order moment of the IR; the power-weighted standard deviation of the excess delays.
- *Fixed Delay Window (FDW):* The length of the middle portion of the IR containing a certain percentage of the total energy of the IR.
- *Sliding Delay Window (SDW):* The length of the shortest portion of the IR containing a certain percentage of the total energy of the IR.
- *Delay Interval (DI):* The interval between the first time the power of the IR exceeds a given threshold and the last time it falls below the threshold.
- $Q_{16}$ *ratio:* The ratio of the power inside to the power outside a window of duration 16 µs. For each IR the window is slid to find the position with highest power inside the window.

These parameters can be used to evaluate how well a digital radio system will work in a given multipath environment, and how damaging multipath propagation is for the communication. For a given modulation method it is possible to calculate the bit error rate as a function of the delay spread parameter, assuming that a channel equaliser is not present in the receiver.

If, however, the receiver is equipped with a channel equaliser, the relevant parameter to predict the radio system performance has to take into consideration the ratio of the power inside to the power outside the equaliser window. The signal components received within the equaliser window can be utilised and is thus a useful signal, whereas the signal components falling outside the equaliser window will contribute to the overall co-channel interference. Knowing the length of the equaliser window and the necessary carrier to co-channel interference rate for a given radio system to operate properly, it is thus possible to use the Q-parameter to predict performance of a radio system employing a channel equaliser.

Examples of how to predict radio system performance using the mentioned parameters is given in the chapter “GSM and DECT systems”.

### Propagation work reported from related projects

A main goal for COST 231 has been the contribution to the development of UMTS. This required a more detailed description of the wideband channel than the one suggested by COST 207 for GSM. Thus, there have been close connections with the RACE projects ATDMA and CODIT for this purpose. Three models have therefore been presented and studied in COST 231:

- The COST 207 approach. These are 6 and 12 taps models with the following basic elements: Tap delay values follow different profiles, tap mean power and Rayleigh (or Rice, for the first ray) distribution, four different Doppler spectrum types. These models have been subject to corrections and also new sets of parameters have been produced covering other types of environments than original.
- ATDMA simulator. Two complementary approaches were followed: Stored Measured Channels and Synthetic Channels. A large number of measurements have been performed to define a *typical channel* and some *atypical channels*.
- CODIT simulator. These activities have been mostly aimed at the development of a synthetic model for WSSUS[3], but then extended to non-WSSUS scenarios by using modulating functions in the filter coefficients.

Both projects ATDMA and CODIT have developed hardware channel simulators for use in their real time testbeds.

## Antennas and antenna diversity

The antennas make up the connection between the communication system and the radio environment. The primary task of the antenna is the connection between transmitter and receiver, but equally important is the possibility to suppress or compensate for transmission media impairments. Three major areas have been considered in the latter case:

- Antenna gain and efficiency to suppress noise
- Multi port antenna diversity to suppress temporal fading and interference
- Adaptive antenna directivity for spatially selective interference suppression.

### Antenna designs

Several antenna designs have been presented. Extreme wideband antennas have been designed giving a bandwidth of up to 15 GHz. For wireless LANs (WLANs), patch antennas printed on top of PCMCIA cards have been designed and tested in the

[3] *Wide-Sense-Stationary Uncorrelated-Scattering (channel).*

5 GHz band (HIPERLAN). Conical horn antennas give near uniform cell coverage. For mm-wave applications, dielectric antennas are suitable because they are easy to produce. These are dielectric leaky wave antennas which can be designed to radiate almost to broadside, i.e. orthogonal to the antenna axis. They have a very strongly frequency-dependent beam-pointing angle, a feature that can be used in a wireless LAN based on FDMA/SCPC[4] and using dynamic channel allocation (DCA).

Antennas for portables have so far been mostly external wire antennas. Internal antennas for hand sets are of increasing importance and interest, partly because of their advantages in design. The *radiation coupled dual-L antenna* is a new antenna designed e.g. for cordless telephones. Work has also been performed on antenna configurations for reducing body loss and absorption of radio frequent energy in the user's body.

### Adaptive antennas

Through the close co-operation with the RACE TSUNAMI project, a lot of work has been performed on antennas for base stations (BS). Keywords here are:

- Angular relations between BS antennas and radio environments
- Environmental influence on perceived antenna pattern
- Adaptive base station antenna arrays.

The latter case is particularly interesting. Adaptive, or "smart", antennas denotes a whole concept of technologies, ranging from "simple" steerable directive antennas to suppress interference and increase range, to spatial separation of users (full Space Division Multiple Access – SDMA) to increase the system capacity.

### Antenna diversity

Another important antenna aspect is *diversity.* This is used at the base station in all current mobile systems, e.g. NMT and GSM. In COST 231 a whole range of diversity techniques have been studied. Diversity separation can be utilised in several radio channel environments. Possible diversity schemes are: space diversity, antenna pattern diversity, antenna orientation angle diversity, polarisation diversity and time/frequency diversity.

Different combining techniques falling into two major groups have been studied: *selection* and *summation.* The characteristic feature of selection diversity is that only one branch is active at a time. The schemes in the second group apply weights to all the branches and the output is the weighted sum. The different schemes have different complexity and gain, with switching diversity offering the lowest complexity but often only marginal improvement. On the other end of the scale, summation using equal-gain combining (EGC) or maximum ratio combining (MRC) gives a theoretical improvement in signal to noise ratio of 3 dB.

Diversity can also be divided between *macro* and *micro* diversity. Macro diversity means combining the signals received at two or more base stations. This will reduce the influence of long-term fading caused by shadowing objects. In this case the spatial separation corresponds to the cell size.

In theory it is possible to reduce the long-term fading margin by 10 dB with selection combining of two uncorrelated branches. As an example, the fading margin for indoor micro-cells is reduced by 7.5 dB with a spatial separation (cell size) of 9–17 λ. The diversity gain is found to be 6 dB in the same case.

Micro diversity is employed by using two (or more) antennas collocated at the same mobile terminal or base station. This technique reduces the influence of the short-term fading. Micro diversity shows a significant gain when two antennas are used, but it is difficult to obtain further improvement using three or more antennas. The estimated diversity gain based on measurements done on 1700 MHz in different propagation environments with an antenna separation of 2.5 λ is 6.5 dB for line of sight (LOS) and 8.6 dB in non line of sight (NLOS) cases.

Antenna diversity can also be employed to combat inter symbol interference in time dispersive channels. The correlation of the delay spread values between two separate branches was estimated at 0.4 in an NLOS micro-cell environment by measurements. In this case, the delay spread was reduced by 20 % by selection of the branch having the smallest instantaneous delay spread.

## Propagation prediction models

Predictions of propagation characteristics are necessary for proper coverage planning, the determination of multipath effects and interference also need to be taken into account when planning how to deploy a mobile network. In COST 231, extensive work has been performed to develop good models.

Four basic mechanisms describe the phenomena which influence radio wave propagation: Reflection, penetration, diffraction and scattering. For all practical predictions, these mechanisms must be described by approximations.

A three stage modelling process has been the basis for the propagation modelling work within COST 231:

1. The real (analogue) terrain has to be transformed to digital terrain data.
2. Defining mathematical approximations for the physical propagation mechanisms.
3. Developing both deterministic and empirical propagation models.

A large amount of work has been carried out during the COST action, and only some highlights will be presented here.

Improved propagation models for macro-cells have been developed. The *COST 231 – Hata Model* is an extension to the well known Okumura-Hata model. This is an empirical path-loss model originally valid for frequencies up to only 1000 MHz. In COST 231, Okumura's model has been extended to higher frequency bands. The COST-Hata Model is valid in the frequency band 1500–2000 MHz, thus covering DECT, DCS1800 and UMTS bands. The validity of the model is restricted to large and small macro-cells, with base station antenna heights above rooftop levels adjacent to the base station.

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[4] *Frequency Division Multiple Access / Single Channel Per Carrier.*

Another important model has been developed, also as a modification and extension to earlier work. The *COST 231 – Walfisch-Ikegami Model* (COST-WI) is a statistically based path loss model for urban macro-cells. No topographical database is used, only characteristic values for buildings and streets are inserted to predict the coverage. The model distinguishes between LOS and NLOS cases. In the LOS case (e.g. for street canyons), free space loss is assumed. Diffraction losses over rooftops are used to model the NLOS case. This model has been accepted by ITU-R and is included in Report 567-4. The mean error using this model is ± 3 dB when the base station height is just above rooftop level. Performance is poor, however, when base station antennas are below the roof. This model is also restricted to frequencies below 2000 MHz.

None of these models consider multipath propagation.

Also small and micro-cell models have been developed, models which are very useful for e.g. DECT-planning purposes. This includes both 2- and 3-dimensional models based on ray-tracing techniques. An example is the *Ericsson micro-cell model*. This is based on a mathematical method for path-loss predictions. It is recursive, very simple and computation-time efficient. The path loss is determined along paths which follow the different streets.

Additionally, separate studies have been done on building penetration, indoor propagation models and models for tunnels, corridors and other special environments, e.g. railway environments and high-speed trains. More details are given in [1].

## GSM and DECT systems

Work has also been carried out in COST 231 with relation to second generation personal communication systems, specifically GSM and DECT. The performance of basic versions of such systems is relatively well known, and the focus of the work was therefore on advanced features and possible limitations. These topics are of importance not only in relation to the full exploitation of the potential of the systems, but also in terms of possible evolutionary transitions towards the third generation via progressive enhancements of the radio and network performance.

### Advanced techniques for GSM and DCS 1800

It is assumed that GSM and DCS 1800 work properly if the usable energy inside the equaliser window is 9 dB higher than the energy outside the equaliser window, i.e. carrier to co-channel interference ratio is higher than 9 dB. Hence, if the $Q_{16}$-parameter defined earlier is higher than 9 dB, GSM or DCS 1800 will not be limited by multipath propagation.

Among the techniques that can be employed to GSM to increase both quality of service and increased capacity is the introduction of random frequency hopping. Quality is increased compared to the non hopping case due to improved burst decorrelation for slow moving users. Capacity is increased by up to 70 % due to interference averaging in the network, giving possibilities of tighter reuse patterns compared to the non hopping case.

Also the gain of using different antenna diversity schemes for GSM has been simulated. Typical values of diversity gain are 5 dB (ranging from 0 to 7.5 dB). Using ideal adaptive antenna array and hence reducing interference and hence blocking can theoretically increase GSM capacity by up to 400 % in a given scenario. More detailed results are given in [1].

### Extending the usage of DECT

Also DECT (Digital Enhanced Cordless Telecommunications) and its performance have been studied within COST 231. DECT is intended to provide cheap equipment and offer high capacity compared to GSM. In addition, there is no need for frequency planning in DECT due to dynamic channel allocation.

DECT was originally designed to be a residential and business cordless system, but lately, the use has also been extended to public DECT and WLL[5] applications. Extending the use of DECT to outdoor scenarios creates challenges with regard to system performance due to the outdoor propagation conditions. In contrast to GSM there are no remedies in DECT to compensate for the influence of the radio channel, i.e. no channel coding, interleaving or channel equalisation are present. Hence, DECT is vulnerable to interference and multipath propagation.

The delay spread parameter defined earlier in this article gives a good measure of DECT performance limitations due to multipath propagation. There is a rule of thumb saying that in a system without channel equaliser, using GMSK[6]-modulation, there will be an irreducible bit error rate (BER) of approximately $10^{-3}$ if the delay spread parameter exceeds one tenth of the symbol interval. A BER of $10^{-3}$ is defined as performance limit for the speech service in DECT. This gives a maximum tolerable delay spread in the order of 100 ns for a DECT implementation not employing channel equalisation or advanced antenna diversity techniques. Hence, DECT performance will in many scenarios be limited by multipath propagation.

DECT tolerance to multipath propagation can, however, be improved by use of adaptive sampling instants (sampling at maximum opening of eye pattern) or use of advanced antenna diversity schemes. Error rate driven diversity schemes generally give better performance than received signal strength driven diversity schemes.

One advantage of the Time Division Duplex scheme used by DECT is that the uplink (hand portable to radio fixed part) and downlink (radio fixed part to hand portable) are reciprocal when mobiles are not moving. Hence, antenna diversity employed in the radio fixed part will improve both uplink and downlink performance[7].

In future PCS[8] applications of DECT, both time dispersion and portable movement may be significant, and simple switch diversity will not provide sufficient quality. Even advanced diversity

[5] *Wireless Local Loop.*

[6] *Gaussian Minimum Shift Keying.*

[7] *This will not work for moving handsets, because the radio channel will then change between uplink and downlink transmission.*

[8] *Personal Communications System.*

algorithms have limitations since they only deliver uplink gain or both. Equalisation can therefore be considered as a possibility. Simulations have shown that a simple 2-state Viterbi equaliser can extend the delay spread range (in high signal to noise ratios) to at least 600 ns.

Also experiences from a DECT field trial in a multipath environment have been reported. The DECT trial system consists of 240 handsets, 160 radio base stations and a central control fixed part, and provides coverage and seamless handover outdoors and partly indoors in an area of about 2.5 square kilometres.

Keeping in mind the potential of DECT in an outdoor environment both as a technology providing local mobility and as a fixed radio access solution, one of the purposes was to understand the strengths and weaknesses and improvements needed on current versions of the DECT system in order to operate in both indoor and outdoor environments.

Experience from the trial has given valuable information about the expected cell range in a variety of different indoor environments ranging from more than 50 metres in open hall areas to less than 15 metres in heavily reinforced areas. As a result of the limited cell radius careful site planning can reduce the number of indoor base stations by more than 30 %.

In outdoor areas, it has been found that the speech quality is generally good as long as there is a free line of sight path between the base station and the terminal, and no major reflecting objects are in close vicinity. It has also been found that the speech quality is variable in open squares (typically surrounded by reflecting buildings) even when there is a line of sight path between the BS and the terminal and high average received signal strength levels are measured. The link quality is also dependent on whether the user is moving or standing still, and is also affected by the user's orientation and positioning of the handset relative to the base station.

The experience in the trial shows that the DECT technology is a strong candidate for providing speech services and mobility in indoor domestic/business/industrial environments. However, for providing outdoor local mobility, the technology is relatively immature and too sensitive to radio propagation conditions. DECT performance would improve significantly if advanced diversity techniques or a channel equaliser are introduced to cope with multipath propagation. This should be kept in mind when planning outdoor DECT implementations for public use.

## Advanced radio interface techniques and performance

General radio system aspects, with the focus on transmission techniques and their performance have been studied. Several technical documents and reports dealing with analysis of radio interface techniques for third generation mobile radio system have been published in the open literature. Both linear and non-linear modulation techniques are analysed and optimised for various radio propagation conditions.

The capacity of cellular TDMA-systems can be greatly increased if enhanced techniques like adaptive modulation, adaptive coding or dynamic channel allocation (DCA) are applied. CDMA has been studied and performance results of DS[9]-CDMA and FH[10]-CDMA and hybrid systems presented.

If the advantages of TDMA and CDMA are combined, a further enhancement of the system capacity can be obtained. CDMA can be mixed with OFDM[11] to provide the system with a multiple access capability.

## Potential radio interface subsystems

### Time Division Multiple Access – TDMA

The most important single project that has provided results to COST 231 is the RACE ATDMA project. The goal was to design a radio interface based on the TDMA principles, fulfilling the following requirements of UMTS/IMT-2000 compared to second generation systems like GSM:

- A wider range of services in a wide range of environments
- Better quality and reliability
- Higher capacity
- Easier network planning and deployment.

A minimum number of radio bearers were selected to support all services:

- Voice (high and normal quality)
- Data service with low delay (9.6 kb/s - 2 Mb/s at < 30 ms)
- Data services with long delay (9.6 kb/s - 2 Mb/s at < 300 ms)
- Data services with unconstrained delay.

The concept of an adaptive radio interface was also important. The aim is that the radio interface should adapt to cell types and associated propagation conditions, interference and source activity factor. The system has been evaluated both by analysis and by the project simulation testbed, and the conclusion from the RACE ATDMA project was that it fully meets the requirements, making it a suitable candidate for the UMTS air interface.

