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Interactive Opportunities of Broadband Communication

Contents

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Special

Guest Editorial

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Front cover:
Interactive Opportunities of Broadband Communication

Interactiveness reflects the fact that we can respond to what we experience on the net in much the same way as others can respond to what we might provide on the net, be it in the form of addressed communication to just one single person – or broadcast to many.

However, each person will always have a particular intention of his/her communication – something the artist Odd Andersen has indicated by the two flows of information across the wavefronts. Given defined bandwidths the wavefronts themselves are edges of access to the ocean of possible information behind.

But the bandwidth itself is undergoing expansion – the end of which we are not sure. This is shown as the gradually fading lines – upward and downward.

Within each period of time people have their own idea of "broadband" and the opportunities that go with it. The limit to opportunities at a particular point in time is visualised as a cut in available bandwidth.

Ola Espvik, Editor in Chief

The telecommunications industry is currently experiencing difficult times. The investments in the telecommunications sector have been reduced by over 30 % over the past two years, significant actors are heavily burdened with poor operating results and huge debts, and some of the largest operators have even gone bankrupt. In the midst of this recession, the belief in a bright future of a communications industry fuelling its growth on innovation and new products enabled by technological opportunities, is still there – at least with a few of us.

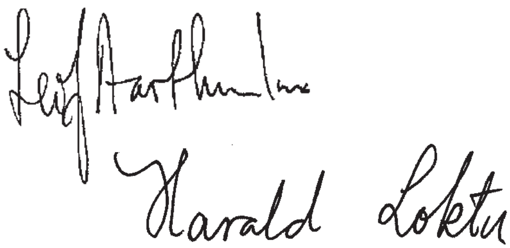
Moving beyond the present recession; which are the main drivers and critical technology success criteria that will enable reinforced innovation and new revenue potential? The possibilities related to Interactive Broadband Communication clearly indicate that interaction between the user and the communication networks will play a major role. Going interactive in the future will imply that the user to a much larger extent will have the possibility to interact with networks and content to enable more personalised experiences. To educate and change the user behaviour towards enjoying these as well as being willing to pay for them, is the ultimate challenge.

And it is all about two-way broadband. There is no established or commonly understood interpretation of the term broadband available. However, intuitively one may argue that there is a certain user expectation emerging. The Broadband Experience should involve high access capacity to provide rapid response times and reasonable delays for file transfer. It is also perceived as carrying the full range of services. As such it should allow for real-time delivery as well as the most demanding application like live video broadcast. Converging this into a unified delivery mechanism and – voilà, you have a full-bodied Interactive Broadband Network.

This issue of *Telektronikk* is dedicated to Interactive Opportunities of Broadband Communications, hopefully providing a valuable insight into the main aspects of interactive broadband. The content is organised in four thematic sections: *The interactive broadband service market, Investments and business opportunities, Enabling Interactive technologies and networks* and *Pilot experiences*.

You will find papers by leading international experts in fields ranging from user behaviour, service design and look-and-feel and service forecasting, to enabling technologies and user terminals. Projections of the future market, assessment of the users, the services and the willingness to pay are presented initially. The investment levels, revenue streams, business models and opportunities of interactive broadband are addressed in several papers, though with different approaches. The important technology enablers for commercial services and key network aspects are covered in section three, with in-depth coverage of a few items.

Finally, we have included reports from the experience gained by the leaders at the frontier of interactive broadband services, namely KT in Korea, Kingston Vision in the UK and Bell Canada in North-America. They all have stories to tell about how the right timing and match of user demand, service offerings and technological capabilities may change the lives of people who have exploited the opportunities.



Broadband @ Home:

How Will Broadband Access Change Our Lives Over the Next Ten Years and How Will Our Lives Change Broadband?

KRISTIN THRANE AND RICH LING

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1 Introduction

In the next decade, new technology and broadband access such as those employed in the HB@ project will, to a certain extent, change the appearance of our homes. This, in conjunction with other technologies such as wireless access, can disturb old norms for home decoration such as TV in the living room and the placement of the home computer in the home office. Broadband technology's improved access will most certainly provide us with more interactive services and new terminals. This will open the way for new behaviour and routines within the home. In short, new technologies within the home will, in various ways, change the organization of our lives, the way our homes appear and the way we use our homes.

This said, it is short sighted to look only at the evolution of new broadband possibilities and solutions. In addition one must also examine how it is that we organize our everyday lives and try to understand how we will do this in the future. The degree to which our everyday routines are entrenched in means that the technologies will have to be adjusted to fit the routines, and not the opposite. This article attempts to place the ownership and use of broadband technology into the physical but more importantly the social context of our homes. Insight like this will provide us with clues as to how the use of broadband access and services – including traditional PC-based such as communication, education and work but also including such "TV"-based activities as entertainment and gaming – will be adopted and domesticated into the private sphere. We will look into how the strength of existing social norms and institutions will reform the technology.

A central issue here is the degree to which the home will be seen as the center of our social and cultural compass as new ICTs are adopted and used. Will these new technologies lead to an increasing centripetal tendency for families to use time together in their homes (cocooning) or will they encourage the opposite centrifugal effect (nodeing)? This is one of the issues we will address here.

2 Technology/ICT and the Domestic Sphere

In this article we focus on the home as the setting for the placement and use of Information and Communication Technologies (ICT). In the 1990s there was a discussion among Norwegian and Scandinavian sociologists, anthropologists and ethnologists about the significance of the home and the home-life in Scandinavian culture. More recently social scientists have been examining the permanence of the "home-centric" model in the face of an increasing globalization. There is the assertion that the home will increasingly lose its importance in our mind and culture. For example, rather than being a cocoon where one retreats from the world, it is increasingly seen as a node in a social network.

The data here seems to indicate that, when compared with 1980, Norwegians are spending less

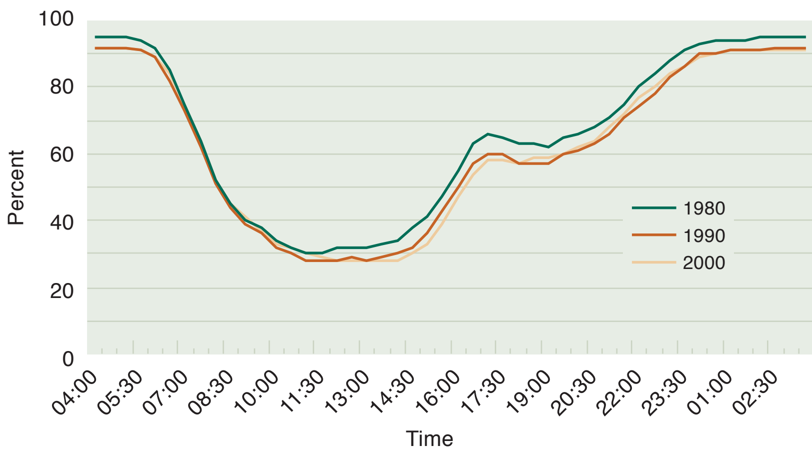

Figure 1 Percent of persons at home by time of day, Norway 1980 – 2000 (Source: SSB)

time at home and more time traveling (Vaage 2002). On the one hand, this may point in the direction that the home is becoming less of a central place in our lives. At the same time, it is clear that Norwegians invest tremendous effort in the decoration and maintenance of their homes. In addition, they clearly see the home as a reflection of the self. Thus, even though less time is being used there, the home has gained a more central role in the psyche. Analysis of household expenditures shows that while money use for transport and to some degree telephony has gone up we also see a moderate but absolute increase in expenditures for furniture and households articles from 1996 to 1999 and 2000 (SSB 2000).

The interest for home-decoration is still intact and growing. This indicates that we still use our home as a base for identity building and -confirmation, we consider that the home will still be an important foundation in our lives, and because of that the technologies that we bring into our homes will not be a matter of coincidence.

2.1 Norwegian Homes

For most Norwegians, the home represents something beyond being simply a place of residence wherein one can cover their basal needs of protection, food and rest. In the assembly of our home we create meaning through binding the different roles we have in everyday life to more or less complete whole. In the Norwegian psyche, the home is a sphere in which one creates a feeling of being a unified family (Gullestad 1989).

Playing on the Goffmanian metaphor, the home can be compared with a theater, with both a front stage and a backstage. It is through the adroit interaction between the front and the back stages that we play out our everyday lives. The front stage is, of course, that area where we try to arrange the appearance of our home and the way we want people to interpret us (1959). This is done through the purchase and placement of products from the mass market in a way that one wants other people to interpret them and by extension, the situation of the family in the home (Featherstone 1991).

There are practical, functional and aesthetic aspects to the appointing and decoration of a home. The various zones within the home each have their own functional requirements, their practical solutions and their demands for aesthetic considerations. These considerations are not simply in relation to the physical arrangement of furniture but also encompass the lighting, the ability to introduce sound via for example a stereo, the use of color and the regulation of temperature and lighting (Thrane 1999; Thrane and Ling 2000; Wilhite and Ling 1989).

At the same time that there is an aesthetic in the furnishing of the home at any one time, the home is also subject to slow changes over time. At one level the home consists of fixed zones that are partitioned by walls, plumbing, electrical outlets and the intentions of the architect and the builder, etc. Thus, the various rooms have their intended purpose, as well as the necessary equipment and appointments with which to fulfill that intention. The lives and needs of families, particularly those with children, change much more quickly.

At the same time there are slow changes in the structure of the home. A new chair is purchased, new curtains are bought and hung, etc. On a somewhat more dramatic scale, a wall might be either set up or removed, a former storage space may be refurbished and become a second living room, etc. As we see there is a certain, perhaps slow, evolution in the home.

It is into this complex context of physical, aesthetic, psychological and social meaning, that ICTs and broadband solutions are being placed. The procurement of new technology can add yet other dimensions. To buy a new cell phone or a new computer may not result in the need for big changes in home decoration, but new cabling and new forms of access can for older dwellings make for fairly dramatic changes in the structure and the furnishing of the home. It is important to see how they are being adopted and domesticated. In order to become a part of the home the new technology needs not only to physically fit in the home, but also fit the owners' aesthetical values and not least their family ideology related to technology use. It is, as we will explore further in the article, not only the benefits of new broadband solutions that will affect our home life, but also more how we want and will live out our everyday lives.