### Code Division Multiple Access – CDMA

CDMA techniques were also studied in several projects with liaisons to COST 231. The UK DTI/EPSRC LINK Personal Communications Programme, project PC019 has carried out a rigorous evaluation of CDMA with the following key objectives:

- Study of UMTS requirements – teleservices and bearers
- Comparative study of FH- and DS-CDMA for UMTS service provision
- Design and development of a DS-CDMA field trial system
- Demonstration of a working DS-CDMA radio link, with a subset of the proposed UMTS services.

At the end of the COST action, the project conclusions were that a DS-CDMA radio link based on a single mobile, base sta-

[9] *Direct Sequence CDMA.*

[10] *Frequency Hopping CDMA.*

[11] *Orthogonal Frequency Division Multiplex.*

tion and mobility manager for a sub-set of UMTS teleservices are viable. Two common channels and three dedicated channels per user are supported on the downlink, while the uplink supports a common random access channel and two dedicated channels per user. The channels are code separated with a common chip rate of 8.192 Mchip/s.

Studies have also been performed on a hybrid access system called *Code Time Division Multiple Access – CTDMA*, which incorporates both CDMA and TDMA aspects. Finally, studies have been done especially on Joint Detection (JD) CDMA.

## Broadband systems

In COST 231, broadband systems have been addressed as a separate issue by WG3. The emphasis has been put on wireless communication to mobile or portable equipment offering very high data rates. "High" data rates are for this purpose defined to be greater than 2 Mb/s to ensure no overlap with UMTS. Examples of such systems are Wireless Local Area Networks – WLANs. These systems will be the main focus for the proposed follow-on action (see below).

Both infrared (IR) and millimetre wave (mmw) technologies were initially considered. IR were early eliminated due to grounds of eye safety, thus leaving the focus on mmw based systems, mainly operating at 40 and 60 GHz.

### Millimetre wave propagation

A lot of work has been done on mmw propagation issues. In the RACE MBS project, studies have been performed on material characterisation at 60 GHz, concluding that walls made of all materials except glass and plasterboard provide sufficient isolation to enable frequency re-use in neighbouring rooms. Propagation has been studied both by measurements and modelling for indoor and outdoor scenarios. Both narrow- and wideband measurements have been conducted. A statistical model for the power delay profile of the indoor mmw channel has been derived from the measurements. In the outdoor environment, the oxygen absorption is expected to limit cell radii to less than 1 km.

### Wireless LAN

Not only mmw based technology has been the issue. Also transmission techniques for HIPERLAN have been studied. DSSS[12] and RAKE receivers, multicarrier or OFDM modulation, antenna diversity and adaptive equalisation are all techniques that can be used to overcome the limitations set by the wideband multipath disperse channel.

### Wireless ATM

Finally, MAC[13] protocols for ATM access to the public B-ISDN have been studied. Other topics are protocols for random access to a wired backbone network and ad-hoc networks. Several anti-collision protocols are described, e.g. request/permit mechanisms, busy/free declaration by the use of inhibit bits on the downlink. For ad-hoc networks with no central BS to control the access, distributed protocols must be used either for sensing the channel at the transmitter or using handshake procedures.

## The follow-up: COST action 259

The MoU for COST action 259 – *Wireless Flexible Personalised Communications* – was prepared in April 1996 and approved by the COST Technical Committee Telecommunications TCT [2]. The final approval has taken place at the October 1996 meeting of the Committee of Senior Officials (CSO), and the MoU is now open for signing. A probable kick-off will be in January–February 1997.

The main objective for the new action is to

> *"... increase the knowledge of radio system aspects for flexible personalised communications, capable to deliver different services exploiting different bandwidths, and to develop new modelling techniques and related planning tools, in order to guarantee the continuity (and quality) of service, delivered by networks of widely different capabilities and structures, across a number of environments."*

The title of the action tries to summarise the objectives.

The cost of the action is estimated at 17.7 million ECU.

The background for the new COST action is the medium/long term scenario envisaged for telecommunications by the European Commission for the time period 2000 – 2005. This period will be characterised by the emergence of PCS with a full integration of user, terminal and service mobility, the Integrated Broadband Communications (IBC) and network intelligence. The COST action is intended to play the same role as COST 207 and COST 231 did in the past on GSM, DCS1800 and UMTS, but now on the progressive deployment of UMTS and MBS.

## References


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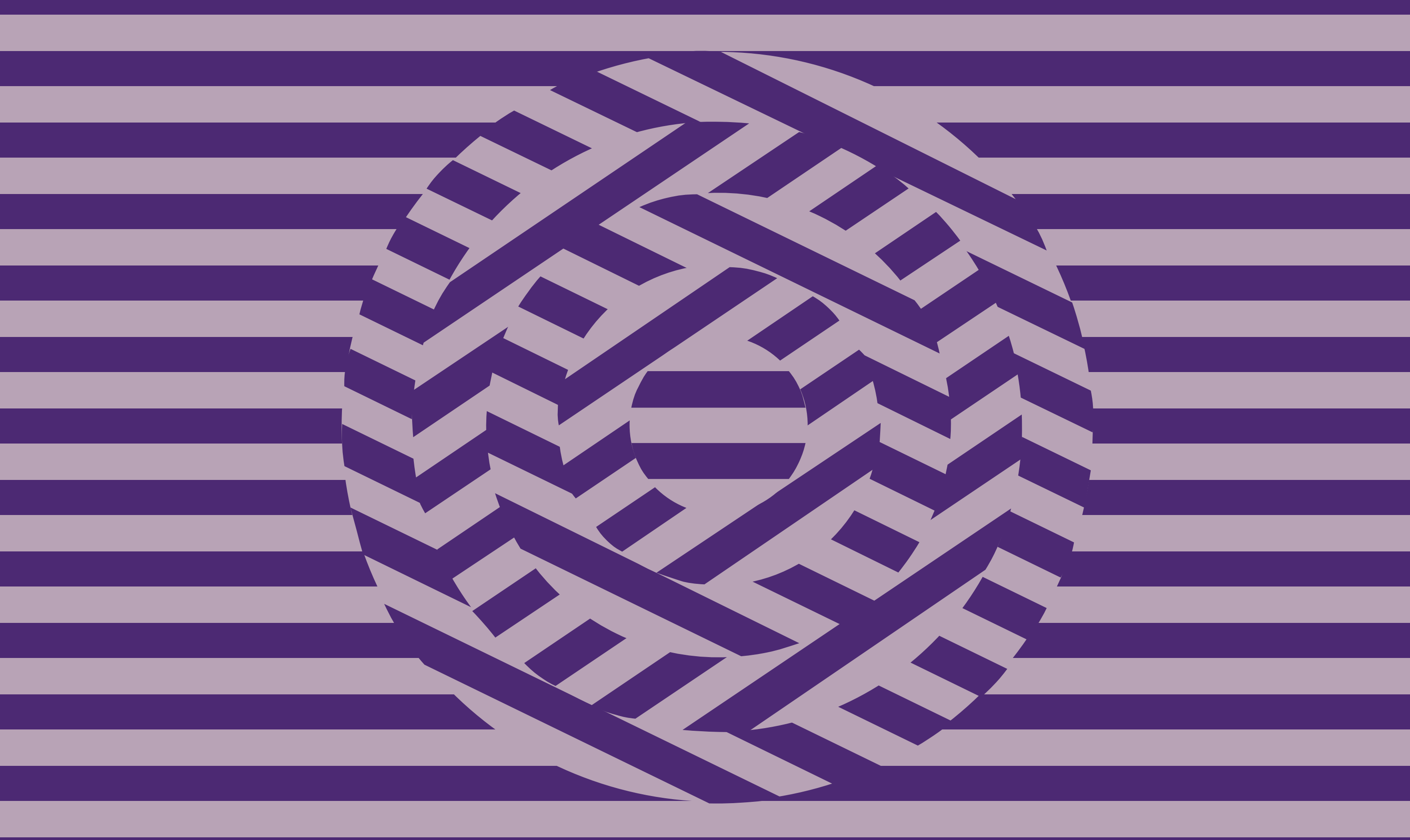
2 Memorandum of Understanding for COST Action 259. *Wireless flexible personalised communications.* April, 1996.


[12] *Direct Sequence Spread Spectrum.*

[13] *Medium Access Control.*

# Kaleidoscope



# 50 years of radio links in Norway
## The transition from the telecommunication Stone Age

BY KNUT ENDRESEN

The teenager clicks with his PC mouse on the Internet icon, surfing for information somewhere in the world and has it printed out with illustrations. Or he collects his incoming e-mail from Internet friends in Australia and other continents. Or chats with a friend in Africa. All he pays is the local telephone tariff! He is, maybe, somewhat annoyed that it takes too many seconds to get the information on his monitor, or that the sound quality is below that of a CD. But never mind, he knows that this will be better in a couple of months or perhaps a year.

Radio link systems (radio links), satellites, computers, information technology: Today, all this is taken for granted. But that was not the case in the IT Stone Age. And when did the IT Stone Age end, – or are we still at the trailing end?

Until just some 40 years ago no telephone lines existed across the Atlantic Ocean. Conversation between Europe and America was only possible on short wave radio when the ionospheric conditions were favourable. Then, the first transatlantic telephone cable was put in operation. Almost unbelievable: 24 telephone channels between the two continents could be used!

In Norway at that time you could get through a telephone call between e.g. the two cities Oslo and Trondheim, provided that

a You were lucky enough to have a telephone – the waiting list was several years

b You had lent the telephone company NOK 3,000

c You could afford to pay express fee for long distance calls

d You had the time to wait for a couple of hours

e The transmission quality was sufficiently high to make conversation possible.

No wonder that today's teenager lacks the imagination to appreciate fully the enormous development that has taken place during just a few decades!

Radio links have played an important part in making Norway a world pioneer in telecommunications. Below, we present the development which has taken place in the transmission network of Telenor and its predecessors.

During World War II and the years to follow, telephone connections were a luxury in Norway, available only to a few people. Telegrafverket, which had the exclusive monopoly on electrical communications by wire and radio, was indeed not a popular state owned agency in Norway. This was, however, a little bit unfair, as the parliament grants for telecommunications every year were less than needed to cope with the increasing demands.

In 1969 Telegrafverket was reorganized and was renamed Televerket. The next major reorganization took place on 1 November 1994, when Televerket became a state owned limited company named Telenor. Today, the monopoly is almost dissolved, and Telenor has for several years been one of the world's leading telecommunication companies. This position has been gained, partly due to the development of radio links carried out by Televerket/Telenor, The Norwegian Joint Signals Administration and the Norwegian industry during the last 50 years.

The rest of this paper mainly concentrates on the activities which have taken place within Telegrafverket/ Televerket and a few of the key persons involved. But first a brief look in the rear view mirror.

## Prelude: A brief history of radio

### First came Faraday, Maxwell and Hertz

The English scientist Michael Faraday (1791 – 1867) is perhaps one of the greatest experimental scientists who has ever lived. In 1831 he discovered the electromagnetic induction and gave an explanation of the electromagnetic fields.

The discovery of Faraday laid the foundation for the Scottish scientist and mathematician James Clerk Maxwell (1831 – 1879) when Maxwell presented his theory on electromagnetic waves in 1873. His theory is defined by four differential equations, which have since been a basis in all education in radio communication theory.

In 1887 the German professor Rudolf Hertz (1857 – 1894) performed the first practical experiment which proved that Maxwell's theory was correct. He used a 3 metre long copper wire with a 30 centimetre spherical ball at each end. In the middle of the wire was an inductor fed by an interrupted DC current. Sparks were generated between the two ends, and electromagnetic waves were emitted. From another copper wire which ran parallel to the first one he was able to extract small sparks.

In 1888 he performed an experiment with a set-up rather similar to a radio link system. He used parabolic disks as directional antennas and transmitted radio waves in the 10 centimetre band across his laboratory.

### Then followed Marconi and the spark transmitter

Based on Hertz' first practical experiment the Italian Guglielmo Marconi (1874 – 1937) developed the spark transmitter and demonstrated in 1895 that radio signals could be transmitted over several kilometres. He was granted a patent in England in 1896, one hundred years ago.

The spark gap transmitter became the dominant method for radio transmitters until World War II. Even after the war it was extensively used in emergency transmitters in ships.

In 1901 Marconi demonstrated the first radio telegraph communication across the Atlantic Ocean. Only five years later the first radio telegraph connection was established by Telegrafverket between Sørvågen on the mainland and the islands Værøy/Røst in Lofoten in the north of Norway. In May 1996 a museum was inaugurated at Sørvågen to celebrate the 90 years anniversary of radio communication in Norway.

At the receiver end the technological breakthrough came in 1907 when the American Lee de Forest developed the triode tube.

### 1934: Radio link system between Dover and Calais

The development within the radio field followed different directions. The first commercial radio link system was put into operation between Dover, England, and Calais, France, in 1934. The radio frequency used was 1700 MHz (UHF), and the transmitter output power was 1 watt. 3 metre parabolic antennas were used. The system was amplitude modulated and could transmit one telephone channel and one telegraph channel.

The first multichannel radio link system was established by Clavier between the Channel Islands and the English coast in 1935. Due to the great depression in the 1930s, the experiments were, however, not followed up. The principles, which were based on the use of very short radio waves in the centimetre band, were further developed by the Armed Forces shortly before and during World War II. The development during the war was mainly for military purposes, in particular radar systems.

The first multichannel radio link system in the VHF frequency band was put in operation in 1936 by the British Post Office (GPO) between Scotland and Northern Ireland. The capacity was nine telephone channels, and a frequency of 65 MHz was used with amplitude modulation. This modulation method, however, gave rise to insurmountable problems in multichannel systems due to intermodulation. As a consequence, both in France and in USA pulse modulation was tried and a few systems were developed and produced. From 1939 onwards, frequency modulation was used, first in Germany by Telefunken and later in other countries.

## Technological development during and after World War II

The Englishman Ranwell developed the magnetron tube for the GHz band (centimetre waves) in 1939. It was to be used for radar systems. The output peak pulse power was several thousand watts. During the war both the magnetron and the klystron were further developed by British and American scientific institutes.

After the war the development of radio link systems progressed very rapidly, and USA became the leader in this field. Public traffic demand increased and the need for larger capacity grew rapidly. The need for world wide telephone connections also increased and also the quality had to be improved. The requirement was to obtain better linearity and lower noise in the systems. Therefore, new technology on higher radio frequencies had to be developed.

## 1947: AT&T with broadband radio link systems for TV and radio transmission

In 1947 the American Telephone and Telegraph Corporation (AT&T) put into operation a radio link system between New York and Boston. The capacity was 100 telephone channels in the 4 GHz frequency band. In 1950 AT&T had in operation 12,000 km of its TD-2 system for TV transmission.

In 1952 a radio link system between New York and San Francisco comprising more than 100 stations was put into operation.

In Europe, the world's first radio link system using travelling wave tubes (TWT) was put in operation in 1951. The link was established between Manchester and Scotland for TV transmission and was operating in the 4 GHz band. In the 1950s several radio link systems were implemented in Europe, both nationally and internationally.

In 1952 more than 25 million circuit kilometres transmission capacity were in operation in USA, Europe and other countries in the world.

International co-operation was promoted through the International Telecommunication Union (ITU, founded in 1865) and its Consultative Committees (CCITT and CCIR). CCITT (now ITU-T), the agency responsible for technical studies, operation and tariff questions, stated in its recommendation No. 40 in 1951 that cables and radio link systems should be considered as equal transmission media for telephony. Radio link systems should as far as possible follow the recommendations issued for cable systems concerning quality and other relevant parameters.

CCIR (now ITU-R), responsible for technical studies concerning radio communication, issued its first recommendation for radio link systems in 1953 (CCIR Rec. No. 128).

As from the mid 1950s the role of the radio link systems became increasingly greater. Already in 1972 more than two thirds of the long distance traffic and nearly 100 % of the TV and radio programs were transmitted by radio link systems in Norway.

## 1926: First public fixed radio telephone connection in Norway

In Norway the use of fixed telephone connections has a long tradition. The first fixed radio telephone connection was established between Kristiansund and Grip in 1926. The equipment was very simple. It operated on medium waves and used amplitude modulation. During a ten year period approximately 60 of these connections were established to isolated settlements on islands along the Norwegian coast. They were in operation right up to the 1960s.

*Torbjørn M. Forberg*

## A prelude to the first civilian radio link systems in Norway

### A pioneer from the high Arctic North

Torbjørn M. Forberg is indisputably "the radio link pioneer" in Telegrafverket. He was born in 1901, in the same year that Marconi demonstrated the first radio telegraph transmission across the Atlantic Ocean. He grew up in the small community Kvitnes at the Tana fjord in northern Norway. The Post Office believed that the place was a community belonging to the minority Same group (Lapps) and renamed the postal address Muoregággu. "Today, I am slightly in doubt if I was really born," says the now 95 years old veteran.

The initial developments took place under very poor economic and technological conditions. "We planned and built a telephone network for eternity, but the technological development was so rapid that in a few years the systems were outdated. When I started in Telegrafverket, the radio tube was not yet invented. When I ended my career the tubes were outdated," he says, referring to transmitter tubes for high frequencies.

The possibility of getting further education after the primary school in Kvitnes did not exist, but Torbjørn's father saw an advertisement for a secondary school in Nordfjordeid in western Norway. "You may apply for this school, on the condition that you complete it in one year," said his father. Torbjørn went to Nordfjordeid where he met young people from all over Norway. But this was a private school, and after a year Torbjørn had to walk across the mountains to an authorized school in Volda, where he passed the examination with the most brilliant results ever in his career.

### Training as a telegraph operator at Stavanger Radio

Shortly before World War I, in 1914, Telegrafverket had ordered equipment for Stavanger Radio from Marconi and started tests in 1918. But Telegrafverket lacked telegraph operators and had to start a training course. Forberg attended the first course and in 1921 he could start his career at Stavanger Radio, a station which somebody has characterised as "built on shear optimism and ignorance".

The station was located very close to the North Sea to minimize the distance to America. The antenna was almost 3 kilometres long and was mounted on 100 metre high masts. The receiver picked up a lot of cosmic noise but very little of the wanted signals. On the other hand, the spark transmitter in Stavanger spread noise to the whole world!

Crystal detector receivers were used, and the information received was engraved on phonograph rolls. Even if some development had taken place during the war, the project was rather hopeless. In order to avoid a complete failure, Marconi sent over to Stavanger a competent engineer who worked day and night. He built a directional frame antenna and succeeded in improving the receiving signals.

In 1925, Stavanger Radio was put out of operation and the activity was transferred to Fornebo near Oslo. Forberg was employed as a technician at Fornebo and later he became a telegraph operator. In 1925 he won a competition in the use of a Kleinschmidt perforator, and in 1927 he won a competition in operating a Corona Morse telegraph machine.

Forberg now took his college education. He then worked at the Oslo broadcasting transmitter at Ekeberg near Oslo, and one summer on Spitzbergen. After that he attended the Norwegian University of Technology in Trondheim, where he graduated as an M.Sc. in 1935, more than ten years older than his fellow students.

On his return to Telegrafverket, no suitable job for his qualifications was available, so he worked for 4 to 5 years in the governing body Telegrafstyret as an engineer with the title of operator. In 1937 he moved over to Tryvasshøgda Radio in Oslo.

The economy of Telegrafverket at the time was extremely bad. The Radio Office had an annual budget of merely NOK 50,000! This left no room for great investments.

### Primitive medium wave radio stations for connections to the islands

Together with other engineers Forberg installed a number of small radio stations in the medium wave frequency band, mostly to isolated islands in the north of Norway. In 1942 there were more than 60 of these radio connections in operation.

During World War II and the following years he continued to work with the radio connections. He had a very good co-operation with Aldor Ingebriktsen, a fisherman, member of the Norwegian Parliament and head of the Parliament's Communications Committee, and later president of Lagtinget, the Law House of the Parliament. Ingebriktsen was a very eager spokesman and promoter for the island connections, being a representative for northern Norway. "If we don't manage to implement these radio connections, I dare not return home," he said, and received full response from Forberg.

In 1945 Forberg was promoted divisional engineer A in Telegrafstyret and advanced later to higher positions.

### The first public Norwegian radio links

Just after the war the term "radiolinje" entered the communications debate in Norway. The word "linje" (line) was widely discussed. "Linje" was used for physical wire connections in the network. France used the word "hertzien cables", and USA used the term "radio links"; should we in Norway use the word "ledd" (link), "kjede" (chain) or something else to describe a radio relay system?

Well, in spite of terminology problems; the first Norwegian radio link, with a capacity of one telephone channel and one telegraphic channel, was tried out between Haugesund and the island Utsira in 1945 by regional engineer Arne Bjørntvedt, Rogaland telephone district, and communication officer Lehne from the Army. They had taken over German military equipment left over in Norway when the war ended. The radio link equipment was produced by Telefunken and operated in the UHF frequency band (540 MHz).

In 1946, Telegrafverket put in commercial operation the first public radio link system between Sørvågen and the islands Værøy/Røst by using the same Telefunken equipment. Later, similar systems were put in operation between Sørvågen – Bodø, Bodø – Svolvær and Gjøvik – Ringsaker.

### The Norwegian Defense Research Establishment (FFI) develops and demonstrates a Norwegian SHF radio link system Bergen – Haugesund[1]

By the end of the 1940s, FFI, in co-operation with Christian Michelsens Institute in Bergen, developed a radio link system in the 3.3 GHz band. It was put on trial between Bergen and Haugesund in 1951. The development work was done by Norwegian engineers who had worked at British research institutes during the war. The engineers Bjørntvedt and Gustavsen from Telegrafverket participated very actively in the measurement on the system at the stations Rundemannen and Stord. The trials went well, and a connection of one telephone channel was put in operation.

The system was later extended to Haugesund Telegraph Station using the mountain Steinfjell as a repeater station. In Bergen the system was extended down to Bergen Telegraph Station by using a passive reflector on the mountain Sandviksfjellet. The capacity was now extended to 8 telephone channels by using a multiplex system (type MEK 8) which was provided by Telegrafverket. The multiplex system had been taken over from the German military forces and was designed for use with copper wire. Also British military equipment was used. FFI produced the equipment and installed and commissioned it, and also trained the maintenance crew. With the capacity of these 8 telephone channels in addition to the 2 existing wire connections, the capacity between Bergen and Haugesund was increased by a factor of 5!

### A/S NERA Bergen was established, and the FFI system was extended to Stavanger

FFI further improved the system. In order to extend the system to Stavanger and also establish a radio link system between Bergen and Oslo, FFI signed a contract with A/S NERA, Oslo. In 1951 NERA established a separate division in Bergen, NERA Bergen, to manage the contract.

The contract committed NERA to deliver a radio link system with a capacity of 12 telephone channels in the 3 GHz band. In the new NERA equipment, the klystron CV67 was used. Due to instability problems with the klystron the system to Stavanger was delayed until 1955 before it was in operation. Because of the problems caused by the imported CV67 klystron NERA decided to develop their own klystron in co-operation with FFI and NTH. The new klystron was produced by NERA.

The establishment of the NERA division in Bergen and the implementation of the radio link between Bergen and Oslo gave the kick-off for the building of a country wide radio link system in Norway. The Norwegian Joint Signals Administration, FFSB (Forsvarets Fellessamband) was established in 1953 to co-ordinate the implementation of the network. Another separate radio link network was established by the Norwegian Air Force (Luftforsvaret) in order to solve the communication problems between the military airports in Norway. They used equipment from the American company Philco in the 7 GHz band, but the system was not very efficient and was operated for only a few years. The military radio link systems are described elsewhere.[2]

### Good co-operation between Telegrafverket and the Army on the operating level, but it was windy at the top

Between the operative staffs in FFI, FFSB, and Telegrafverket the co-operation was always good. Delegates from both parties participated in international fora. They were not always in agreement, but: "When one is attending a meeting and has to express oneself in public it may happen that one uses expressions that are a bit provocative," says Torbjørn Forberg with a smile.

Also at the top levels in Telegrafverket, FFI, FFSB, and the industry the co-operation at the beginning was good. As an example, one may mention that the annual convention "Studiemøtet i radioteknikk og elektroakustikk" (Study group in radio technology and electro-acoustics) was started in 1948 on the initiative of Helmer Dahl, chief of research, FFI's radar division; Sverre Rynning Tønnesen, managing director of Telegrafverket; A. David Andersen, manager and chief engineer, David Andersen Radio; and Fr. Brodtkorp, R&D engineer, Tandberg Radiofabrikk. The first convention was held in Åsgårdstrand, with radio link systems as the opening topic. Also in almost all of the following annual conventions – 49 to date – radio links has been a central theme.

In the first conventions the discussions between the representatives of Telegrafverket, FFI and FFSB were, however, very aggressive. The discussions also went on within the organisations. On the surface the issues were the use of radio links versus cable systems, the choice of frequency bands to be used, reliability of the systems, and the economy. There were, however, deep undertones. The level of the discussions might indicate that not all of the participants would be suitable for jobs in the diplomatic corps!

In retrospective one may say that the debates were in fact very useful. No problems were hidden under the carpet and with stubbornness the participants stressed the technology to its utmost to prove their points. Without this endeavour from all parties involved, Norway would hardly been able to establish its strong international position in the world market today.

### A study trip to USA in 1950 gave Telegrafverket the start-up kick

In 1950, an event took place that really initiated the start up for an independent development of the radio link systems inside Telegrafverket. Through financial resources made available by

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[1] *In general, Norwegian abbreviations will frequently be used in the text, e.g.:*
*FFI: The Norwegian Defense Research Establishment*
*FFSB: The Norwegian Joint Signals Administration*

[2] *E.g. Knut Endresen:* Fra topp til topp. Kampen om radiolinjene (From peak to peak. The fight for the radio links). *INTRA sivilingeniør Knut Endresen, Oslo. ISBN 82-993291-0-8.*

the Norwegian Broadcasting Company (NRK), which began thinking of implementing TV in Norway, Torbjørn Forberg got a 3 months grant from Standard Telefon og Kabelfabrik to study radio link systems in the USA. He visited several radio link stations, met the key people and acquired a good knowledge of maintenance experience, traffic prognoses and future plans for implementing radio link systems. Of special interest was the broadband systems TD-2 which had been put in operation between New York and San Fransisco.

The reports from this system and others indicated that broadband radio link systems were a very promising method for establishing a communication network in mountainous Norway, and that less manpower and equipment resources were needed than one had previously believed. The systems could be implemented quickly and economically. Future expansion of the systems would require small additional costs, and the reliability of the systems was very satisfactory.

## Great scepticism, because "radio is always radio ..."

"On my return to Telegrafverket I became the real EXPERT on radio link systems," says Forberg. He was giving several lectures in Telegrafverket on the promising new technology and the stability of the systems: "But I had to be very careful, for the scepticism was strong and many were very doubtful about this new technology. They said: 'Radio is always radio and we know its performance ...' The American systems operated on 3 – 4 GHz . When I once said that I thought that radio link systems could obtain the same reliability as fixed copper wire and cable systems one of the listeners to the lecture said: 'Now we shall hear this, too ...!' " But, as mentioned above, ITU (The International Telecommunication Union), had already in 1951 said in their recommendation (CCITT rec. No. 40) that cable systems and radio link systems should be equal as transmission media.

## Budget proposal for a radio link system in 1951 was turned down in favour of a coaxial cable system

In January 1951 a budget for an extension of the existing military system Bergen – Haugesund – Stavanger (which was now also used by Telegrafverket) across the mountains to Oslo was proposed. The system was planned to start from Jåttanuten close to Stavanger, via Skaulen (1575 metres above sea level), Gaustatoppen (1883 metres above sea level), and to Tryvasshøgda close to Oslo, a distance of 331 kilometres. It was proposed to use a 36 channel frequency modulated system from Marconi, England, on this route. On the route between Bergen and Stavanger the proposal was to change the existing FFI system with a system from Storno, Denmark. The latter system was pulse modulated with 24 channels operating in the VHF band.

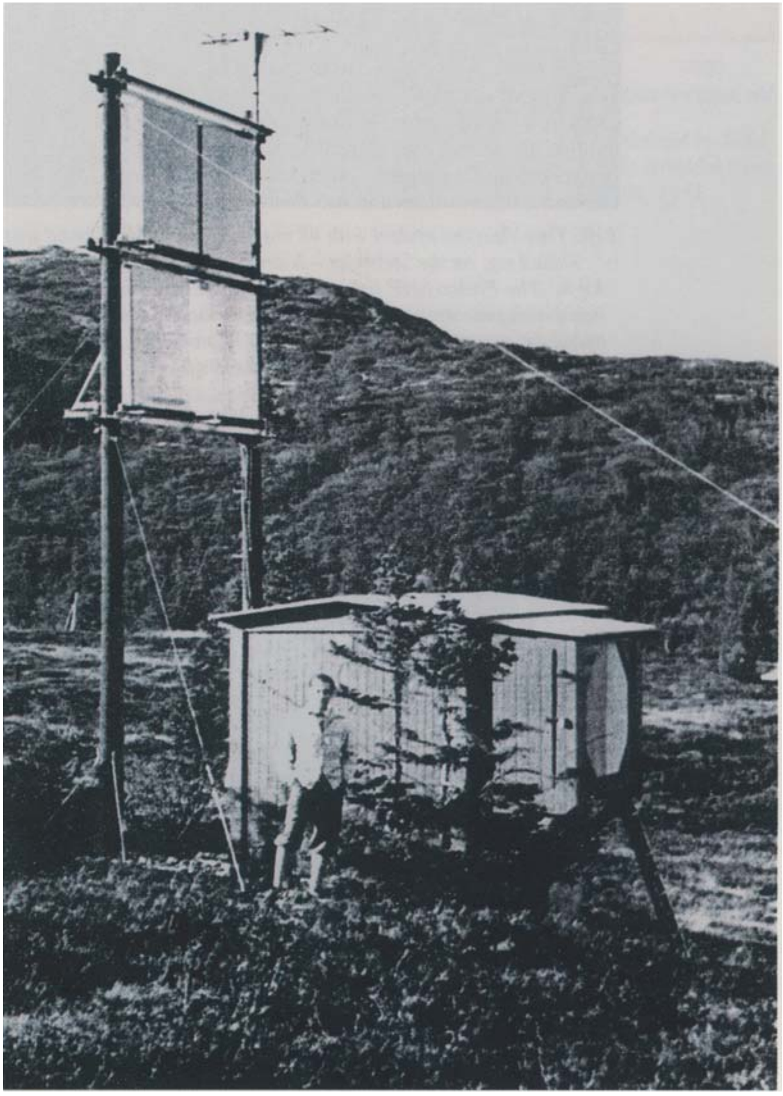
The proposal for the new Stavanger – Oslo link was, however, rejected by Telegrafverket. Later on, in 1953, a Marconi system was installed between Bergen and Stavanger. The system was later moved to Steinkjer – Namsos in 1954.

The official reason for Telegrafverket for not implementing the proposed link was lack of investment capital. With the limited financial resources Telegrafverket preferred to extend the coaxial cable system with a capacity of 600 channels between Oslo and Gjøvik, with a cable across Hardangervidda to Bergen. Installation of the cable between Oslo and Gjøvik had started in 1946. The total system Oslo – Gjøvik – Bergen was completed in 1956, after ten years installation time.