2.2 Adoption, Use and Domestication of ICT in Norway

When looking at the changes in ICT and media use in Norway one is struck by the general stability of the picture over time. At the same time there are some moderating trends and one dramatic shift.

In Figure 2 one can see that, in general the use of most media remained stable throughout the 1990s. TV use, newspaper use, fixed line telephony, the various forms of magazine, book and journal reading were stable. The use of the radio

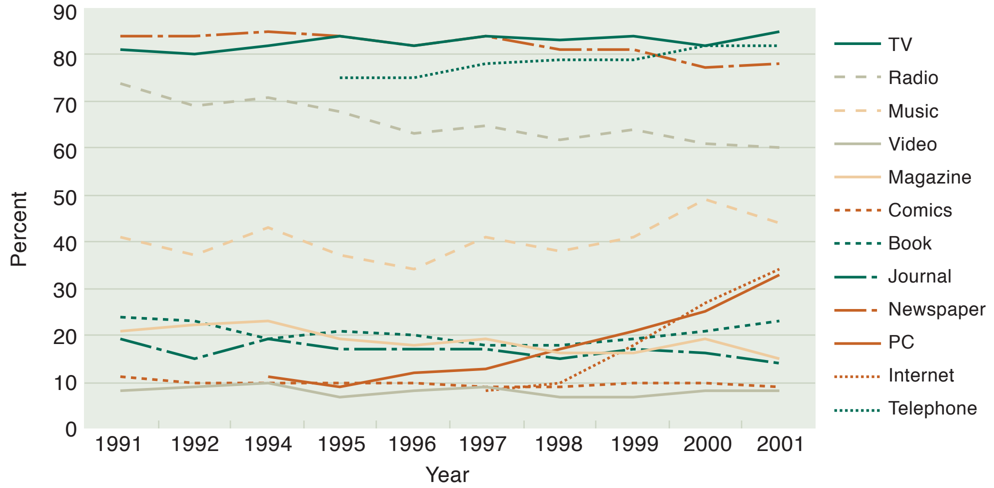

Figure 2 Percent of Norwegians who use various media on a daily basis, Norway 1991 – 2001 (Source: SSB)

saw a moderate decline in use, from about 75 to 60 %. At the same time there was an increase in the percentage of people listening to music on a daily basis.

Against this rather staid backdrop, the major shift was the use of the PC and the Internet. As of 2001 just under 75 % of all people in Norway reported having a PC in their homes. Looking beyond ownership, about 33 % of the entire population reports using a PC on a daily basis. Internet use rose from less than 10 % of the population to almost 35 %.

These statistics point to two shifts in the function and furnishing of the home. First, the simple ownership of the PC means that space must be made for the device. This is often in a "home office" in those dwellings where this space is available. However, in other situations, space is often more difficult to come by. Persons living in apartments often say that placement of the PC is awkward. In the words of a mother living in a townhouse apartment:

> Mother: I don't want a PC in the living room because I can't stand all the stuff around it and talking and all the things with that ... We sit in the sofa and there is a lot of [TV] watching. That is why I don't want it here ... [The PC] belongs more to the workroom.

At one level one sees the conflict between two technologies in this citation. One also sees the fact that while the PC/Internet is in the process of being adopted, this is not always a simple procedure. Rather, it is a type of negotiation over the way in which one wishes to use their homes and in how they wish to present themselves to possible guests. The other dimension of PC/ Internet adoption is that it colonizes time that might have been given over to other domestic activities.

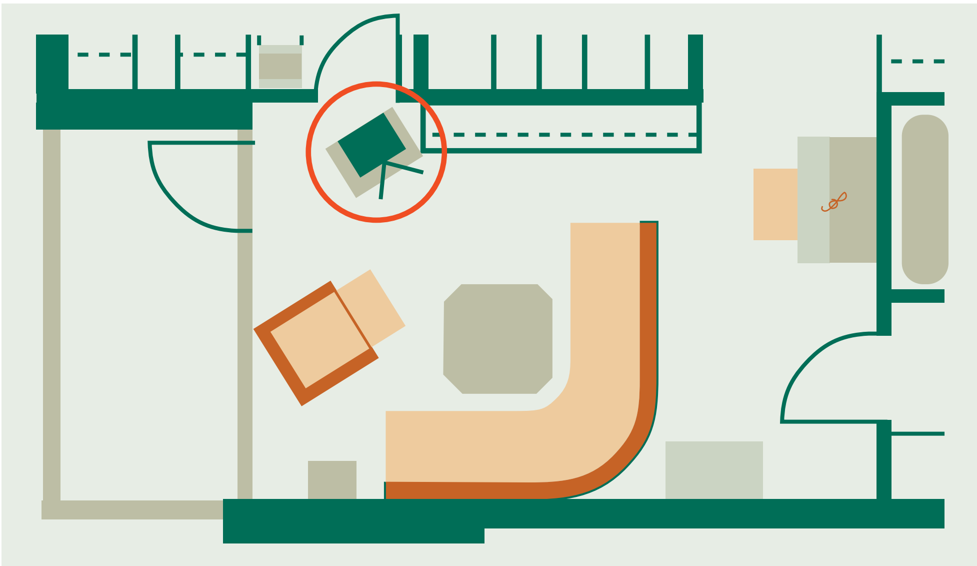

Figure 3 A Norwegian living room from 1985 wherein the placement of the TV was unforeseen by the architects who designed the home (Guttu, Jørgensen and Nørve 1985)

This type of interaction is however nothing new. The introduction of the TV into homes wherein architects had not foreseen the development of that technology meant that the people living in those homes have to develop decorating schemes that were less than optimal.

As one can see in Figure 3 the placement of the TV/sofa complex in the living room actually blocks access to the balcony and the bedroom. The introduction of the TV to the living room in the 1960s and 70s eventually led to the introduction of larger L-shaped sofa groups that allowed the TV to become the visual focus of the room. This development was out of tact with the imagined use of the space wherein one assumed that furnishings in the living room would prioritize conversation circles with a type of face-to-face orientation. As a result a provisional solution had to be found. One example of that type of solution is that shown above. Another is a second living room for the TV, a solution that was not necessarily available to those living in smaller apartments. While the shown solution functioned, it was not the most advantageous.

As one can see, technologies such as ICTs are not randomly placed around the home. Rather, their placement is the result of well-considered deliberations, both in relation to the home's aesthetics and façade, the physical possibilities afforded by the home and the functionality of use. One can read the placement as a type of moral statement. The physical as well as the "moral" placement within the context of the family is what Silverstone has called the moral economy of the home. This moral economy is, in part, achieved through the domestication of the various elements included in this sphere (Silverstone 1993; Silverstone, E. Hirsch and Morley 1992). The domestication approach suggests a process wherein objects are 1) *appropriated*, that is purchased; 2) *objectified*, or planned for a certain type of display; 3) *incorporated* into the actual display and routines of the home; and finally 4) *converted* into an integral part of the home's or the individual's identity. This is the process by which one takes something from the commercial sphere into their homes, by which one locates it physically, temporally and morally in their own world, and finally by which one integrates it into a portion of the way they are seen by others. The new broadband solutions for the domestic market will become an element in a life-style, which indicates one's social condition. The technological solutions in one's home reflect their social placement vis-à-vis economical and cultural capital (Bourdieu 1995).

Once in the home, ICTs have a type of career wherein their placement, use, function and perceived value shift and change over time. Objects and the social flux of the home are also managed through the negotiations over the varying needs and desires of individuals. Artifacts and accesses are not simply placed in the home and left there to gather moss until they are replaced with other more current versions. Indeed, the placement and use of ICTs are elements in an ongoing process. Where domestication and institutionalization perhaps indicate a one-way process wherein the final resting place of the artifact is eventually achieved, one might also imagine a slightly more dynamic approach.

Instead of seeing the integration of artifacts as a linear process we assert that it is an ongoing one. Where it makes sense to place the TV in the living room when children are infants, it may be better to put it into another more remote portion of the home as they enter pre-adolescence. In the meantime new broadband access may provide new services that provoke new user habits and which make the original function of the TV outdated. Thus the life cycles of the devices and of the family go in different tempos and interact with each other in unforeseen ways.

3 Broadband at Home the Next Ten Years

Up to this point we have tried to take a general look at the way that the integration of technology into the home is not simply the installation of a new box with a couple of wires. Rather it involves, in many cases, complex considerations and negotiations.

Looking into the potential for broadband and the way that it will play itself out in the home is more or less impossible. But a good compensation in this connection is to look at people's everyday life today – what they value and how they organize their life. Taking this perspective one sees that personal communication such as telephony, SMS and e-mail, Instant Messaging, etc. are often important and well used services today. Another issue here is that new technology will have to find its place in pre-existing homes. It is important to keep these points in mind when designing future services.

3.1 Barriers to the Adoption and Domestication of Broadband Technologies

In spite of dramatic technical changes in the next decade, there will not be the same changes in the housing stock in Norway. Thus, like the TV of the 1960s, the new technologies will have to nuzzle their way into the pre-existing structure of the home. This may mean that various forms of cabling, terminals, screens, electrical access and ancillary equipment will be the focus of negotiations within the home.

Since these devices have arrived on the scene long after the physical spaces in the home were designed and the inhabitants of the home had adopted one or another decoration aesthetic, the PC is left to find itself in this context. It is not always clear how this can work itself out. In our work, for example, we have found that generally there is the sense that the PC does not fit into the décor of the living room. So long as this idea has currency, families will resist the placement and use of these technologies in various portions of the home. Further, there are often gender- and generational-based factions within the home that argue in different directions on these issues.