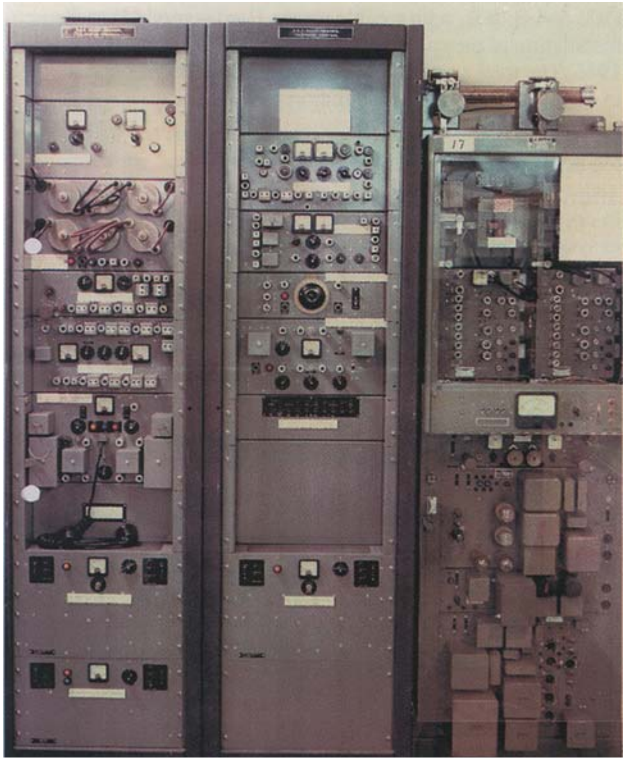
## Positive field tests in Trøndelag

In co-operation between Telegrafverket and FFI an experimental system was put up between Gråkallen close to Trondheim and Offenåsen, Steinkjer in the summer of 1951.[3] Wave propagation measurements were carried out over the 89 km hop during one year . The frequencies used were in the VHF (160 MHz), UHF (540 MHz) and SHF (3.3 GHz) bands.

[3] *Bjarne Hisdal: Feltstyrkemålinger Trondheim – Steinkjer (Field strength measurements Trondheim – Steinkjer).* Teknisk Ukeblad, *No. 18, 1953, p. 363.*



*Field strength measurement in the VHF, UHF and SHF bands at Gråkallen in Trondheim of signals transmitted from Offenåsen, 1952*



*Left: This Marconi system with 48 channels in the VHF band was used e.g. on the Steinkjer – Namsos connection, 1953.*
*Right: The Philco SHF link with 24 channels in the 5 – 6 GHz band with time division pulse amplitude modulation was used by the Norwegian Air Force for NATO connections to the airports Bardufoss – Lista – Sola during and after the Korean war 1950 – 1953*

The conclusion was very clear: "The reliability is primarily dependent on the power supply system and the quality of the radio equipment and to a very little extent on the atmospheric conditions if the planning is performed well. The propagation conditions in Norway are very favourable. Therefore the reliability of the system should not be worse that in other countries," writes Forberg in "Verk og Virke".

## The first systems from Marconi: Trondheim – Steinkjer – Namsos on VHF

In 1952 Telegrafverket ordered radio link equipment in the VHF band with a capacity of 48 channels from Marconi for the route Trondheim – Steinkjer. The system was opened for traffic in 1953 and a year later was extended to Namsos with equipment removed from the Bergen – Haugesund link.

In 1954 FFI opened the military radio link system between Bergen and Oslo. It had a capacity of 22 telephone channels and 36 telegraph channels and was operating in the 3.3 GHz band. At first, Telegrafverket was not interested in this link, but later leased several channels on it.

During the following years Telegrafverket installed several radio link systems in the VHF band with equipment from Marconi. The first system with a capacity of 36 channels was put in operation between Bodø and Svolvær in 1955.

*Power panels for the Marconi 48 channels VHF link are carried up to the site Offenåsen on the radio link between Steinkjer and Namsos in 1954*

*A VHF yagi antenna being mounted at the Falkhetta site near Rørvik on the Trondheim – Bodø link 1956*

## Low capacity radio links to islands

During the period 1954 to 1957 several pieces of single channel systems in the VHF band was ordered from Norsk Marconi and Standard Telefon og Kabelfabrik. The equipment, which was produced in Norway, was inexpensive and rather simple. It was mainly used to replace the old medium wave radio equipment in Trøndelag and northern Norway.

Low capacity systems were also bought from the English company Pye. They were used in the local networks and had a maximum capacity of 6 to 8 channels.

In 1959, some 2,000 circuit kilometres of island connections were in operation.

## Gjøvik – Trondheim: Coaxial cable lost to radio link system

It was originally planned to connect Oslo with Bergen and Trondheim with the extensions of the coaxial cable system first established between Oslo and Gjøvik. As mentioned above, the system between Gjøvik and Bergen was completed in 1956. The plans for extending the system from Gjøvik to Trondheim were, however, dropped, and it was instead decided to build a radio link.

The radio link was implemented during the period 1955 – 1956, using as sites the link stations built by the Norwegian Air Force for the Philco link. The Philco link had been established during the Korean war 1950 – 1953. The new radio link system had 48 telephone channels. It was produced by Marconi and operated in the VHF band.

## Severe icing problems on the mountain peaks

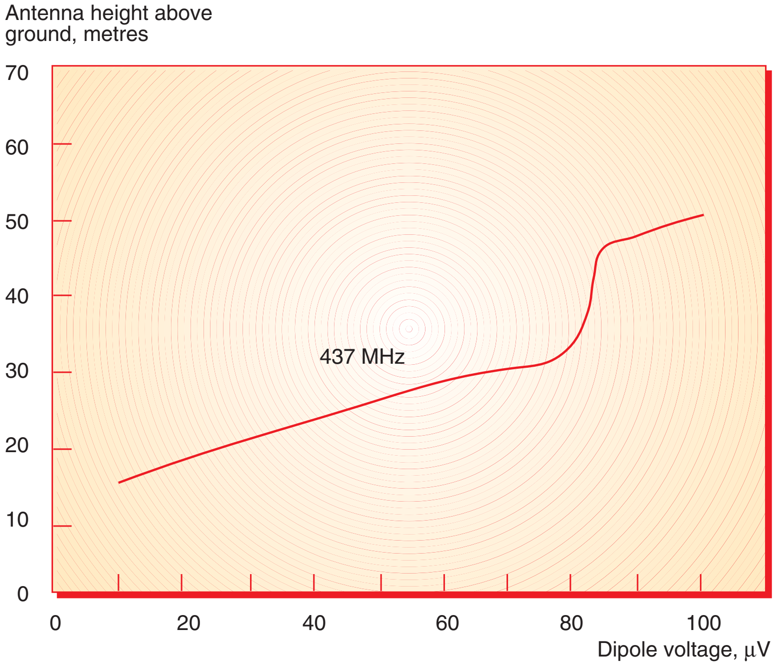
The link between Gjøvik and Gråkallen near Trondheim had mainly rhombic VHF antennas. Some yagi were also used. Severe icing occurred, in particular on the rhombic antennas. To solve the problem ordinary 12 volts transformers used for melting frozen water pipes were mounted as de-icing equipment on the antenna elements. “The amount of power needed for melting the ice was rather high!” says Asbjørn Nilsen. For the yagi antennas plastic cylinders were mounted around the antenna elements in order to minimize the icing problems.

## All the way to Kirkenes in 1960

In 1957, the radio link proceeded northwards. The gap between Namsos and Bodø was closed by a VHF radio link. Between Bodø and Svolvær a system was already in existence since 1955.

In 1959 a radio link was built between Bodø and Narvik, operating in the 400 MHz band with a capacity of 60 channels. The system was produced by Elektrisk Bureau, Norway, and was similar to a system put up between Bergen and Florø on the west coast in 1957.

In 1959 – 1960 Telegrafverket implemented the so-called “Arctic coast link” with a capacity of 48 channels along the coast of Finnmark between Hammerfest and Vardø. At the same time several single channel radio link systems were implemented on Finnmarksvidda to give better connections to the Lapp (Same) areas.




*To obtain a free Fresnel zone one had to use high masts, as evidenced by field strength measurements by Elektrisk Bureau of signals received in Arendal from the Risør transmitter as a function of the antenna elevation, 1958*

Between Tromsø and Hammerfest a system operating in the 2 GHz band with a capacity of 120 channels was put in operation in 1963. It was produced by Elektrisk Bureau and was later expanded to 300 channels.

## Southbound with equipment from Elektrisk Bureau on UHF

From Oslo and southwards the radio links were operating on UHF. Elektrisk Bureau was the supplier with equipment in the 400 MHz band and a capacity of 60 channels. In 1955 the system between Oslo and Arendal was put in operation.

In 1956 the system was extended to Kristiansand to give connection to Jutland, Denmark.

In 1955 a system between Oslo and Fredrikstad was opened, and in 1957 a similar system was, as mentioned above, established between Bergen and Florø.

## Well prepared for the expected national plan for an FM and TV network

During the years 1950 to 1958 long term planning was made to meet future requirements. More than a hundred station sites had been selected all over the country, many of them more than 1,000 metres above sea level. Altogether more than 200 sites had been surveyed.

The surveys were very time consuming since one was dependent on optical sight between the sites. It was hard physical work and required good physical fitness, but according to Forberg: It was almost immoral to receive monetary compensation for walking in the mountains, as mountain tourists had to pay for the same experience!

In order to select the proper route for the radio links it was necessary to estimate the future traffic demand and its routing, the length of the hops, the Fresnel zone clearance, interference conditions, the climatic conditions at the site, physical access for maintenance, the possibility to have electrical power to the planned station, and so forth.

The highest site between Oslo and Trondheim was Tronfjell, 1,666 metres above sea level. The existing access road ended at an altitude of 850 metres. From that point there was only a footpath further to the top where the measuring equipment had to be placed. The mast used for the measurements and a prefabricated cabin were brought to the top by a helicopter and were firmly guyed. The mast was telescopic for adjusting the height of the parabolic antenna used for the propagation measurements.

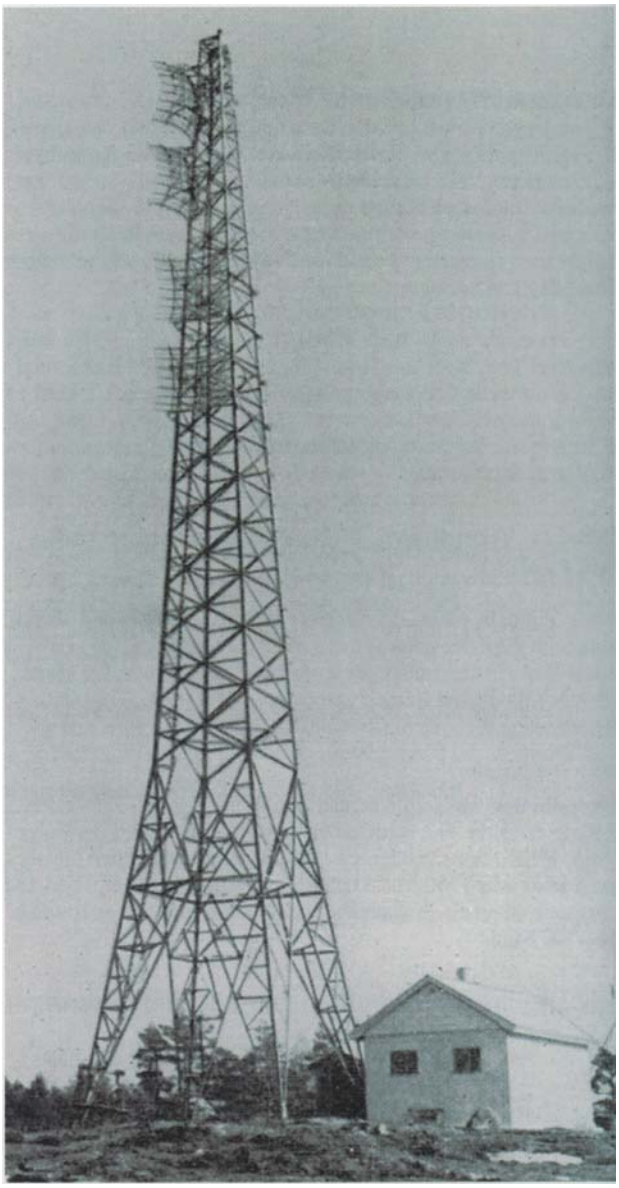
The icing problems on the site were severe, and one stormy night the mast was blown down. It was then re-erected and secured by better guys.

One day in December 1958, the Marconi engineer S.D. Sissons,[4] together with Hans Walland from Telegrafverket and two technicians, were on their way up to the top carrying equipment when they were suddenly overtaken by a heavy snow storm. The visibility was down to 5 metres and they lost their sense of direction in spite of their compass, and they planned to dig a cave in the snow for the night. Fortunately, Kåre Johansen, who had previously arrived on the top site to install equipment, guessed what was happening and he started banging on some metal plates which he found at the site. By following the sound they managed to reach the top after a very tough and exhausting walk.

Another technician who had started towards the top a few hours earlier had, however, not arrived. After 6 hours of tough wading in deep snow he managed to return to the valley again, and a rescue expedition that was set up could be cancelled.

When a site had finally been selected, the installation people started the planning of the infrastructure. They had about two years to plan how to transport more than a thousand tons of construction material to isolated mountain peaks all over Norway. Very often access roads or funiculars had to be constructed, and in some cases helicopters were used. Then followed the planning of the maintenance scheme. Therefore, one was well prepared when the plans for a nationwide radio link network to serve FM broadcasting and TV transmitters were proposed in 1959.

The Tronfjell site attracted many visitors. One of them was Mr. Beer, a disciple of Sri Ananda, who settled on Tronfjell where he is now buried. This Indian philosopher came to Norway in 1914 to seek the loneliness on Tronfjell which he considered a holy mountain. He gave lectures on Eastern philosophy at Oslo University, and he had plans to build a World Peace University on the mountain.



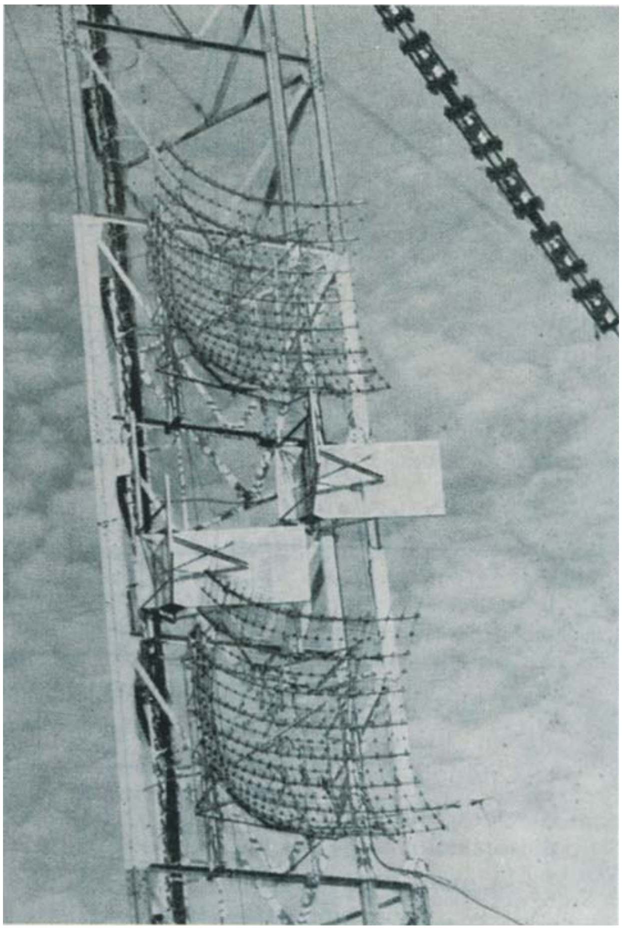
*The site on Aaleberget in Fredrikstad 1958. The height of the mast was 50 metres*

## Sites of great beauty

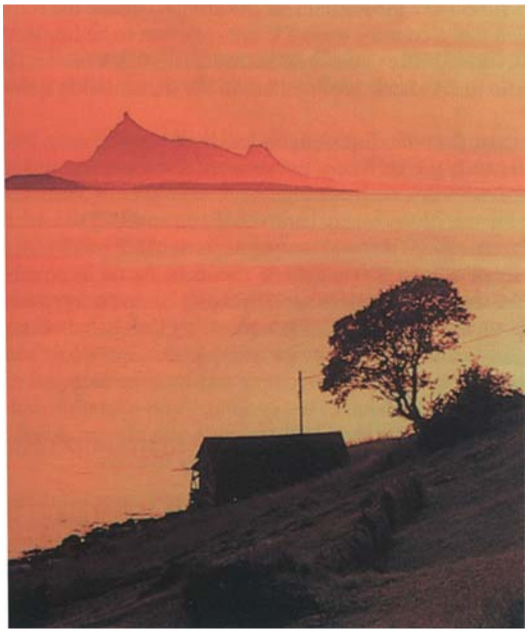
The sites selected had often a very beautiful scenery. In an article in “Verk og Virke” in 1958 , Harald Hauge Heskestad becomes almost lyrical in his description of the site Hestmannen (The Horseman) on the route Sandnessjøen – Bodø:

> *“The radio link station Hestmannen is situated like a Soria Moria castle on the shoulder of the rider. From the western side of the building one can see how the ocean waves are breaking along the shores more than 500 metres below. And*

[4] *S.D. Sissons: I storm på Tronfjell (In gale force on Tronfjell).* Verk & Virke, *No. 1, 1959, p. 19.*



*Parabolic antennas and V-shaped reflectors mounted in masts at the Tryvann site in Oslo (Elektrisk Bureau, 1958)*



*The building on the Hestmannen radio link site is located 500 metres above sea level near the Arctic circle. The antennas are located at 568 metres above sea level. (1957)*

*the eagles are flying around the hat of the rider. The yagi antennas in the mast seem to attract the eagles, because one day when we arrived at the station we heard a lot of noise from the antennas. When we came closer, we saw the eagles taking off.*

*From the top of Hestmannen you can see towards the south Dønnamannen close to Sandnessjøen, and towards the west one can see Trænastaven which is the stick belonging to Dønnamannen. The Arctic Circle crosses through the bay at the northern end of Hestmannen, and further to the north is Rødøyløva. In the direction of Telesund towards north east one can see the glacier Svartisen. Hidden behind Svartisen is Glomfjord. At the inlet to the fjord is Ørnes. From there the road goes to the next radio link station, Kunna. The road turns in a valley which opens towards the ocean. The houses are secured to the ground by using guys in order to withstand the storms from the north when the wind is compressed between Skrovfjellet and Skjeggen."*

## Radio link systems: At first a small group within the Radio office

At the beginning the radio link activities were taken care of by a small group within the Radio office (Radioanleggskontoret) of the board of Telegrafverket (Telegrafstyret). Head of the Radio office was senior engineer Paul Falnes.

*Asbjørn Nilsen*

In 1955 only four people were working in the Radio link group, headed by Forberg: Hans Fremming, Alf Ketil Hageler, Sverre Knudsen, and Asbjørn Nilsen.

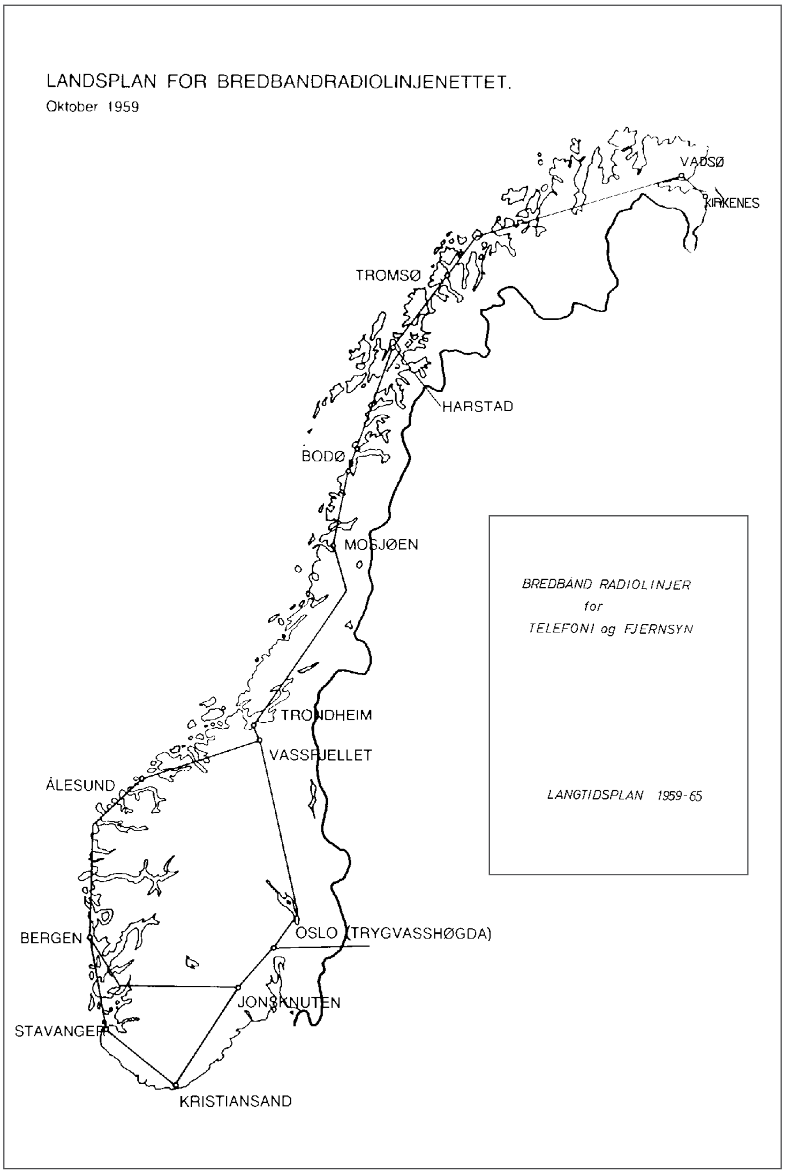
Asbjørn Nilsen, born in 1926, had first attended a signalling course in the British Navy in Scotland and thereafter the radio school at the Maritime College in Oslo. After four years at sea as a telegraph operator he took his engineering examination at Stockholm's Tekniska Institut in Sweden and was employed by the Radio office in 1955.

Alf Ketil Hageler, born in 1925, was employed by the Radio office in 1953. He was an electronics engineer from The Norwegian University of Technology, NTH, and had taken his diploma on radio link systems in 1953. During his thesis work he participated actively in the propagation tests between Gråkallen and Offenåsen mentioned above.

*Harald Hauge Heskestad*

Hans Fremming, born in 1926, was first employed as a telegraph operator at Gardermoen airport. He then took an M.Sc. degree at an American university. He came to the Radio link group in 1955 and started working with the islands connections.

Harald Hauge Heskestad, born in 1925, started in Telegrafverket in 1944. After having completed Telegrafverket's internal training course (Lavere kurs), he was ordered to start working as a telegraph operator at Arendal telegraph station. But when the war ended in Norway in May 1945 he was temporarily ordered to guard the German radio station at Lista airport. The German occupants had established radio connections between the airports and their central command during the war. Heskestad took Telegrafverket's higher course in 1949 – 1950. After serving for two years in Lofoten he went to Switzerland and got his M.Sc. degree at Eidgenössische Technische Hochschule in Zürich. He started work in the Radio link group in 1957.




*Long term plan 1959 – 1965 for covering the entire country with broadband radio links for telephony and TV*

## 1959: The Radio link group is established as a separate office

In 1959 the Radio link office was established as a separate office inside the Radio technical division, headed by senior engineer Forberg. The number of employees, now nine, soon increased to more than 30 persons. As the work load increased, special groups were established:

- Planning (headed by Fremming)
- Implementation (headed by Ketil Hageler)
- Maintenance (headed by Asbjørn Nilsen).

A maintenance centre was also established. This group was planned by Lars Håland and Ole Johan Haga and was headed by Rolf Sæhle.

## Frequency problems and TV transmission paved the way for SHF

Use of the VHF band started to create problems for the Marconi equipment. The expansion of FM broadcasting and TV transmitters in the VHF band created interference problems for the radio link systems.

In the early 1950s the discussion on future TV transmissions in Norway began. TV would require substantially more bandwidth than could be realised in the VHF band. Therefore, the use of SHF frequency band had to be used. The radio links using the VHF band was therefore steadily relocated further to the north of Norway as Telegrafverket started to implement SHF systems in the southern parts of the country.

## TV opens a new era for the radio links

On 25 June 1957 the Parliament (Stortinget), made the formal decision that a country wide TV network was to be implemented in Norway. The decision marked the start of a new era for the radio link system development in the transmission network.

Until then, the radio link budgets had been very meagre. Now, one suddenly got sufficient government resources for planning a modern radio link network, and the former intense discussion about the use of frequency bands could be ended. The new radio link systems were planned to operate in the SHF band with a capacity of at least 600 telephone channels. As far as possible the network should be implemented by using common infrastructure together with the Norwegian Broadcasting Company, NRK. The expenses would then be less for both parties. One would have possibilities for common re-routing and more economical maintenance and supervision of the systems. A co-operation with FFSB in order to use their infrastructure was also proposed, but this was turned down for military security reasons.

In 1960 – 1961, Telegrafverket had some 115,000 circuit kilometres of multichannel radio link systems in use in the network. This capacity amounted to 17.8 % of the total capacity of the network and had passed the capacity of the coaxial network (17.5 %). Open wire lines and high frequency systems on copper cable were still the dominating transmission media in Telegrafverket with 64.7 % of the capacity.

## Country wide plan for broadband radio link systems

As mentioned above the Radio link office (Radiolinjekontoret) was established in 1959 and the first long term plan (1959 – 1965) for implementation of a radio link network for telephony and TV transmission covering the entire country was presented.

The backbone system should be:

- A two way radio link system for up to 960 telephone channels
- A one way radio link system for TV transmission from Oslo
- A two way back up radio link system for up to 960 telephone channels, which could alternatively be used for transmitting TV, and could automatically switch between the telephone and TV traffic.
- A two way narrow band auxiliary radio link system for control and supervisory signals, service channels and sound channels for radio programmes.

The plan was for four main routes:

- From Tryvasshøgda in Oslo towards the north passing the eastern part of the lake Mjøsa, along Østerdalen to Trondheim and further north to Hammerfest and Kirkenes.
- From Tryvasshøgda to Jonsknuten close to Kongsberg, along the south coast and further on to Bergen, Møre on the west coast, and then north to Trondheim.
- From Tryvasshøgda towards the west coast to Bergen across the mountain range Langfjellene.
- From Trondheim to Bodø – Harstad – Tromsø – Vadsø.

The terminal stations as well as the repeater stations should have the possibility of inserting and extracting TV signals along the way.

## 1959: The radio link system Oslo – Karlstad links Norway with Eurovision and Nordvisjon

The first broadband radio link system for television transmission in Norway was opened 1 October 1959 between Oslo and Karlstad, Sweden, as a connection to the Eurovision and Nordvisjon networks. On 10 December 1959 the Nobel Peace Price ceremony was televised to the Eurovision network for the first time.

The Norwegian part of this radio link system was financed by Telegrafverket alone. The equipment was delivered from Marconi and had a capacity of 600 telephone channels. In addition, an auxiliary link with a capacity of 60 channels was installed.

## Simple equipment – but hard to maintain

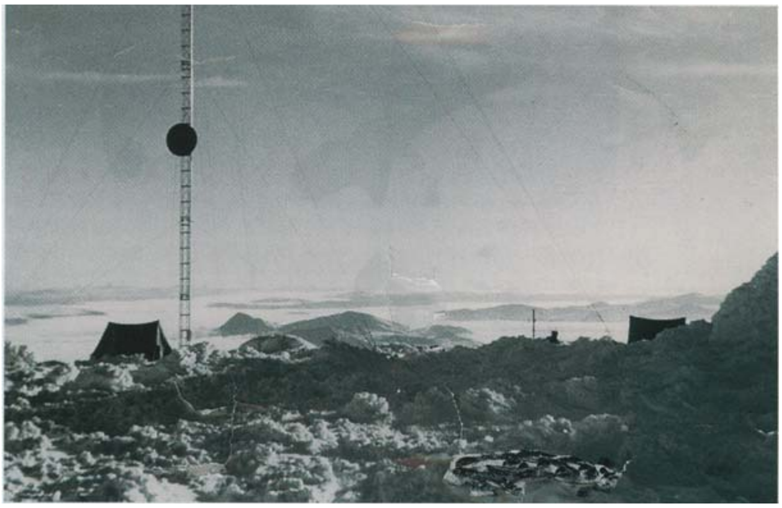
The terminals were installed in a tower near Karlstad and at Tryvasshøgda in Oslo with repeaters at Sunne in Sweden and Rundelen in Norway. The first transmission was from a meeting in the Nordic Council (Nordisk Råd). The system operated in the frequency band 3.8 – 4.2 GHz. The link was very vulnerable in use as it was not a heterodyne system with an intermediate frequency. A shift oscillator of 213 MHz simply changed the frequency at each hop. Since no IF frequency existed in the repeaters it was impossible to make an IF loop on the system when faults occurred, and fault location was very difficult.

Even if the technical solution and the equipment were rather simple, the maintenance problems were great. Therefore, no additional equipment of this type was ordered. The system was in 1966 replaced by a system produced by the Italian company Magneti-Marelli, which later became GTE, Italy.

## Safer with a solid partner as a supplier

The dominating suppliers of VHF and UHF radio link systems to Telegrafverket in the 1950s were Marconi, England, and Elektrisk Bureau, Norway. Both companies possessed a high technical know-how in the radio field, and it was considered important that the responsibility for technical weaknesses could be pinpointed to the suppliers. And as the management of Telegrafstyret in the early 1950s were very sceptical to radio link systems, the engineers found it safer not to be guinea pigs, trying smaller producers.


*Field strength measurements at Tronfjell, 1666 metres above sea level. Winter 1958 – 1959*



*Measurement mast at Tronfjell in winter 1958 – 1959*

*The Trolltind site 924 metres above sea level on the Tromsø – Hammerfest connection, 1960. The cabin with the equipment was burnt down in 1967, making evident the need for alternative transmission paths and for transportable mobile radio link equipment for restoration*

*Hard to distinguish the details? Provisional site with 300 channels VHF link at Trolltind 924 metres above sea level on the Tromsø – Hammerfest link, 1963. The wind is pushed low by the mountain formation and a 2 – 3 metres deep heap of snow is formed*

### 1960: Norwegian TV officially opened, with a NERA radio link Oslo – Bergen

NERA Bergen won its first contract with Telegrafverket for the Oslo – Bergen radio link in 1960. The system had a capacity of 300 channels and was installed between Tryvasshøgda, Oslo, and the TV transmitter station Ulriken in Bergen with repeater stations at Jonsknuten, Gaustadtoppen, Snønut, Lysenut and Fanafjellet. It was put in operation on 20 August 1960 when the TV was officially opened in Norway by King Olav. From the repeater station Lysenut, a temporary branch link was installed to feed the Bokn TV transmitter, giving TV coverage to the northern part of Rogaland.

### STK won the contract for the Oslo – Trondheim system

The next broadband radio link system for TV transmission was installed between Oslo and Trondheim. In 1961 the system was commissioned to feed the TV transmitter at Melhus and was one year later expanded to also include telephone traffic to Trondheim. Standard Telefon og Kabelfabrik won the tender with equipment from STC, England, in competition with NERA Bergen. The capacity was 960 telephone channels.

A decisive argument for choosing the STK offer was that their equipment had higher output power. Therefore, one could use smaller parabolic antennas than by using the NERA equipment and thereby reduce the icing problems. NERA was at that time using SHF triodes with only 1 watt output power. STC – like Marconi and Siemens – used travelling wave tubes with much higher output power. Later, NERA also changed to travelling wave tubes, giving an output of 10 watts.