In the same way that the TV was, and often still is, the subject of "placement" discussions within the home, the siting of the PC along with broadband access will be the subject of familial discussions. It is clear that these discussions will have a different character depending on the possibilities within the home. Those living in larger homes with many rooms will not have to make the same hard decisions as those who live in smaller apartments with limited space and wherein many activities compete for the same space (Frønes 2002; Ling and Thrane 2001). Thus, while the technologies may provide useful services, the fact that their aesthetics clashes with powerful pre-existing notions of how the home should be, they will not be welcomed into the home.

3.2 Things Encouraging the Adoption of Broadband Services and ICTs

3.2.1 The Emergence of New Family Patterns

We have examined the importance of the home in the Norwegian psyche. Against this backdrop, one can see that one uses the home differently now as compared with earlier periods. Specifically, we have seen the rise of more both diurnally and geographically distributed families. Thus the scheduling of the family has become more complex. In spite of the fact that the family lives under the same roof, the requirements of of work, school and leisure activities mean that they spend only certain parts of the day together at home. In addition one sees the rise of geographically distributed families; that is families with children and parents living in separate places. Where in the period 1960–65 one found 2.9 divorces per 1000 women in Norway, the level was almost four times higher for the period from 1996 to 2000 at 10.9 per 1000 (SSB 2002). In Norway, 25 % of children under 18 live in a geographically distributed family.

In spite of these developments, children have the same needs for communication with their parents. In addition parents have new challenges in organizing their everyday lives; both for themselves (with or without children) and for their children. Our analyses have shown that, for example the mobile phone, SMS and to some degree e-mail and IM have become the new types of extended umbilical cord.

This way of organizing our lives will affect our ICT use and the use and demand of new broadband services, for both children and parents. These trends mean that one must coordinate the various interactions between family members. Mobile and wireless technologies that support this need for communication and coordination have indeed gained a prominence (Ling and Yttri 2002). When looking to broadband services, they will be those that facilitate coordination; family calendars, location and context sensitive senders that indicate others' location and help to maintain a common group focus in spite of time and distance based barriers.

3.2.2 The Location of Entertainment, Work, Mediated Communication and Schooling in the Home

As noted in the introduction, the combination of broadband and wireless access in addition to the use of PC and IP for streaming of video and entertainment material opens up the possibility for personalized entertainment "web pads". This idea suggests that instead of, for example, a central TV and PC in the home, family members could take their web pads to whichever area of the home was most suitable at the moment in order to enjoy entertainment and/or interactive gaming.

This approach to use of ICT would in many cases change one's approach to the furnishing of the home. For example, instead of an L-shaped sofa group that facilitated collective TV viewing, one might imagine areas in the home that encourage collective face-to-face interaction as well as other more removed, but not closed, locations for the use of personal entertainment systems. In addition it might mean that some areas of the home might expand the type of use that takes place there. For example, when the kitchen is not being used for food preparation, one might use it as a place to view a film or to exchange e-mail with friends or colleagues. Thus, the possibilities afforded by broadband/ wireless mobility will possibly challenge today's notions of how we organize our homes and the types of activities that are carried out in the various zones of the home.

While entertainment services present one the general use of broadband wireless ICT use, other more "functional" services also present one with the opportunity to use these services. These technologies will allow one the ability to quickly set up or close down their office, send and receive e-mail or do school work, regardless of where one finds themself in the home.

Given this flexibility, it seems that we may move away from the recent technology based definitions of particular rooms. Thus, instead of having a TV room or a home office, we may increasingly see homes wherein there is open, relatively undefined space and where one can use a broadband wireless web pad in order to access various types of information. Just as the cordless telephone has changed the location and dynamics of private telephony, these technologies will change the other dimensions of the way we use our homes.

4 What Comes First – Technology or Needs/Use

It is clear that technology has changed our lives during the last century. Electricity is common, telephony is part of our lives and the world has become smaller with new transportation possibilities (Marvin 1988). Technology can change our everyday life, our work situation and the appearance of our home. It can increase our opportunities and in worse cases for some of us feel like an obstruction.

From the discussion above it is also clear that the introduction of technology into the home is a type of two-way interaction. On the one hand, the technology provides new possibilities while also demanding changes in well-entrenched ways of doing things. At the same time, we change the technologies in order to suit our sense of ourselves and how we should appear. One can see this in the use of various devices through which technology is adapted to the décor and the life style of the home (see Figure 4).

Figure 4 The domestication of telephony ca. 1960 in Norway

Historically the development of technology has changed the role of the home. The development of the automobile, electricity and telephony have all had an impact on the way we organize our lives. The development of suburbanization was, for example, in conjunction with the development of suburban railways and later the automobile/highway system of transportation.

We are now, seemingly, on the cusp of a new transition in the way we organize our private lives. On the one hand technology, in the form of broadband and wireless access, is ostensibly storming through the door into our homes. To say that it is only technology that determines the way we live is to ignore the social definition of the technologies and the latency of our cultural identities. This interaction will result in new, and perhaps unexpected forms of technology use in the home. It can, for example, encourage so-called "cocooning", "nodeing" or perhaps both. Regardless, their adoption will affect how we communicate, entertain ourselves, do our jobs and educate our children and ourselves.

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Future iTV Services

PEARSE CONNOLLY

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1 The Interactive TV Future

"I'm sitting around East Side bus terminal during a business trip to New York, thinking about what you can do with a TV set other than tuning in channels you don't really want. And I came up with the concept of doing games. That was 1966, in August." – Ralph Baer, Father of the Video Game.

The interactive TV (iTV) industry latched onto games about three years ago, and figured it wouldn't add up to much. TV video games were seen as 'nice to have' additions to the interactive service offering, but certainly not critical. There were new revenues to be exploited in other content categories such as t-Commerce, premium rate information services, TV banking, personal video recorders, interactive advertising and Internet or email on TV.

The TV viewer was just primed and ready for the opportunity to start leaning forward, up and out of the lean back couch potato position where they had languished for years. More importantly, if viewers wanted it they were willing to pay for the rich new experiences that iTV would deliver. Convergence was coming, convergence was indeed content made King, and convergence had the promise of vast new revenues.

Things did not quite turn out like that. The iTV industry did not figure out a way of dealing with the real spanner in the works of its predictions – people. TV viewing behaviour is deeply ingrained. For most people it is a lifetime habit and still the most popular way to spend leisure time – A body at rest tends to stay at rest! (1) While technology develops at Internet speed allowing a huge array of new features to be added to television viewing, people need far longer, more *human* time scales to change their viewing behaviour.

For the most part, iTV was riding the wave of dot com economics, not making waves of behavioural change (and sound business models!) through applying media production and user experience knowledge together with technology. The dot com effect dispensed with conventional wisdom. Viewers would interact because they could, not because they really needed or wanted to.

So there have been a few surprises. Of the many content categories that have been tried in iTV, only video games and game or entertainment related enhancements to a linear TV programme have so far been a commercial success.

The article will take a brief overview of the progress of iTV content from late nineties irrational exuberance to a future of cautious optimism based on the potential for games and gaming content. I have decided not to focus on development of tools such as the Electronic Programme Guide (EPG) and Personal Video Recorder (PVR) that help people actually structure, sort and manage their viewing. I take it as a given that these tools will evolve in functional sophistication, will be adopted by viewers but will remain as tools, and not become a form of viewable and interactive content in themselves.

I have intentionally steered clear of the vastly complex technology that is required to deliver interactive television services and can only marvel at those who understand its workings. What I will predict is that as broadband penetration rises, the ability to add more engaging return path activity also rises. However, at present the bottleneck for iTV is the viewer and viewing habits rather than the pipe into the home.

I would like to thank all the employees of Zonavi who have spent countless hours working on the problems of iTV. Your reward will be in your living room. I would also like to thank Johan Dolven for seeing the wood from the – well, Amazonian rain forest actually.

2 We Interrupt this Programme to Bring You – Interactivity

Some time around 1999 you could have read this vision of interactive TV viewing, there was probably a demo authored in Macromedia Director to help you along. All you would need for this new experience would be a set top box:

"Imagine you are sat on your sofa, relaxed and watching Ally McBeal. You like the show, makes you laugh, and the production gets better every season. Tonight you really like the top that Ally is wearing. A little symbol, the letter i, appears on the screen to tell you there is some interactive content. You press a couple of buttons on your remote control to pull up the shopping menu, you look for your size and colour say 'what the heck!' and buy it. You have to say yes to a couple of dialogues, put in your pin code and confirm the payment and address, but you are soon back watching the show.

The illustrations to this article have been provided by Ole Gunnar Dokka (36). Mr Dokka is Creative Director in Zonavi and has worked with screen oriented art and design since the early 1990s. He heads Zonavi's Communication department, which does all design, interaction and marketing tasks in Zonavi.