The STK system was no big success. It had a complicated tube system, designed for manned stations. There were a lot of system failures giving much maintenance work. Several modifications of the equipment were done, but the maintenance costs were still high and the system was taken down after ten years of operation. This was not to the dissatisfaction of the coaxial cable fans!

### A man and his dog ...

Countries like Denmark and England had relatively easy access to the stations and could therefore have maintenance personnel at the stations. With a few exceptions Telegrafverket's stations were unmanned. To the surprise of the sceptics this resulted in a high system reliability. The reason was simple: Visiting the stations high up in the mountains was so physically demanding and took so much time that the technicians preferred to do a thoroughly good maintenance job when they had reached the top, and they made sure that everything was in order before they left.

"At the manned stations or at the stations it was easy to reach it was more tempting to postpone the work until the next day or until the next visit," says Asbjørn Nilsen, who quotes a Danish colleague: "The staffing at the stations should consist of a man and a dog. The task of the man is to feed the dog, and the dog should prevent the man from touching the equipment."

It was not without danger to do the work at the mountain peaks in Norway. Harald Heskestad reports from a visit together with two technicians to Hestmannen just before Christmas in 1957: The station is situated on a steep mountain 500 metres above sea level. A heavy snowstorm started and it was impossible to go outside the station. They were isolated for three days and had food for only one day. Luckily, they had brought with them three bottles of the special Norwegian Christmas beer. By rationing the consumption to one bottle a day, the spirit was kept high. After three days they managed to climb down the mountain side by using a rope in the deep snow. They looked with envy to an eagle who flew elegantly from the yagi antenna. After this experience, emergency food was placed at every mountain station.

The implementation of the broadband radio link systems during the decade 1960 – 1970 was quite extensive. Ring structures were built in southern Norway; Oslo – Trondheim and Oslo – Kristiansand – Stavanger – Bergen, and later on, Bergen – Ålesund – Trondheim. In parallel, the system Trondheim – Bodø – Tromsø – Hammerfest – Vadsø was implemented.

The first systems were implemented by using equipment from Magneti-Marelli, Italy. Later, NERA Bergen had completed the development of their equipment NERA 960-4G (NL50) and this system was operating satisfactorily. Therefore, the rest of the broadband system was mostly implemented with this type of equipment.

The radio links were built as a 2+1 system with a capacity for 960 channels:

- One channel transmitted telephone traffic
- One channel transmitted TV signals
- One channel was used as a common reserve.

An additional auxiliary radio link had a capacity of 300 channels and was produced and delivered by Elektrisk Bureau.

From Trondheim towards northern Norway NERA Bergen and EB equipment were used up to Tromsø. From Tromsø to Hammerfest equipment from Marconi was at first used, but was later, in 1969, replaced by new 1800 channel equipment in the lower 6 GHz band produced by NERA Bergen.

The country wide plan for a broadband radio link system for TV and telephone traffic was realised as shown in Table 1.

In addition to the backbone systems, 19 broadband radio link systems were implemented as spur links to the TV main transmitters that were located outside the backbone system. In addition, 37 radio link systems were in use with a capacity of 120 to 300 channels, 41 radio links with a capacity of 24 to 60 channels, and 126 systems with a capacity of 1 to 12 channels.

## The first breakthrough for delivery from NERA to Telegrafverket was in 1960

As mentioned above, the first radio link system – with a capacity for 300 telephone channels – for TV transmission from Oslo to Bergen was ordered from NERA Bergen in 1960. But the real breakthrough for deliveries from NERA came in 1964 when Telegrafverket ordered equipment for the backbone system. Then the capacity and the quality of the NERA systems were acceptable to Telegrafverket.

The following systems were delivered by NERA:

- Bergen – Ålesund
- Ålesund – Trondheim
- Trondheim – Mosjøen – Bodø

*The snow was often 2 – 3 metres deep at the Kistefjell site in Troms 1004 metres above sea level. Therefore one had two entrances: One summer entrance through the door at ground level, and another winter entrance on top of the building*

- Bodø – Harstad – Tromsø
- Oslo – Bergen
- Oslo – Gothenburg

## Elektrisk Bureau delivered 300 channels auxiliary systems

Elektrisk Bureau A/S delivered radio link systems in the 2 GHz band with a capacity of at first 120 channels and later modified to 300 channels. The systems were used as auxiliary systems on the routes Kristiansand – Stavanger – Bergen – Ålesund – Trondheim – Mosjøen – Bodø – Harstad – Tromsø – Hammerfest.

During the period 1962 to 1970 more than 80 % of the radio links delivered were produced by the Norwegian manufacturers NERA Bergen and Elektrisk Bureau.

## Transistorized equipment from "the small bird on the eagle's back"

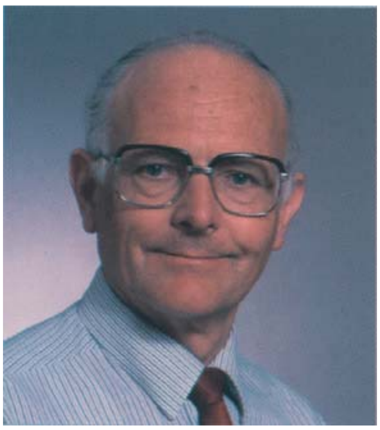
The world's first solid state radio link equipment was produced by the American company RCA. One of these systems (CW60)

*Table 1 The implementation of the country wide plan for broadband radio link for television and telephone traffic*

| | Main supplier | km | Year | No. of channels | Auxiliary channels | TV channels |
|---|---|---|---|---|---|---|
| Oslo – Karlstad | Marconi | 170 | 1959 | (1800)* + 600 | 60 | Two way |
| Oslo – Bergen | NERA, Bergen | 360 | 1960 | 300 | 1 | One way |
| Oslo – Trondheim | STK | 397 | 1963 | (1800)* + 960 | 120 | One way |
| Oslo – Kristiansand | Magneti-Marelli | 265 | 1963 | (1800)* + 960 | 960 | One way |
| Kristiansand – Stavanger | Magneti-Marelli | 179 | 1963 | 960 | 300** | One way |
| Stavanger – Bergen | Magneti-Marelli | 164 | 1963 | 960 | 300** | One way |
| Bergen – Ålesund | NERA Bergen | 268 | 1965 | 960 | 300** | One way |
| Ålesund – Trondheim | NERA Bergen | 252 | 1966 | 960 | 300** | One way |
| Trondheim – Mosjøen | NERA Bergen | 327 | 1965 | 960 | 300** | One way |
| Mosjøen – Bodø | NERA Bergen | 204 | 1965 | 960 | 300** | One way |
| Bodø – Harstad | NERA Bergen | 204 | 1966 | 960 | 300** | One way |
| Harstad – Tromsø | NERA Bergen | 134 | 1966 | 960 | 300** | One way |
| Tromsø – Hammerfest | NERA Bergen | 244 | 1969 | 1800 | 300** | Two way |
| Hammerfest – Vadsø | Siemens | 323 | 1967 | 1800 | 12 | Two way |
| Oslo – Bergen, new route | NERA Bergen | 452 | 1970 | 1800 | 300 | Two way |
| Oslo – Gothenburg | NERA Bergen | 215 | 1972 | 1800 | 300 | Two way |

* 1800 channel from Magneti-Marelli in 1967. ** Delivered by Elektrisk Bureau.

was delivered to Telegrafverket by their Norwegian representative NERA. This system had a capacity of 300 channels and was installed between Ålesund and Molde in 1965 – 1966. This was the first transistorized equipment in operation in Western Europe at that time. Even the output power tube was solid state. The equipment was easy to maintain and the maintenance cost was very low.



*Ole Johan Haga*

The good performance of the system inspired NERA Bergen to start their own development of solid state equipment – at first with 300 channel capacity and later with 1800 channels.

Bernt Ingvaldsen, who was president of the Parliament and chairman of the board in the parent company of NERA Bergen, said: "A small bird flies higher by starting from the eagle's back."

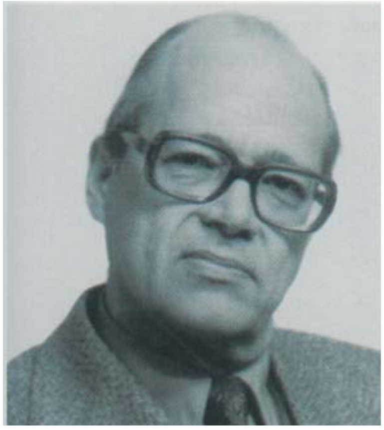
The 1800 channel equipment was first put into operation between Tromsø and Hammerfest in 1969. Then followed Oslo – Bergen in 1970, and Oslo – Gothenburg in 1972.

## Major reorganisation

During this period a major reorganisation of Telegrafverket took place. The managing board Telegrafstyret became Teledirektoratet in 1969, and Telegrafverket was renamed Televerket. In 1970 Forberg retired as leader of the Radio link office and was succeeded by Hans Fremming, who unfortunately died the day before he should take his position. Ole Johan Haga was then appointed new leader of the Radio link office.

*Ole Johan Haga* first attended the technical college of the Norwegian Air Force as a radio link specialist. He then graduated at the University of St. Andrews, Scotland, in 1960 and was employed at the Radio link office in the same year.

During his first years as an engineer he was working with low capacity systems – often single channel radio link systems for connections to islands along the coast of northern Norway. Later on, he was working more with large capacity systems and was responsible for implementing the broadband system Kristiansand – Stavanger – Bergen and further from Trondheim towards the north of Norway as the TV radio link systems were implemented. Haga headed the Radio link office until the next major reorganisation of Televerket in 1972 when he moved to



*Einar Ekeberg*

the Transmission section. Today, he is director of Telenor International.

In 1972, *Einar Ekeberg* was appointed head of the Radio link office, a position he held until he retired in 1991. After graduation at the Norwegian University of Technology in 1953 he was employed at Elektrisk Bureau where he worked as an R&D engineer on the radio link system that Telegrafverket had ordered for the route Oslo – Arendal – Kristiansand.

In 1954 Ekeberg was employed as a senior engineer at FFSB. He there had a central role in the co-operation with NATO, first in connection with the FFI radio link system Oslo – Bergen, and later on the communications infrastructure of NATO.

Also at NERA Bergen major changes occurred. The company was bought by Elektrisk Bureau in 1977 and became a division in Elektrisk Bureau. In 1988 the Swedish company ASEA and the Swiss company Brown Boveri were fused and renamed ABB. ABB gathered all their Norwegian activities in Elektrisk Bureau.

In 1992, ABB bought all the shares in Elektrisk Bureau, and the latter was renamed ABB Konsernet i Norge, and NERA became ABB Nera AS. Then, in 1994, ABB Nera became NERA ASA, an independent limited company, listed on the Oslo stock exchange.

## Country wide radio link network II

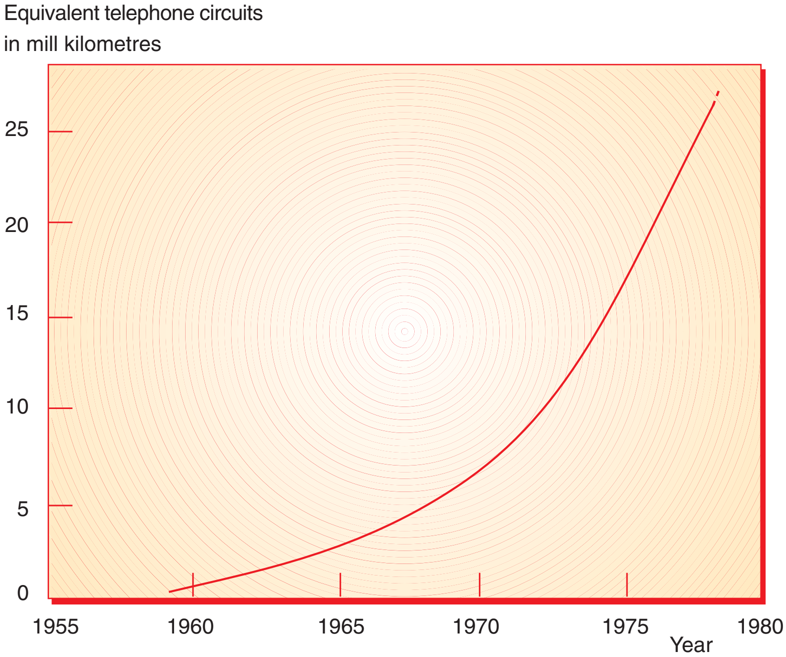
The first broadband radio link system was implemented as a common network for Telegrafverket and NRK, consisting of a 2 + 1 system with 960 channels. The first systems using electronic tubes were gradually replaced by solid state 1800 channels equipment.

During the decade 1970 – 1980 an alternative country wide radio link network was built in order to increase the capacity in the transmission network in connection with the automation of the telephone exchanges and also to improve the reliability of the network.

The radio link network for NRK and Televerket was now built as two separate networks:

- A network with 1800 or 2700 channels for Televerket
- A separate network with 960 channels for the Norwegian Broadcasting Company, NRK.

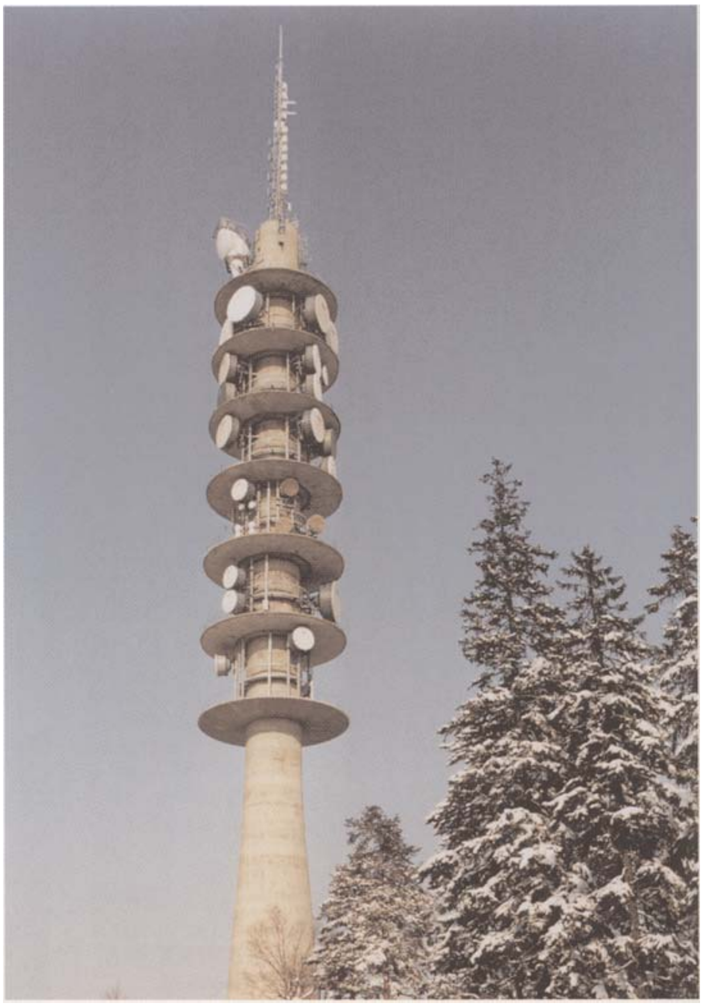
Planning started in 1972 – 1974 and the new network for NRK was implemented from 1976. This network was built by using equipment from NERA, which had won the contract after




*During the 1955 – 1980 period the broad band radio link network in the SHF band 4 – 6 GHz expanded exponentially*


*The Tryvann tower, Oslo, completed 1961*

*The country wide radio link system for telephone and programme lines, 1980*



*Røverkollen radio link station in Oslo, main station in the alternative radio link network (Photo: Frank Aarhus)*