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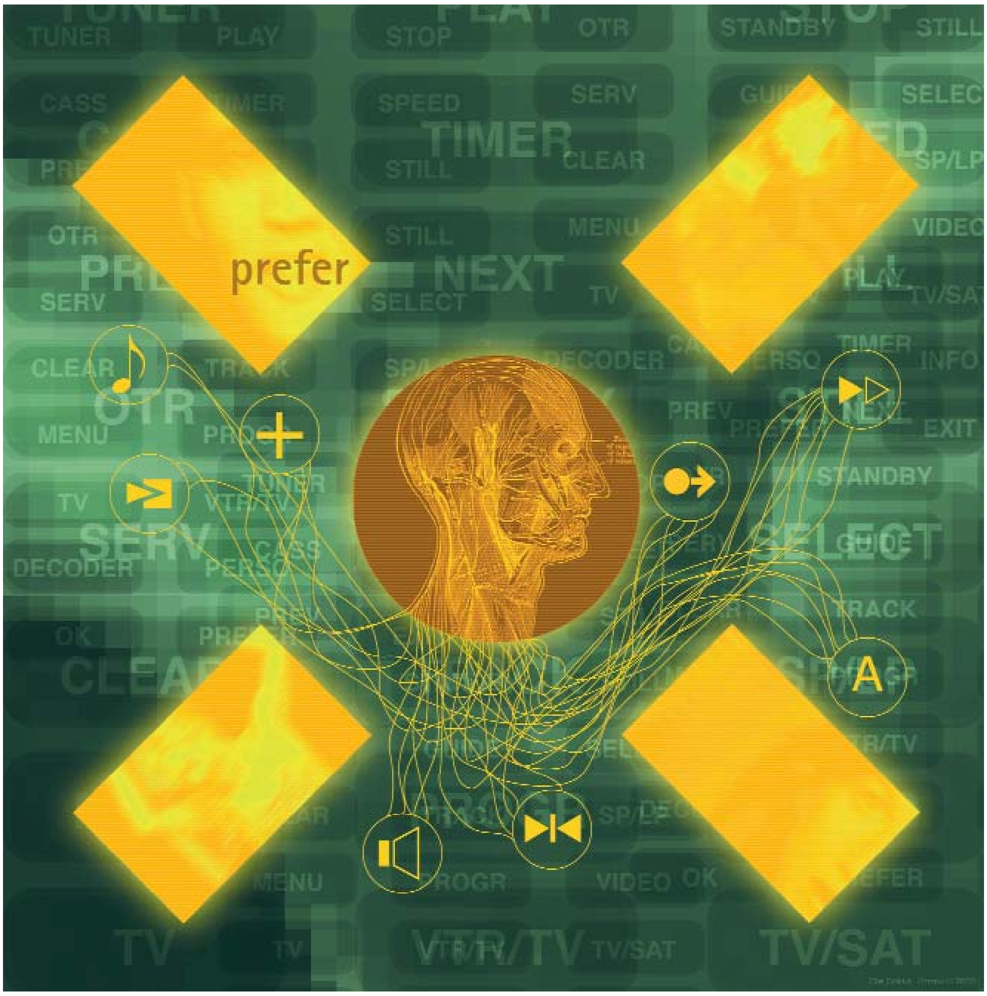

Ole G. Dokka © 2002

The i symbol pops up a few times more, you know there are lots of offers and extra information available but you can check that later in the Ally McBeal magazine on the channel portal. After the show, you press a couple of buttons on the remote and go to the TV channel website. You enter a "What does Tony eat?" competition to travel to New Jersey, check your mail and then get ready to watch interactive Sopranos."

Sounds good? Sounded good, attracted a lot of investment, our own company Zonavi was founded on the back of such a vision. It never happened.

It was a vision driven by technology. The iTV industry, we included, did not really understand either the reasons or the behaviour of how people view television and adopt new technology to an existing medium. The vision never happened and at least with a format like Ally McBeal, never will.

Interactive TV was a fantastic business opportunity that captured the minds and investment of almost all major technology and media companies. Interactivity and the Internet were coming to TV! People will surely want to buy stuff from their sofa and interact with their favourite shows. It had to be good!

The technology sector convinced the media sector that this vision was just what viewers wanted and would pay for. As Virgil observed – It never troubles a wolf how many the sheep be. The view was that there were a lot of potential sheep out there sitting comfortably in their sofas.

Fortunately the great viewing public are anything but sheep and to most of iTV's new vision reacted with a "Yeah, right …" complacency that clearly meant "No, Wrong!". Those working in iTV are having to look again at how deep rooted TV viewing behaviour actually is and how best to modify that behaviour from plain *viewing* to interactively *doing*, over time.

3 Prediction is Difficult, Especially of the Future

Having learnt from the mistakes of the past we can make a prediction for how one might watch Ally McBeal, albeit in the unlikely event that it still aired, five years from now:

"Imagine you are sat on your sofa, relaxed and watching Ally McBeal. You've liked the show since it first aired. Tuesdays 21.45 – time for Ally. It's aging well. The producers still pull some new tricks out of the bag. You laugh where you are supposed to, feel sorry that Ally still

Ole G. Dokka © 2002

can't get her man and when the credits roll you wonder how next week's episode will be."

That's it? What happened to all the exciting interactive services from the earlier vision? Our prediction – they won't be in Ally McBeal.

I believe interactive services *will* become an integral part of TV viewing in five years. For millions of viewers in different countries they already are. But the kind of interactive services described earlier do not add real viewing value to a format like Ally McBeal. That's a good story told well. It works. However, new formats with interactivity built in from the foundation concept will emerge. Examples of this have already been hugely popular. Big Brother would never have the same success without the interaction of the audience to select the winner. Interactivity is an integral part of the format.

4 The Challenge of Production

Currently it is only in the UK, which leads the world in iTV, that linear programme producers are starting to consider interactivity as a central element in programme production. Examples from both the commercial channels and public broadcasters have shown potential both in terms of audience response and willingness to pay. What is certain is that the longer people are exposed to interactive services, the more people will use the good ones. The bad ones die horribly. Whether stand-alone services that are a discontinuity from regular TV viewing (e.g. leave the programme to enter a competition), or enhanced programming that is not a valuable and contextual addition to the programme (like iTV Ally) – they don't work, people don't use them.

Broadcasters and operators from the rest of the world are closely following developments there and learning lessons from the UK experience that they hope will translate to their own territory. Zonavi's own experience of commercially operating our own portal and also launching an extensive service offering for the FIFA World Cup 2002 have taught us a huge amount about the realities of interactive TV on today's technology platforms. We have learnt how today's viewer behaviour must be taken as a critical input into the design and promotion of new iTV services.

We have also found that broadcasters have to actively push interactive services within the programme itself for them to be a success. Without this the viewer awareness of any interactive content and hence the take-up is just too low. People watch TV to watch TV, without promotion the interactive programme content is just an unseen distraction. We will see a lot of creative work directed at finding ways to promote iTV awareness without detracting from the editorial values and flow of a programme

There will be a generation shift in TV production, a natural organic progression. A younger generation will emerge who has lived digital with the Internet, mobile phones and whose influences are, more simulation than reality, more online community than home alone – more Mario than Morse. This generation will find it completely natural working with both linear and non-linear interactive elements of a production.

For those working with iTV now a critical success factor for future iTV services will be to build relations with existing and emerging TV producers, programme directors and commissioning editors. If iTV is part of the programme commissioning and production process from the start rather than as an add-on towards the end the chances of producing an excellent overall viewing experience are far greater.

Some organisations such as the American Film Institute are already tackling this by running annual sessions and workshops on iTV with a focus on producing new talent. The BBC has produced a set of interactive guidelines as an addition to its existing commissioning process and Sky has a developer programme for its platform. I assume that these initiatives will gain momentum and number as iTV gradually matures to become an accepted and expected part of the overall TV offering.

5 Pause Life – Play Games

We began this article with a reference to using the TV for playing games. The sleeper hit of iTV has definitely been simple stand-alone games (the set-top box is no dedicated games console such as PS2, Game Cube or Xbox). The games are primarily forms of arcade classics, e.g. Tetris or brand extensions to TV programme content e.g. the *Big Brother* game and titles from Cartoon Network shows such as *Cow and Chicken*. They're simply fun and fun is addictive.

Ratings figures for dedicated games channels in the UK such as Sky's *Gamestar* and Static's *Playjam* place them well into the top 15 channels on the network. Gamestar reports over 1.5 million games played through its service each week. I believe that with the exceptional reach of digital TV and the evolution of set-top box technologies that stand-alone games will continue to be a major success story for iTV. The value proposition to the viewer of partaking in a game while either waiting for a favourite show to come or as leisure activity in its own right has been proven. Stand-alone games are already and will continue to provide a new and sustainable revenue stream through either subscription or pay per use.

The challenge for iTV stand-alone games is to encourage a large enough developer community to enable a steady supply of affordable products to keep the offer fresh. This is especially true in the Nordic market, which despite being relatively small has two incompatible platforms in the form of Canal Digital's Mediahighway and Viasat's OpenTV. The interim period before a common platform will see a lot of re-skinning of a core game engine.

It can be argued that stand-alone games are not really iTV. They are just a lower spec version of a dedicated games console. Seen in isolation this is actually true. However, even in their present form they are so convenient to access and play from the familiarity of the remote control they are much closer to lean back TV viewing behaviour than a console game. Accessing a stand-alone version of Jeopardy from the TV is a lot easier and closer to the TV context than a console version.

When coupled to developments in broadcast synchronisation and return path capability, future stand-alone games have the potential to become a more TV-near version of online games. Our thinking here is that the games will become more episodic – play along each week, as either game character or game play develops. Previous episode winners can become a focal point of a game without having to leave the living room of their home.

The other form of games that have been a success with iTV and which will see rapid future developments in terms of sophistication and engagement are known as Play-along games. The idea behind play-along games is simple, you at home get to take part in the quiz, game show, reality show etc. *while* you are watching. The interactive content is an integral part of the show and is synchronised to give you a real-time experience.

The BBC reported that of the 1.4 million Sky viewers who tested their IQ through a programme called Test the Nation, 55 % of them used the iTV application. Game shows such as Millionaire have already shown that viewers are very interested in testing their own skills and knowledge. Incorporating the interactivity into the show by allowing the interactive high scorers to take part in the actual recorded show reinforces the basic value proposition. It's fun and fun is addictive.

Our view is that play-along games are most probably going to become part of the broadcaster's offer to attract ratings and loyalty. There will be a reaction against paying to interact with basic elements of a show. However, the viewers will probably accept premium rate call charges or competition entry fees related to a programme or event.

For a hint of future developments of play-along games I believe we have much to learn from the video game industry where structure and game play have become extremely sophisticated. A version of a new game show might incorporate cinematic cut scenes and advanced AI all packaged in high end TV production quality. The Mario show in 2010 might just be a blending of broadcast content and locally generated game play, you'll be in the show and it's a hundred times better and more fun than any early vision of virtual reality.

6 The Future

In describing the huge array of advanced features and services enabled by developments in television technology it is often easy to forget that it's the basic service, a moving image with sound, that still gives people the greatest service and pleasure. In the future TV will still deliver that service and be the primary source for relaxed viewing of entertaining and informative content in a social setting.

However consumers will have the choice of a much richer set of networked experiences and functionalities to compliment linear viewing. Finding which of these services is popular and profitable is the challenge for those working in iTV at the moment. The current success of games and enhanced entertainment is a good indication that the guiding principle of interactive services should be that "TV is for fun, not function". And just to repeat it once more, fun is addictive.

As a separate industry, iTV will gradually evolve and consolidate to become an integral part of the overall TV industry. Right now they are still two distinct segments but it is changing fast in response to market requirements. When tools for composing and video editing have interactivity features incorporated seamlessly into the workflow, when adding an interactive game element is as easy as doing colour correction, then iTV will be mainstream.

The effect of this consolidation will be to increase the quality and inventiveness of interactive content, as it gradually becomes the responsibility of creative professionals. Their primary goal is to entertain and engage the viewer in the best possible way, through a programme or a game, using the tools and techniques available to them. Interactive TV has to be seen as a compliment to TV, not as a replacement.

To conclude, the future will look a lot like the past but it will look immensely different too! People will always watch television to watch television, leaning back and just watching – that's the killer app, it's already been found. The trick now is to make it better. So more and more they'll play-along and take part in all kinds of shows and games. They'll take part in TV communities with contextual messaging and chat. They'll take part in all this for the same reasons people have always watched TV – to be entertained at home.

I believe in five years time I will glance through the daily schedules at a huge array of sophisticated, engaging TV shows and dedicated game channels that have great interactive content. I will look back at 2002 and marvel at how naïve the predictions in this article were as types and forms of interactivity I hadn't dreamed of have become mainstream viewing.

Don't worry Mr Baer, there'll be plenty to see and do on TV!

Game on.

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Drivers in the Broadband Market

ASKE DAM AND PÅL S. MALM

Developments in multimedia production tools and in end-user terminal equipment will enable new concepts and business opportunities for broadband networks in entertainment, communication and education. Individual exchange – peer to peer distribution (P2P) – of rich media experiences is one possible result of the arrival of inexpensive and easy-to-use digital storytelling tools (digital cameras, editing tools, etc). Another one is the rise of new markets for narrow media content, created by individuals or small production teams, which are not necessarily part of the existing broadcasting or publishing industries. Local storage in the end-user terminal also changes the way such material is distributed, presented and consumed.

Traditional mass entertainment – with or without interactive elements – may still be the main attraction, but narrow content that cater for individual taste and interests may become an important part of the media menu.

The challenge is to create an environment where such new media creators can "meet" their potential customers. A number of enabling services must be developed by the service provider in order to establish and maintain such markets. This paper point out some of the major trends in these developments, and offer some possible scenarios.

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New Tools for Content Creation

The rise of the PC population coupled with the advent of inexpensive desk-top publishing tools, has resulted in a revolution not only in the printing and publishing world, but also in all other activities where thoughts and ideas are to be distributed in written form. Executives no longer depend on their secretaries to put their thoughts on paper, and entire professions like typists and typesetters have almost disappeared.

The next decade will produce a similar trend in desktop multimedia publishing [1]. Digital story telling tools are no longer reserved professional media specialists, but are rapidly becoming a part of people's daily life. Miniaturization and the advantages of mass production have given rise to whole new sets of easy-to-use and inexpensive communication toolboxes.

Film and TV production are industries where production tools have changed dramatically. Production methodologies in established media industries have not changed in a similar way. Digital production is often handled much the same way as film was created almost a century ago. Professional routines and conventions are hard to change, and we see cases where small production units with limited resources have been able to compete with established media giants. The "Blair Witch Project" movie was produced on low budget equipment by a small group of individuals, but was nevertheless able to compete, at box offices, with movies produced by the Hollywood establishment.

The Dogme movie movement in Denmark has shown a similar trend, and digital cinematography is rapidly replacing film all over the world. In two years the Cine Alta format has been the master format for twelve Swedish feature films, and the digital technology has taken about one quarter of the feature film market [2].

In a transition period all digitally produced movies must be transferred to film for exhibition, but even theatres will eventually be in for a change to digital projection [3].

The dissemination of small and relatively inexpensive digital still- and video cameras has at the same time put communication tools in the hands of common folk who a few years back had no opportunity to create digital multimedia content themselves. The Internet and – very soon – broadband distribution channels have given them the means to distribute their content – everything from simple messages to artistic expressions – to other individuals or to a larger public.

Randy Roberts of Nokia last April (2002) told an audience at NAB (National Association of Broadcasters) that he expects his company to become the world's largest distributor of digital cameras and the news about Vodafone ordering 1 million mobile camera phones from Sharp (July 2002) seems to prove this trend. The first "camera phones" may be crude compared with digital video cameras, but if they are equipped with local storage and access to broadband networks, they may become very valuable communication tools.

Figure 1 ViperCam – High-end Digital Cinematography camera from Thomson – IBC 2002

All these digital story telling tools – from Sony's CineAlta cinematography equipment to inexpensive web cameras from Logitech – should be seen – not as separate gadgets, but as components of a much larger communication system.

They can be linked together in networks, and people may exchange audio/visual material along with software tools for creating content. "Production tools" are readily available – a Logitech digital still camera priced at 200 Euro is for example bundled with quite advanced archiving-, picture enhancement- and video editing software.

Software tools for a variety of platforms will replace entire hardware equipment suites. This author – for example – does advanced video editing on his Vaio laptop – a task that as late as ten years ago would have required an editing suite with tape recorders, mixers, text generators, editors, monitors and a lot of other special equipment. This trend is being acknowledged even for professional television production.

> *"There is every reason to believe, and evidence to suggest, that software will also gradually take over from hardware in television programme production, as it has already done in radio. The age of television programme-production centres, based on software, is not very far away. This poses major problems for many organizations in Europe, whose traditional base has been hardware systems. Somehow, they will have to re-engineer themselves as software companies, and this will be the great challenge of the next ten years."* [4]

Figure 2 Panasonic camera – aimed at both the high-end amateur market and the professional news gathering market – IBC 2002

All content creators – from individual hobbyists to broadcasting companies – face this challenge. The new tools create new opportunities, and new business concepts – using broadband networks – may be based on offering software tools bundled with training, management and other support services to content creators.

Advanced End-user Terminals

In the analogue world, introduction of new TV services depended on established hardware platforms. If you wanted stereo you needed a stereo chip in your receiver, and it didn't make sense to broadcast Teletext without a sufficient number of Teletext enabled receivers. The Multimedia Home Platform (MHP) of DVB (Digital Video Broadcasting) introduces the ability to download software applications to digital home terminals like set-top boxes and integrated TV sets.

> *"Today, a much larger step can be taken in software – by creating an "engine" for running applications, like we have become accustomed to with the PC. This implies that the step now being taken with the introduction of MHP will influence the introduction of new applications for many years to come. This will significantly reduce the time to market for new applications. Similar applications coming from different broadcasters will potentially have a different look and feel. It will be possible to bring new applications into use for just a limited time and scrap them afterwards, since they will not require additional investment by the consumer.*
>
> *MHP applications will have an impact beyond the traditional broadcasting world. There will be extended commercial potential for these applications and, as a consequence, applications will also be developed by non-broadcasters"*. [5]

MHP or not – digital receivers with open or proprietary APIs do make it easier to establish new services. The trend is moving towards open standards or at least proprietary standards that may "live together". Here again the ability to create new programme formats is no longer limited to the established media industries. Small content creators – and even individual "communicators" may establish their own "congregations" in broadband networks or digital TV channels.

Another important trend at the receiving end is the introduction of local persistent storage. *In Japan, standardization of the "broadcasting system based on Home Servers" is currently ongoing at the governmental level (Telecommunications Council, Ministry of Public Management, Home Affairs, Posts and Telecommunications), and is expected to be completed in the autumn of this year*. [6] Japan will begin digital terrestrial broadcasting in 2003, and the Japanese standard organisation ARIB – Association of Radio Industries and Business in Japan – has been very active in an international effort to establish a global standard for local persistent storage – The TV-Anytime Forum.

Tivo and Replay-TV were first to bring PVR / PDR (Personal Video Recorders and Personal Digital Recorders) boxes to the American market, and in the UK, NDS and Sky have had their Sky+ service in operation for about a year. Besides these "organized" boxes (boxes bundled with a service) there are many stand-alone digital recorders on the market worldwide. Most boxes have a capacity of 40–80 GB of storage that is approximately the same as 40–80 hours of video. The exception is Replay-TV's most powerful PDR that can store as much as 320 hours of video material. Available storage capacity will rise with the falling cost of memory technologies. PDR boxes, integrated TV sets or home servers may hold as much as 160 hours of video per dollar of storage in 2010 [7].

This is going to change the way we consume media. Any live broadcast may be stored on the

MP3 on PC	Today	2007	2012
$600 PC – 20 GB (gateway.com)	400 hours	12,800 hours	400,000 hours
$1500 PC – 80 GB (gateway.com)	1,600 hours	50,000 hours	1.6 mill hours
MP3 players	Today	2007	2012
Apple Ipod – 5 GB $400	100 hours	3,200 hours	100,000 hours
SonicBlue Rio – 20 GB $400	400 hours	12,000 hours	400,000 hours
Tivo box – $400	Today	2007	2012
	60 hours	2,000 hours	64,000 hours

Table 1 Local storage capacity development – as presented by Marc Andreessen – at NAB 2002

fly, giving the user VCR-like access to the material, and programme material may be downloaded at timeslots when networks are not busy.

In the case of Flash Memory Cards like Memory Sticks and SD Chips the capacity is 256 kB today, and Panasonic has announced a 4 GB SD Chip to be released already in 2004. This means that also mobile terminals connected directly to broadband networks, and those indirectly connected via eg. Wireless LAN or removable media, in the very near future can store vast amounts of rich media content.