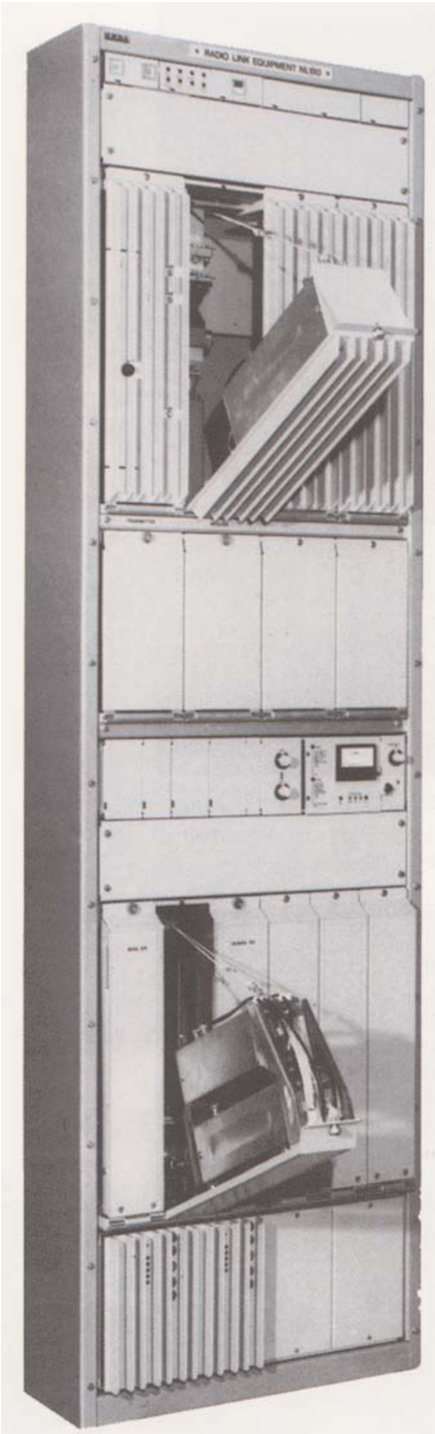
*Snow track at Tronfjell*

*Vassfjellet radio link station in Trøndelag (Photo: Frank Aarhus)*

*Tifjell radio link station in Trøndelag*
*(From photo file of NØ.EA)*

*As a consequence of the major implementation of the digital radio link network, new masts had to be erected on several stations, as for instance at Ålfjell*

*Saurdalseggi radio link station in Sogn og Fjordane*



The NERA system NL180 with 2700 channels, 1 + 1 radio and modem

international competition with GTE (formerly Magneti Marelli) in 1975. The complete renewal of the NRK network took more than 10 years, as the financial resources made available by NRK were limited.

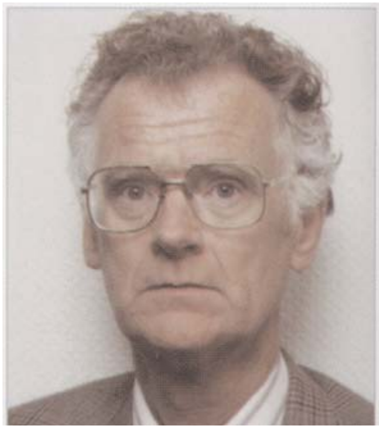
The new NRK network for radio and TV was supplemented with equipment from GTE on the spur links. In total, NERA has delivered 80 – 90 % of the radio link systems used in the NRK network.

## A new pioneering era

In parallel with the renewal of the NRK network, the backbone radio link network for telephone traffic was extended and renewed all the way to Kirkenes. An alternative network was implemented, in particular in northern Norway. In the southern part of the country a ring structure was established. Televerket thus possessed two parallel radio link networks covering the whole country.

"This introduced a new pioneering era for Televerket, because we had to start afresh, building new stations on alternative mountain peaks all over Norway. Nevertheless, the work was completed within ten years", says Inge Vabø, who headed the Planning group within the Radio link office from 1974 to 1993.

After obtaining his B.Sc. degree at the University of Strathclyde, Glasgow, Inge Vabø was employed at the Radio division of Elektrisk Bureau in 1961. Elektrisk Bureau had then quite an extensive production of radio equipment, including e.g. FM broadcast transmitters, HF ship transmitters, military equipment and radio link systems. Through L.M. Ericsson (LME) in Sweden, which was a majority shareholder in the company, Elektrisk Bureau had a substantial export of radio link systems, in particular to Latin America. Telegrafverket and FFSB were also important customers of UHF radio link systems.



*Inge Vabø*

In 1967, LME started to transfer more and more of the radio link know-how to Gothenburg and in the beginning of the 1970s Elektrisk Bureau stopped producing radio link systems. In 1969, Vabø was employed in the Radio link office of Televerket, at first working with island connections and low capacity systems. In 1974 – 1976 he was actively engaged in the implementation of Televerket's first satellite earth station at Eik in Rogaland.

## 2700 channel systems developed

In the 1970s, when Televerket was extending its broadband analogue radio link network, Televerket negotiated a contract with NERA Bergen for the development of systems with a capacity of 2700 channels in the upper 6 GHz band. The contract was signed in 1974 and was financed by the Research Establishment of Televerket and the Ministry of Communications.

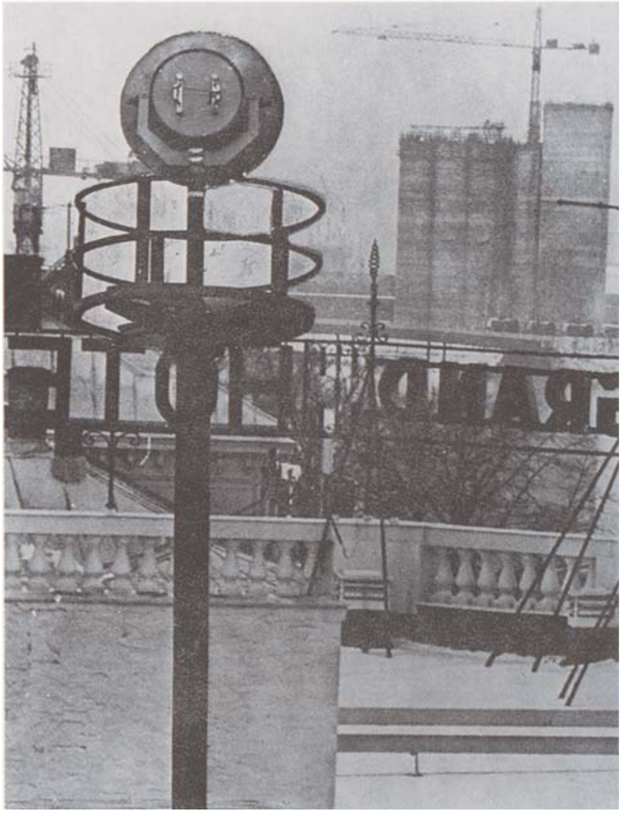
The first 2700 channel system was installed between Oslo and Hamar in 1978. Televerket had also bought a system between Oslo and Bergen with 8 hops, and several smaller systems in both southern and northern Norway. On some of the stations the NERA equipment had stability problems, and it was therefore decided to issue an international tender for 2700 channel equipment. The contract was won by the Japanese company NEC and the NEC equipment was installed on some of those stations where the NERA equipment had stability problems. The NEC equipment was taken down in 1995 after 15 years of almost fault free operation.

## The transmission becomes digital – on a high ambition level

The first digital radio link had been put in operation between Svelvik and Drammen in 1969. It was produced by the Italian manufacturer Telettra and was operating in the 13 GHz band with a capacity of 24 channels, in accordance with the US hierarchy, and was one of the first digital radio links in use in Europe.

Televerket was now entering its digital era. Televerket's Research Establishment was established in 1967. The research director, Dr. Nic. Knudtzon, had new ideas from his previous work with radio relay systems at FFI and his experience in transmission network planning as head of the Telecommunication Division at SHAPE Technical Centre in the Hague. His ambitions were so high that many – including NERA and other telecommunication companies – were of the opinion that he was too far ahead of the technological possibilities. But the sceptics were wrong!

*Antennas mounted on an antenna tower at Rønvik-fjellet in Bodø 1988 (Photo: Truls Arnesen)*



*13 GHz mast link mounted on the roof of Drammen telephone station*

Former technical director at NERA, Per Fremstad writes:

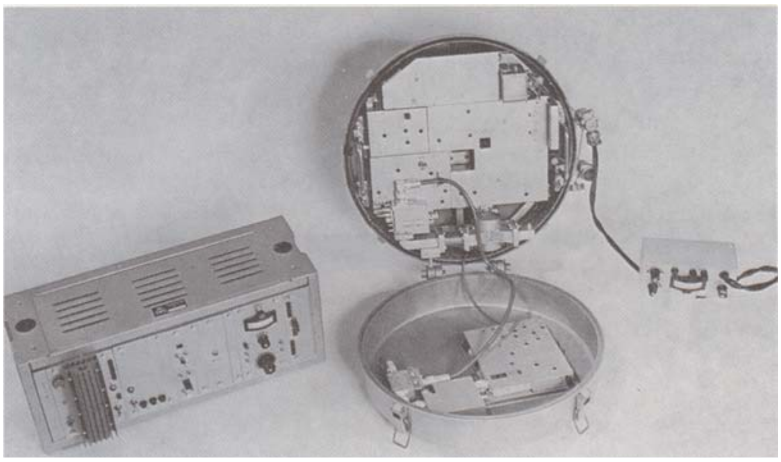
> *"Televerket had at an early stage a clear strategy for digitizing the network. This strategy was not taken seriously at NERA. The opinion was that Televerket never followed their plans. With hindsight one might say that Televerket did just that. The new general manager of Televerket, Kjell Holler, well backed up by technical director Ole Petter Håkonsen and the research director Nic Knudtzon, did a great job to modernize the telecommunication network during the ten year period 1978 to 1988 ..."*

## Telettra/GTE won the first round, but NERA the next

The implementation of the new high capacity radio link network in Televerket followed as a consequence of the digitization of the main telephone exchanges.

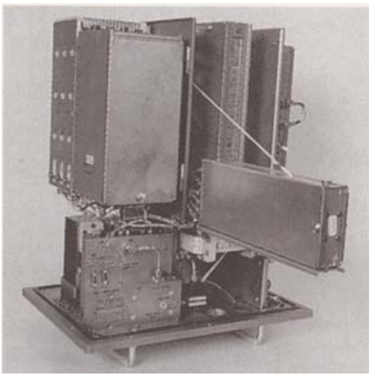
Standard Telefon og Kabelfabrik won the tough international tender for the main digital telephone exchanges with its System 12. After a substantial delay the first digital telephone exchange was put in operation in Trondheim on 13 June 1986, making Televerket one of the most advanced telephone companies in the world. The next System 12 exchange was opened at Økern in Oslo in September 1986, and from then on everything went rather fast.

At the end of 1987 Televerket had in operation two transit exchanges, 100 subscriber exchanges and 140 concentrators with more than 400,000 telephone lines and some 130,000 communication lines. In the following year, in 1988, altogether 152 exchanges and 275 concentrators were in operation, and System 12 had a total of 640,000 subscriber lines. At the end of 1993 more than 50 % of the telephone subscribers in Norway were served by System 12. And already in 1989 Televerket had

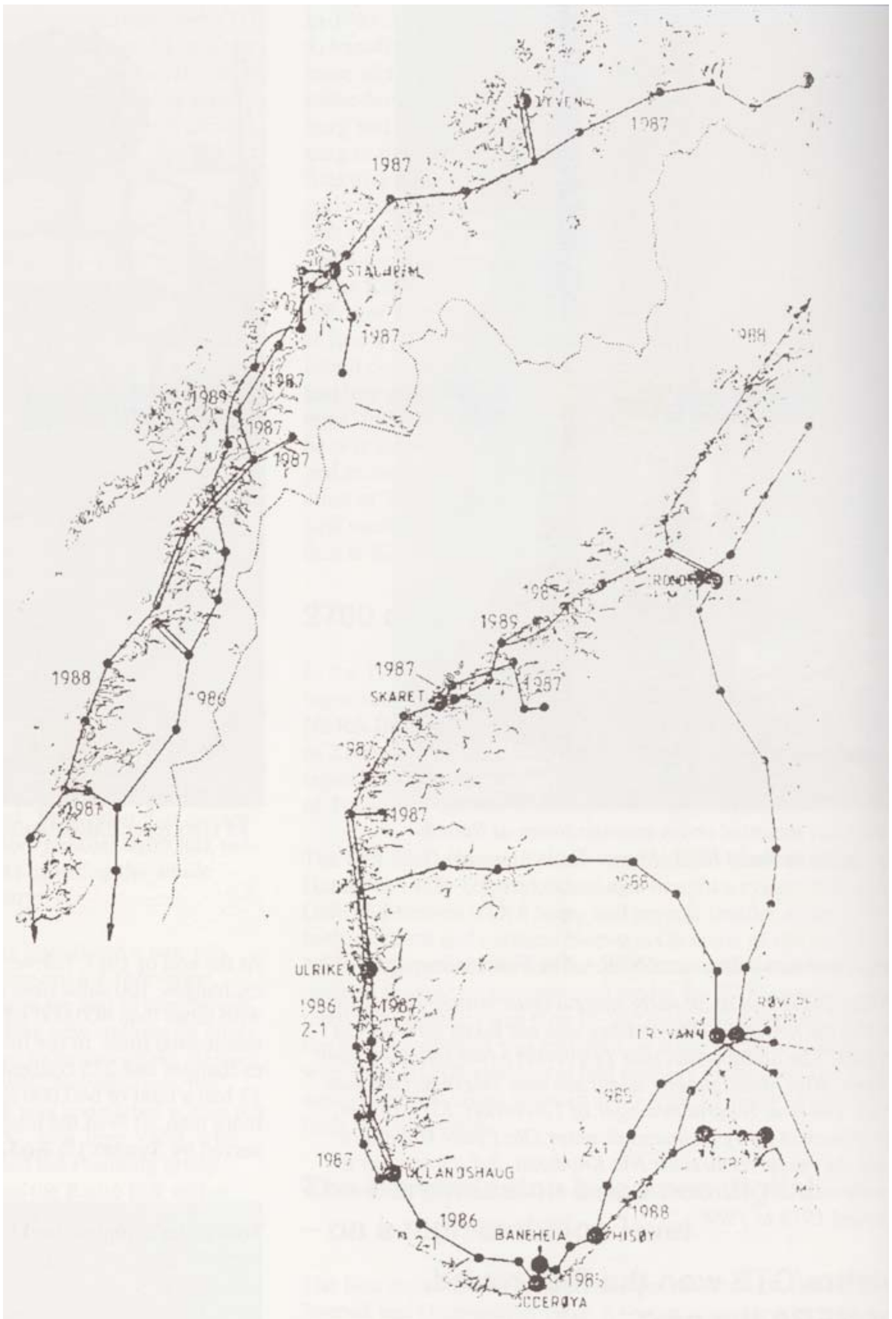


*Digital radio link equipment mounted in a closed container*

*From the installation work in Drammen*



*NL100, NERA's first digital radio link*




*Planned broadband digital radio link network 1985 – 1989 with capacity 1920 channels (2 x 140 Mb/s + 1x140 Mb/s common backup)*

issued a new tender for additional digital exchanges to be in operation 1991 – 1994. The tender was won by Ericsson – and delivery was again delayed.

Between all digital exchanges common channel signalling was used, in accordance with CCITT Recommendation No. 7.

## 140 Mbit/s 16QAM system is developed

The digitizing of the telephone network involved very strong requirements to the transmission network. Televerket therefore signed a contract with NERA already in the early 1980s for the development of a 140 Mbit/s, 16QAM radio link system in the upper 6 GHz band to be used for connecting the digital exchanges to be ordered. The development at NERA, however, took longer than expected.

As a consequence, Televerket had to order equipment from Telettra/GTE after an international competition. Also this equipment was delayed, but as even System 12 was more than a year late, the Telettra/GTE delay was not the critical one. The first

*The Tyholt tower in Trondheim (From photo file of NØ.EA)*

*The radio link site at Ulriken in Bergen (Photo: Frank Aarhus)*

high capacity digital system was put in operation in the backbone network in 1985.