> *The viewer or listener becomes his own programme scheduler, though predetermined channel flows may still be present for those who want them. Some media items will need to be available at particular times, such as sports events, so we [the public broadcaster] will still have available the power of the shared moment, but most will be there when and where we want them.* [8]

Digital downloads are not limited to audio or video, but can be anything from graphics, animations and games to software applications for new services.

Huge local archives may also serve as a basis for content production and exchange of programme material – for and amongst content creators of various sizes.

Media Distribution via Broadband and/or Broadcasting

Americans spent 2.3 billion hours online during the month of January 2002. 53 % of all connections (both business and home) were via broadband – SDSL, cable or T1 connections [8]. Even though Gilder's Law (bandwidth triples every 12 months [9]) may be up against all sorts of regulatory and market related barriers, broadband networks are definitely becoming an important part of the media distribution menu. Last March the Nagoya Dragons Baseball team in Japan established its own multicast ADSL-based TV station and so did other companies and organizations.

Almost one fourth of all Japanese households are expected to be using broadband services by the spring of 2003. Although ADSL providers offer broadband services with an average speed of 8 Mb per second, they are in serious competition with optical fibre providers as consumers seem eager to access even higher bandwidth. Fibre To The Home (FTTH) consumers pay less than 70 Euro per month for an FTTH connection. This service offers an always-on connection and a throughput of up to 100 Mb per second. At such speed a two-hour movie may be downloaded in just 6 minutes [10].

Transfer of material in non-real time is a very powerful concept that is only possible to terminals with local persistent storage. A related possibility is to transfer a 6 minute long "micro-movie" to a PDA in two hours – using for instance a slow Wireless LAN connection. Local storage has also been described as "Pseudo Bandwidth".

A broadband network may face serious capacity- and cost problems if everybody starts accessing rich media content in a point-to-point fashion. Chet Rhodes, Senior Video Editor, of Washingtonpost.com told an audience at NAB last April that "we can't afford to succeed" because success means more traffic and more traffic means higher costs. He told about news sites which after September 11 ran up "millions of dollars in debt" because of heavy traffic.

Digital broadcasting via satellite, cable or terrestrial transmission may still be the preferred way to distribute content of general interest. Local storage may help to utilize the frequencies better as content without any particular urgency might be broadcast in off-peak time slots.

The most popular websites – especially when they contain more and more rich media content – might preferably be broadcast to PDRs and PCs. Most users only visit their favourite websites once a day, so rather than accessing them in a point-to-point manner, they might use the latest saved version from their PDR (eg. Aftenposten.no, digi.no, vg.no or nrk.no might be broadcast to local storage devices whenever there are any major changes – replacing previously stored versions).

Thus a combination of digital broadcasting, point-to-point and multicasting, peer-to-peer exchange and datacasting for decentralized caching at end user terminals or at hubs, strategically located in the network – may be the ideal solution. There can be different pricing policies associated with each distribution route, and service providers will be able to offer cost saving distribution services to both content providers and end users.

Narrow Content, Global Markets and Third Party Content Management

Mass produced entertainment and movies may continue to be the main diet for the average viewer, but the above mentioned developments will give rise to a new market for niche programmes to be distributed to a global audience – programmes often produced by independent content creators. *Organizations are becoming less constrained by national boundaries and are providing services, although tailored to local* *needs, across ever wider geographical boundaries* [4]. What is regarded as narrow content in a Scandinavian setting may have an audience equal to that of a huge nationwide success if it is being promoted to special interest groups worldwide.

Companies of any size may produce their own PR material and store it at a third party media hotel. Same third party may handle practical matters like marketing, distribution and transaction fulfilment. Individual communicators, media artists and other one-person operations may need the same sort of services.

Broadband networks also support networked production. This is the case internally in big content creation companies like the EBU (European Broadcasting Union) member organizations.

> *"The whole production process can be transformed by 'networked' production systems using content stored on computer servers. This will allow production staff to assemble programme material on computers, including searching material from the archives. Using information technology for production will increase efficiency and facilitate multimedia production."* [11]

A number of proprietary systems are available for broadcasting stations. The Danish Broadcasting Corporation has for example appointed SGI – Silicon Graphics International – to supply them with a complete News production system to be installed over the next couple of years. Networked production may have an even greater influence on smaller production units or individual users, if facilitating systems can be put in place. Here interoperable and open systems become of critical importance, and so does a standardized set of metadata.

> *A key to networked production is the development of systems of 'metadata'. This is text and numerical information about the content which is recorded and kept with it. This can be used for labelling, for search and retrieval of content, and for a wide range of business elements of programme production and delivery. Metadata will be an important constituent of archive systems, and it will be the fundamental element of the whole production "media asset management" system. ... The metadata will be the basis for the production process for decades to come, and it is the glue that will bind together the elements of networked production.* [12]

Different metadata will be present during the entire lifecycle of media content. Metadata related to production, indexing, search and retrieval, rights management, usage history and transactions etc., must be dealt with. In advanced networks this may eventually lead to the use of artificial agents – provider agents who offer specific content to user agents, who in turn are being constantly updated according to the user's preferences.

Main players like public and commercial broadcasters may themselves want to handle and control as many of these enabling functions as possible. Smaller players will need special support services by some sort of third party umbrella organization.

One such organization for supporting the exchange of multimedia content between mobile users is Remote-I. *"It is not only about how you consume multimedia. It is about creating a destination where those who create media and those who want to purchase media can find each other."* Remote-I is establishing a *"Digital Media Exchange™"* where *"– any user on the exchange can act as an eye for other members in other parts of the world. Therefore it will be possible to obtain instant visual access to any worldwide location – both requested and paid for via a 3G device, PDA etc."* Their subscribers – whether consumers or companies – will *"register to browse, buy and sell digital media."* [13]

Similar services may be envisioned for content creators, working with anything from 3G phones and digital still- and video cameras to HDTV- and digital cinematography equipment. Other support services may include training of content creators to utilize the new tools, metadata management, complex interaction authoring, global promotion, financial transactions and media hotel services.

A Practical Experiment with Digital Storytelling Tools

In connection with the HBA pilot project, the Future Media group of Telenor R&D was able to bring some of the ideas about garage production and digital story telling tools to test in a small exercise, during the summer of 2001.

For several years the group had been in contact with a Japanese university whose aim is to *"train experts, "Media Masters", with the capability of contribution to industrial and cultural advances in the 21st Century"*. IAMAS – the International Academy of Media Arts and Sciences – is situated in Gifu Prefecture, and is part of a larger scheme of introducing software industries to the region.

> *"With the rapid expansion of recent digital technology and world wide networking systems, a drastic change in human life has been*

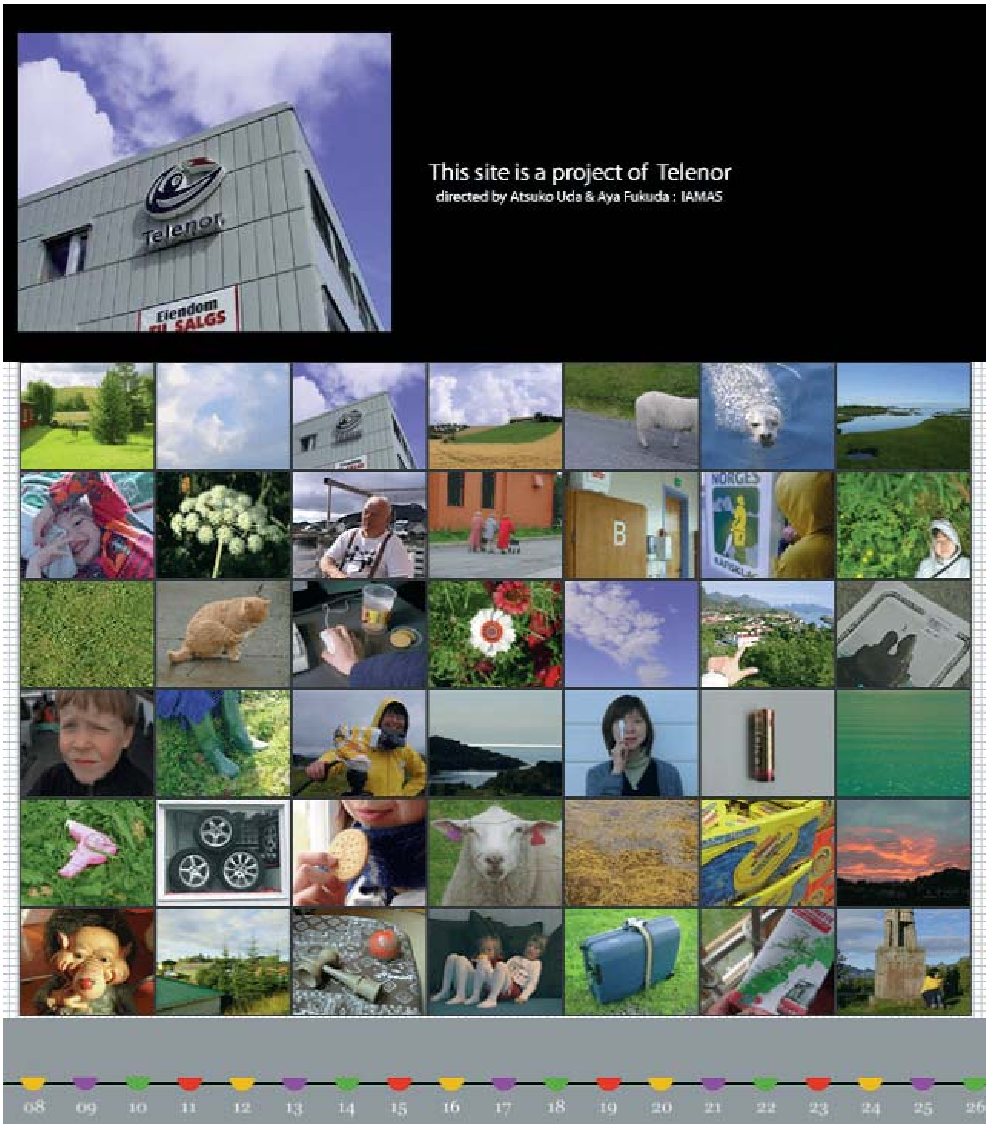
taking place in almost every aspect, from the fields of politics, business and welfare to social and cultural life. It has particularly brought about a new way of expression through the convergence of traditional media, using images, sounds, texts, graphics and even performances appealing to the five senses and the human conscious." [13]

75 % of both teachers and students have their background in the fine arts and 25 % come from computer science. They are "forced" to co-operate in projects, and thus able to draw on the shared know-how of both groups – thereby developing the necessary qualities for multimedia creation.

Two graduate students, Aya Fukuda and Atsuko Uda, were invited to Norway and given the task of creating a "digital vignette" about life in Norway – every day for one and a half month. They produced their vignettes with what in 2001 was regarded as high-end amateur equipment.

Aya Fukuda (left) and Atsuko Uda on location in Svolvær, September 2001

The reason for using the concept of digital vignettes was to test as many aspects of digital story telling as possible, rather than creating one traditional documentary programme. Their format of short compressed video clips, still pictures and computer graphics was particularly well suited for distribution and exchange in a broadband network environment. During August and September 2001, they worked at the Nordland Art and Film School in Kabelvåg, creating a website with around 40 short art pieces. They can be found at: http://www.iamas.ac.jp/~aya/ telenor/.



http://www.iamas.ac.jp/~aya/ telenor/. Front page of website created by Uda/Fukuda during their stay in Kabelvåg, September 2001

Their work showed interesting ways of creating a sense of "live video", that – due to clever use of flash animations – did not require huge data files. The amateur equipment – high-end in 2001, but mainstream in the near future – was sufficient for creating these expressions.

Uda and Fukuda's deep knowledge of rather sophisticated image creation– and video editing software was required for doing this kind of work. Using such tools still call for specialist know-how, but simpler tools doing less sophisticated work are available for consumer PC platforms. We assume that this trend toward simple and inexpensive software will continue, making digital story telling part of many people's daily communication. Very simple still cameras – with some video capability – were tested at schools and institutions in the Vågan Municipality. Due to technical constraints, we were not able to test a planned exchange of multimedia content among the schools in a broadband environment, and a similar international exchange with Inatori – a fishing village in Japan.

Conclusion

Many new tools are available for content creators, and it is in the interest of the service provider that these are being put into daily use – not only by the established industry – but by anyone who wishes to communicate with multimedia. Individual users and small organizations may generate an important part of the resulting traffic in broadband networks, but they need to be made aware of – and capable of utilizing – these tools.

New terminal equipment with local storage enables a new kind of personalized media consumption. Advanced interaction and financial transactions will be some of the key features of this consumption, and again the smaller players may generate much of the resulting traffic. Indexing, search and retrieval and rights management are other features that will require metadata management, and yet the importance of metadata has only been recognized very recently. Traditional service providers and/or third party metadata management providers may have to offer many of the enabling services – not only to the smaller players – but even to broadcasters and other major content creators.

Broadband networks will handle individual communication and can be supplemented with data broadcasting for distribution of multimedia content outside the established broadcasting channels. The result can be that narrow content produced by small specialized or local content creators can be distributed to individual consumers worldwide. Specially tailored content may be presented on a wide range of terminals from 3G phones, PDAs and PCs – to TV sets and even to digital cinema screens.

Most content creators need new support services if they are to succeed. Such services can be offered either by the existing service providers or by new independent organizations. They may become a critical factor for the development of new broadband communication markets.

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Broadband Access Forecasts for the European Market

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The first part of the paper gives a review of broadband forecasts and broadband forecasting methods which have been applied during the last eight years to predict the broadband evolution in Western Europe. It is documented that the Delphi survey has developed rather good long-term forecasts based on surveys carried out in 1994 and 1997.

The second part of the paper presents demand modelling and forecasts for different access technologies for the fixed and mobile network based on results from the IST project TONIC[1)2)]. The demand modelling and broadband forecasts are important input to four techno-economic business case analyses in the TONIC project. Forecasts for three generic types of Western European countries have been developed: A Nordic country, a Central European country and a Southern European country.

For the fixed network, a model has been developed for forecasting the total broadband penetration in the European residential market. Forecasts are made from 2002 to 2010 based on diffusion models. A specific model is developed to predict the market share evolution between ADSL, VDSL, fixed wireless broadband and cable modem/HFC, and then penetration forecasts for the different access technologies.

For the mobile network, specific forecasting models have been developed to forecast the total mobile access penetration in Europe and for the mobile system generations GSM, GPRS/HSCSD, 3G and 3G/WLAN.

1 Introduction

Broadband forecasts are important input for a wide range of areas. Specific models are developed to forecast broadband subscriptions and broadband traffic generated in the network [1]. Short-term forecasts are used to estimate the revenue. The forecasts are also input to the budget process and even for following up the budget month by moth.

In addition, the forecasts are used to estimate the investment and operations and maintenance costs. Broadband forecasts are important for predicting purchase of broadband equipment, network components and to predict manpower used for the installations.

However, this paper focuses on long term evolution of broadband technologies. The broadband forecasting models have to take into account various broadband technologies. A battle has started between incumbent operators and cable operators in Western Europe. In some countries the cable operators have rather high broadband market shares since they have started broadband deployment earlier than the incumbent operators. The forecasts show that DSL access technology within a short time will be the dominating technology in Europe. However, in areas were there exist cable networks, the competition is intensive and the broadband penetration higher than normal [2,3]. The situation in Europe is different from North America where forecasts show that cable modem technology based on HFC during the coming years still will have more than 50 % of the market. Fixed wireless broadband access based on technologies like LMDS is for the moment rather expensive. A lot of operators plan to utilise the technology, but it will take some years before the technology is cheap enough to compete with DSL and HFC.

To be able to make the right decisions for the rollout of broadband platforms, overall techno-economic calculations have to be performed. The European Commission has since 1992 supported the following portfolio of techno-economic projects:

- TITAN, RACE 364 (1992–1995)
- OPTIMUM, 2087 (1996–1998)
- TERA[3)], ACT 226 (1998–2000)
- TONIC, IST 25172 (2001–2002)

The broadband forecasting models have been an important element in techno-economic modelling.

2 Broadband Forecasting Models for Techno-Economic Analysis of Broadband Roll-out

Important input to techno-economic modelling of broadband rollout is broadband forecasts. Both quantitative and qualitative forecasting

1) *TONIC: TechnO-ecoNomICs of IP optimised networks and services*
2) *http://www-nrc.nokia.com/tonic/*
3) *http://www.telenor.no/fou/prosjekter/tera*

models are candidates for making broadband forecasts. Actual quantitative forecasting models could be Smoothing models, Time Series models (Box Jenkins approach), Kalman filter models, Regression models, Logit models, Diffusion models and other econometric models. Actual qualitative forecasting methods could be Market surveys, the Scenario method, the Analogy method, Experts methods and the Delphi method.

The question is what type of models can be used for techno-economic analysis of broadband rollout. The forecasting models have to satisfy the following:

1) Because of the nature of investment projects, long term forecasts are important.

2) The forecasting models should also have the ability to be applied with limited or no data at all as input.

In addition there should be possibilities to include relevant expert information.

To establish a new broadband platform, it is necessary to examine a project period of 5 – 10 years. Because of heavy investments the payback could be 5 years or more both in the fixed network using DSL, HFC or LMDS technology, and in the mobile network for UMTS. The mobile business case has also to take into account the mobile licences for UMTS. Hence, long term forecasting models have to be used to evaluate rollout of a new broadband platform.

In case of no historical data the qualitative forecasting models are of course the most relevant models. Time series models and Kalman filter models are not relevant since they need a substantial number of observations. HFC and DSL were introduced in Western European countries in the period 1999 – 2001. Therefore the number of yearly historical observations in different European countries varies from 1 to 3. The forecasting models used have to utilise limited observations and in addition make long term forecasts.

3 Forecasting Models Used for Broadband Forecasts 1993 – 2000

The EU has since 1992 supported a portfolio of techno-economic projects, with the objective to analyse and evaluate broadband rollout. This chapter gives a review of the forecasting methods used in the techno-economic projects: TITAN, OPTIMUM, TERA and TONIC.

3.1 TITAN

Quantitative forecasting models could not be used in TITAN (Tool for Introduction Strategies and Techno-Economic Evaluations of Access Networks) since the project was carried out a long time before broadband services were introduced in the residential market. Even parts of broadband technology, which are used now, were not known. In the first phase of the project, internal expert evaluations were performed to make predictions of the future broadband market. The applications teleworking, telelearning, telegames, teleshopping, teleinteraction and information/thematic channels were examined. In 1994 a postal two-round Delphi survey was carried out among 100 experts from 10 different Western European countries. The experts had to answer questions about the demand for broadband applications, the demand for access capacity and willingness to pay. The access capacities were segmented in ISDN, wideband accesses (2 Mbit/s) and broadband accesses (8 Mbit/s).

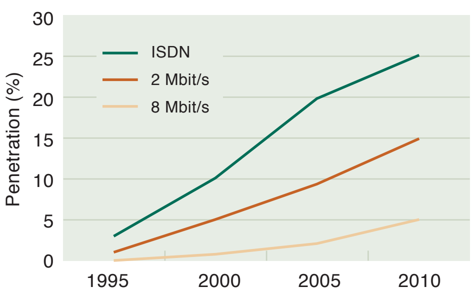


Figure 1 Forecasts of penetration of ISDN, wide- and broadband accesses in the residential market, Western Europe (Delphi survey, 1994)

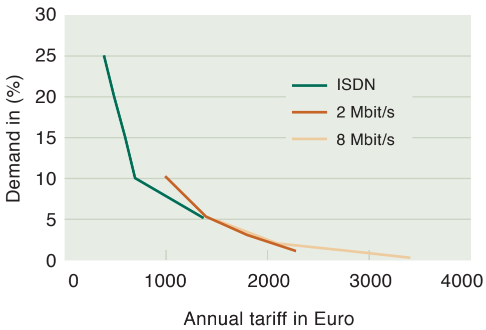


Figure 2 Demand curves ISDN, wide- and broadband accesses in the residential market, Western Europe (Delphi survey, 1994)

The Delphi results contained demand forecasts for ISDN, 2 Mbit/s and 8 Mbit/s accesses in the years 1995, 2000, 2005 and 2010. The results are shown in Figures 1 and 2.