NERA had its high capacity 140 Mbit/s system ready for delivery in 1987 – 1988, and the system was implemented on a large scale in the backbone network. Equipment was also bought from NEC, in particular in the 11 GHz band, and from Siemens in the 18 GHz band, where NERA could not supply such equipment at that time.

An auxiliary system with capacity 34 Mbit/s was implemented in parallel with the high capacity systems. Both NERA and GTE supplied equipment for these systems.

## From 16QAM to 64QAM

A new contract was signed with NERA for the development of a 64QAM, 140 Mbit/s system to be used in the lower 6 GHz band. This development was ready in 1990. In the meantime, Televerket had bought similar equipment from Fujitsu, Japan, for the Oslo – Drammen route.

Several 64 QAM systems were ordered and delivered from NERA in the early 1990s.

Today, the complete backbone radio link network for telephone traffic is digitized with equipment delivered from NERA, Telettra/GTE, NEC, Fujitsu and Siemens. The NRK radio link network is still analogue for TV transmission.

## Regional and local networks

In parallel with the implementation of the backbone network, an extensive number of radio links in the regional and local networks have been implemented. Altogether more than 1800 stations are used in these networks in addition to the more than 150 stations in the backbone network. The regional and local networks have analogue links with capacities from one telephone channel and up to 2700 channels and digital links with capacities from 30 to 1920 channels. A majority of the radio link manufacturers in the world are represented.

*Table 2 Number of radio links as per 31 December 1989. In addition to the numbers listed, The Norwegian Broadcasting Company, NRK had two digital radio links (each with 30 channels) and 46 analogue links (33 with 960 channels, 11 with 30 channels, one with 60 channels, and one with 24 channels). The NRK radio links are included in column 2 (circuit length) and column 3 (communication circuits, km)*

| Capacity, channels | Circuit length, km | Commun. circuits, km | No. of analogue radio links | | | No. of digital radio links | | |
|---|---|---|---|---|---|---|---|---|
| | | | New | Dismounted | Total number in operation | New | Dismounted | Total number in operation |
| 1 | 3,373 | 3373 | 11 | 9 | 151 | 0 | 0 | 0 |
| 2 | 412 | 949 | 7 | 4 | 29 | 0 | 0 | 0 |
| 8 | 34 | 275 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 52 | 523 | 0 | 0 | 0 | 0 | 0 | 2 |
| 12 | 1,376 | 16,507 | 3 | 2 | 70 | 0 | 0 | 0 |
| 24 | 220 | 5,278 | 2 | 1 | 10 | 0 | 0 | 0 |
| 30 | 4,946 | 153,672 | 0 | 0 | 0 | 37 | 13 | 252 |
| 60 | 1,236 | 74,142 | 0 | 0 | 16 | 6 | 3 | 7 |
| 120 | 4,524 | 550,020 | 0 | 7 | 55 | 23 | 7 | 131 |
| 300 | 652 | 195,510 | 0 | 6 | 12 | 0 | 0 | 0 |
| 480 | 6,865 | 3,373,248 | 0 | 0 | 0 | 29 | 6 | 133 |
| 960 | 7,820 | 11,208,960 | 8 | 10 | 90 | 0 | 0 | 0 |
| 1800 | 6,045 | 11,511,360 | 1 | 3 | 39 | 0 | 0 | 0 |
| 1920 | 4,447 | 19,600,320 | 0 | 0 | 0 | 21 | 0 | 53 |
| 2700 | 2,170 | 5,859,810 | 0 | 0 | 19 | 0 | 0 | 0 |
| Total | 44,172 | 52,553,947 | 32 | 42 | 491 | 116 | 29 | 578 |

Altogether, there are more than 8000 transmitters/receivers in the radio link network, in frequency bands from 140 MHz up to 38 GHz.

In parallel with the implementation of the fixed networks, special mobile link systems have been supplied from USA for emergency and restoration purposes. The systems are built to military specifications and are very robust.

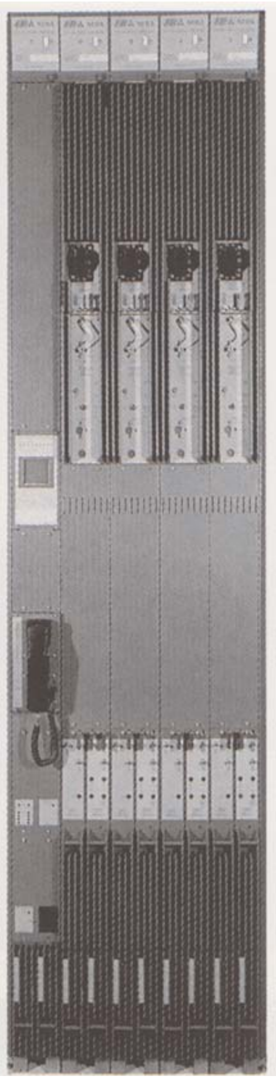
## Optical fibre cables take over in the backbone network

Today, the activity on new radio links in the backbone network is negligible. The optical fibre cable systems are taking over. As an example, it may be mentioned that in 1988, 49 new digital systems were put in operation. 12 of them were using coaxial and fibre cables (565 and 140 Mbit/s) and 37 were radio links (140 Mbit/s). From then on, the number of optical cables has been steadily increased, at the expense of radio links.

In this connection it may be of interest to note the cooperation between Telenor and the Norwegian State Railways, NSB. Under this agreement Telenor installs optical fibre cables along the railways. The capacity is so high that Telenor has now rented the excess capacity from NSB in order to keep new operators away from the Norwegian market as from 1 January 1998, when the competition becomes quite open. However, the said contract is contested by other companies, stating that it is in conflict with EU rules. The matter may eventually be solved by the ESA court.

## The phased out radio links are used in other countries

As from 1992, the analogue radio links which had been in operation since the 1970s were gradually taken down after serving their purpose and earning a lot of money for Televerket. The equipment was now offered to East-European countries. A lot of the equipment was delivered to the mountainous Albania



*140 Mb/s 64QAM radio link, 3 + 1 terminal*

which had a primitive and quite insufficient transmission network. The delivery and the installation of the equipment in Albania was sponsored by the European Development Bank, EBRD in London. Some equipment has also been sent to other developing and newly industrialized countries, for example Vietnam. Thus, the Norwegian radio link know how is also shared with others.

Today, NERA is one of the leading manufacturers of radio link systems in the world and has delivered equipment to a great number of countries.

Several Norwegians, among them Inge Vabø, have been consultants on radio link systems in a number of countries in Europe, Africa, Asia, and Latin America.

## Televerket and the power companies

In the 1960s, the power company Oslo Lysverker (now Oslo Energi) decided to use radio links in its own transmission network. After applying for a license Oslo Lysverker got permission to build its own network. The first systems were installed between Oslo and Hallingdal in 1965. Later in the 1960s building of the hydro-electric power plants in the Aurland valley was begun, and Oslo Lysverker again applied for a new license for establishing radio links for the new transmission demand.

*Risdalsheia radio link station (Photo: Truls Arnesen)*

But now, the general manager of Telenor, Per Øvregard, put his foot down: The power companies had already an extensive radio relay network that could be used for telephone traffic. But Televerket had the monopoly! Previously, in the 1950s, the military had built their own separate network, and now the power companies represented a new threat to the monopoly. He therefore decided to have a committee under the chairmanship of Haakon Nymoen to evaluate the situation.

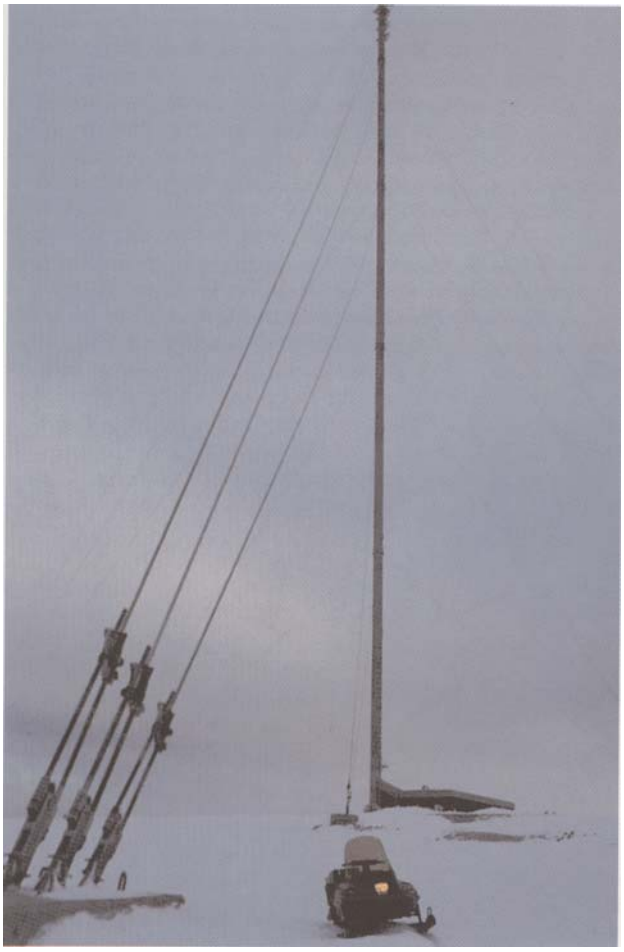
When Oslo Lysverker in cooperation with other power companies in addition applied for a license to implement radio links towards Gudbrandsdalen and further on to Møre in connection with the building of a hydro-electric plant at Aura, Øvregard said no. Instead, it was decided to set up an agreement to the effect that Televerket should implement the radio link network for the power companies at their expense. A quite extensive network was built, following the valleys Hallingdal, Hemsedal, Aurlandsdalen and Gudbrandsdalen, and further on to Møre on the west coast.

*Passive reflectors may connect stations which are not within line of sight of each other*

*Andfjell radio link station at Saltfjell (From photo file of NØ.EA)*

*Mobile radio link station equipment*

*Salten radio link station and TV/FM transmitter in Nordland (Photo: Håkon Ringdal)*



*The tallest construction in Norway was put up by Televerket at Hamnefjell near Båtsfjord in Finnmark, 1988. This radio link mast is 242 metres high and weighs 270 tonnes. It is put together by cylindrical sections of galvanized steel tubes. The construction has an internal maintenance elevator in the 2 metre wide cylinder. Steel wire guys of 40 to 66 mm in diameter prevent the top of the mast from swaying more than 2 metres at wind bursts of twice the strength of a hurricane*

*Storhogen radio link station at Sogndal 1173 metres above sea level, winter 1981 (From photo file of NØ.EA)*

Also the state electricity administration, NVE, was included in the agreement, and when NVE needed transmission capacity to power plants in Telemark, Tokke, Sira Kvina and to Sweden, a radio link network was built by Televerket.

At first, the capacity was 24 analogue channels, but later digital 2 Mbit/s systems were implemented. The suppliers of these systems were NERA and GTE for equipment in the 1.5 GHz band, and EB and Telettra in the 400 and 800 MHz bands.

In 1980, the personnel resources needed for this work was increasing, and the management of Televerket had to stop it. As a result the power companies were again granted a license to build and operate their own networks. At that time no one could foresee that the monopoly would ever end for Televerket. Today, Telenor is faced with the consequence that the power companies are becoming formidable competitors in the transmission infrastructure.

## Epilogue

Norwegian radio links during 50 years. The radio links gave Telegrafverket a new life, but the road was long and the fight for success was tough. At the beginning, the economy was bad and the technology was obsolete.

The engineers knew what they had at hand, but one would have to be a Jules Verne to foresee what was hidden in the future. For example, leading scientists visualized a future with a world wide network based on a number of short wave radio stations for telephone connections between the continents. More daring was the technology leading British telephone company GPO, which developed the first transatlantic cable. To be on the safe side, they used thermionic valves of pre-war design, having a proven life of some 30 years. The life time of modern tubes would only be known a couple of decades ahead. And no sensible person could dream of transistors, satellites or optical fibre cables.

Since 1899 Telegrafverket had the monopoly and the responsibility for all telecommunications in Norway, an almost

*Radio link know-how: From Arctic conditions in Norway to a tropical site in Tanzania. (Photo to be published in an ITU handbook in 1997)*

*Radio link station for Oslo Lysverker in the Aurland mountains*

impossible task. And, as with GPO, one dared not to take the really great risks – it was safer to use the equipment and technology at hand, with which one was well familiar. And with limited resources, e.g. rather simple radio connections and radio links were established in the more isolated areas. With today's technology in mind, the connections were very primitive, but in reality an amazing pioneering work was done, starting from scratch with a poor economy.

During World War II several Norwegian engineers were attached to British military research establishments. Immediately after the war The Norwegian Defense Research Establishment (FFI) was established, and later on The Norwegian Joint Signals Administration (FFSB). The engineers entered the arena with new and unorthodox ideas, and they pinched the first hole in the monopoly. Suddenly there were two – and in fact three if the Philco radio link of The Royal Norwegian Air Force is included – operators on the arena. The competition which followed was tough and the discussions sometimes noisy, but became in fact an important stimulus for all parties, including the industry. Later on, Televerket got its own research establishment which could concentrate its activities on planning for the future, without bothering about the then long telephone waiting lists and other trivialities. Later on, also more funding became available. The technology soon reached an international top level, and the self confidence increased.

Today, Norway has one of the best radio link networks in the world. Telenor shares a place in the front line with the world's leading telephone companies. Norwegian telecommunication industry is the market leader in important telecommunication sectors. Who is to receive the laurels? The honour must be shared between FFI/FFSB, the industry, and Telegrafverket/Televerket/Telenor, because the results have been generated through the competition, the interaction and the cooperation between the parties involved. But what really matters is the pioneering work of the many individuals who took the lead and opened new paths into the future. The number of individuals is so high that it is an almost impossible task to name them all. Being a close observer through a few decades, the author therefore decided to describe as objectively as possible what actually happened, without mentioning special achievements and arguments. Names of individuals have been carefully omitted, with the exception of the very first pioneers and those who have been interviewed to establish certain facts.

## A family of new technologies was born

Today, the activity on new radio links in the backbone network of Telenor is negligible, as optical fibres and satellite technology are rapidly gaining bigger shares. In local and regional networks there is still great activity, for Telenor as well as for new operators. The époque of the radio links is thus far from ended.

More important, however, is that the radio links have raised a big family. The technological know-how directly and indirectly created by the radio link development has been a catalyst and in some cases decisive for the development in adjacent areas. One example is the Råö project near Gothenburg, Sweden – the very first earth station for satellite communication in Europe based on European technology. The project was the result of a three party cooperation between the telephone administrations in Denmark, Norway and Sweden.

Soon followed the Tanum earth station south of the border between Norway and Sweden for international satellite communication. The fatherhood was shared between the Norwegian and the Swedish telephone administrations.

Then followed earth stations at Eik in Rogaland and at Nittedal near Oslo and satellite communications to the oil and gas fields in the North Sea. Next came Isfjord satellite station, making Spitzbergen an integral part of the Norwegian network.

Mentioned must also be maritime satellite communication, where Telenor has played a leading part. And optical fibre cables, where a Norwegian company holds a couple of world records.

### A thrilling future

What about the future? The telecommunication monopolies in the world are withering away. New competitors are entering the Norwegian market, and some of Telenor's former suppliers and customers are now competing with Telenor. On the other hand, Telenor is trespassing into other countries. New markets are won in Europe, Africa, Asia, including China and Indonesia. And Norwegian industry and consulting companies have markets almost all over the World, often including complete communication systems over land, under oceans and by way of satellites.

The radio link has got offspring who carries the development further ahead. The protecting monopoly umbrella has been replaced by more efficient offensive weapons: know-how and front line technology.

Quo vadis, where are we going? Without making definite prophecies, it feels safe to assume that future development will be even more exponential, the competition increasingly tougher, and it is better not to slumber behind the wheel. Certainly: the future will be a true thriller!

*The radio link backbone network, 1996*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