Figure 1 shows the demand curve for ISDN, wide- and broadband accesses. The experts in the Delphi survey had to estimate the demand based on rather high annual tariffs. For wideband the tariff interval was [1000 – 2300 Euro], while the interval was [1500 – 3400 Euro] for broadband accesses.

The differences between the demand curves are small and show that the users are not willing to pay much more for higher capacity. One reason is the relatively high tariff levels.

Ranking of broadband applications is shown in Table 1. The demand curve and price elasticity was estimated based on results from the Delphi survey. The results are documented in [4–7].

3.2 OPTIMUM

A new Delphi survey was performed in OPTIMUM (Optimised Network Architectures for Multimedia Services) to predict the future evolution of the broadband market. The survey was an on-site two-round Delphi survey carried out on the Techno-economic Workshop arranged by OPTIMUM in 1997. In 1994 a set of applications were described. Now, the relevant applications were grouped in the following application classes:

1 Tele-entertainment (Symmetric and asymmetric)
- Multimedia telegames
- Virtual reality
- Video on demand
- Audio/music on demand

2 Information services (Asymmetric)
- Information retrieval
- Electronic magazines
- Information retrieval by intelligent agents
- Electronic newspapers

3 Teleshopping (Asymmetric)
- Teleshopping
- Advertising

4 Private communications services (Symmetric)
- Videophone
- Teleconferencing

5 Teleworking (Symmetric and asymmetric)
- Videophone
- Joint editing/publishing
- Teleconferencing
- Teleparticipation
- Information retrieval
- Multimedia application

6 Telelearning (Symmetric and asymmetric)
- Video-on-demand
- Videophone
- Virtual reality

7 Telecommunity (Symmetric and asymmetric)
- Telesurveillance
- Videophone
- Telediagnostics

The questionnaire starts with a description of the applications. The capacity classes defined were 2–4 Mbit/s with 384 kbit/s and 25 Mbit/s with 384 kbit/s and 6 Mbit/s return, respectively. The main questions in the survey were:

- Usage as a function of charge;
- Penetration as a function of charge;
- Penetration as a function of time (forecast);
- Demand as a function of disposable household income.

The experts in the Delphi surveys were asked to select the three most interesting broadband applications. Table 1 shows the ranking of the application in the Delphi survey in 1994 and 1997. The table shows that the Delphi survey in 1994 and 1997 predict that home office/teleworking and tele-entertainment/video-on-demand will be important future broadband applications.

The broadband penetration forecasts from the Delphi surveys in 1994 and 1997 are described

Applications 1994	Answers 1994	Application classes 1997	Answers 1997
Video-on-demand	28 %	Teleworking	28 %
Home office	27 %	Information services	25 %
Videotelephony	18 %	Tele-entertainment	24 %
Remote education	8 %	Teleshopping	7 %
Multimedia telegames	7 %	Private communications services	6 %
Home ordering system	4 %	Telecommunity	4 %
Interactive TV/specialised channels	4 %	Telelearning	3 %
Electronic newspapers	3 %	Others (Telebanking)	1 %
Advertising and marketing	1 %		
Telecommunity	0 %		

Table 1 Evaluation of applications. Percentage score

Figure 3 Broadband penetration forecasts for the residential market in Western Europe (1994 and 1997)

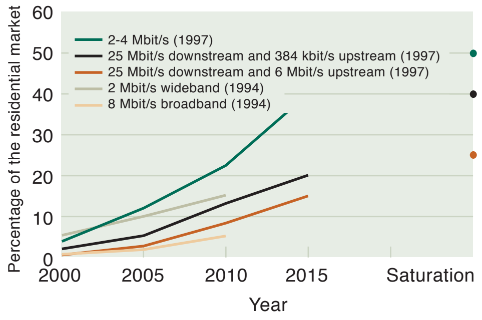


Figure 4 Demand curves as a function of annual cost in Euro (ECU) for broadband subscription (1997)

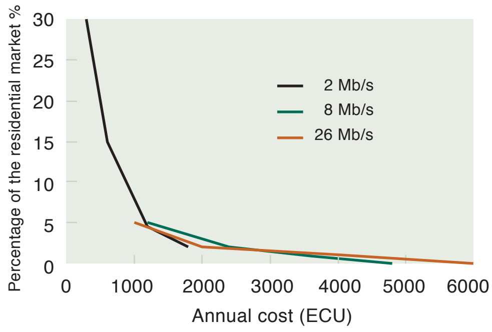


Figure 5 Willingness to pay for increased capacity relative to ISDN (128 kbit/s)

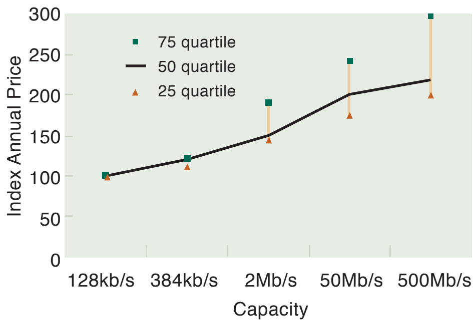


Figure 6 Demand forecasts for 2, 8 and 25 Mbit/s accesses in the residential market in Western Europe (1999)

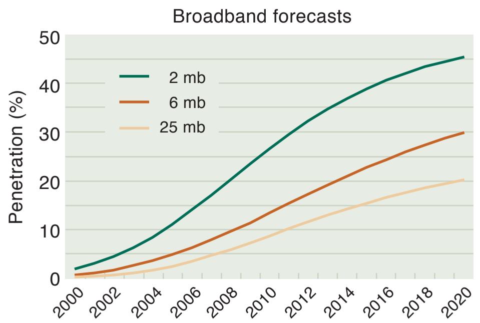
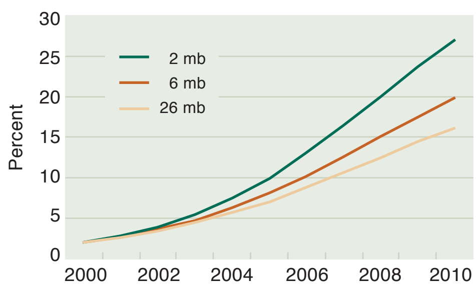


Figure 7 Market share evolution of symmetric broadband accesses in the residential market



in Figure 3. The 2 Mbit/s penetration forecasts in the two surveys are rather close, while high access capacity predictions are lower in 1994 compared with 1997. The Delphi survey from 1994 predicted 13 % broadband penetration in year 2005, while the survey from 1997 predicted 20.5 % broadband penetration.

In OPTIMUM the demand classes were revised to 2, 8 and 25 Mbit/s downstream access capacities. The demand curves based on the Delphi results are shown in Figure 4. The figure shows limited broadband demand when the annual tariff exceeds 1000 Euro. The willingness to pay for access capacity was examined with reference to ISDN. The results are shown in Figure 5.

[8–10] describe results from the 1997 Delphi survey in more detail.

3.3 TERA

TERA (Techno-Economics Results from ACTS) utilised the demand data from the 1997 Delphi survey. Diffusion models were examined to describe the evolution of broadband penetration. A four parameter Logistic model was used to the modelling. The model is defined by:

$$Y_t = M / (1 + \exp(\alpha + \beta t))^{\gamma}$$

where the variables are defined as follows:

Y_t is demand forecast at time t
M is saturation level
t is time
α, β, γ are parameters

The model was used to forecast the demand for 2, 8 and 25 Mbit/s accesses. The results are shown in Figure 6.

Since there was no reason to adjust the Delphi forecasts, the Delphi observations were used as input to fit the parameters in the Logistic model. In addition a specific model was used to predict market share between asymmetric and symmetric accesses. The model was described by:

$$S_t = S / (1 + \exp(\alpha + \beta t))$$

Where the parameters are defined by:
S is saturation level
S_t is share of symmetric demand
t is time
α, β are parameters in the Logistic model (Model 2)

Figure 7 describes the market share evolution of symmetric accesses

Results are described in more detail in [10–17].

4 Forecasting Models Used for Broadband Forecasts in TONIC

A model has been developed to forecast the total broadband penetration in the European residential market. Forecasts are done from 2001 to 2010 based on diffusion models. Specific models are developed to predict the market share evolution between ADSL, VDSL, fixed wireless broadband and cable modem/HFC, and then penetration forecasts for the different access technologies.

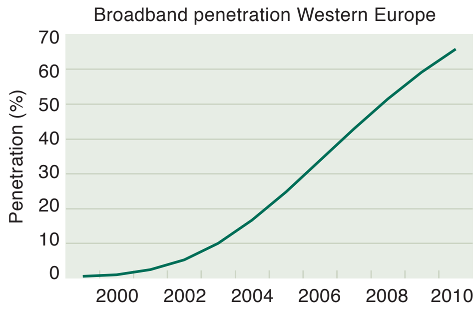


Figure 8 Long-term broadband penetration residential markets Western Europe

Especially the evolution of broadband in Germany, Sweden and Denmark speeds up the broadband demand in Europe. Germany reached 2 million DSL accesses already at the end of 2001. The wide use of (narrowband) Internet, the flat rate tariff and the broadband competition are important drivers for broadband. Introduction of wholesale and the possibility to hire copper lines (LLUB) increase the competition. Also different broadband technologies compete to catch significant market share. Monitoring on the demand data shows that the cable operators have been dominating the first years. However, the broadband penetration at this stage is not very high.

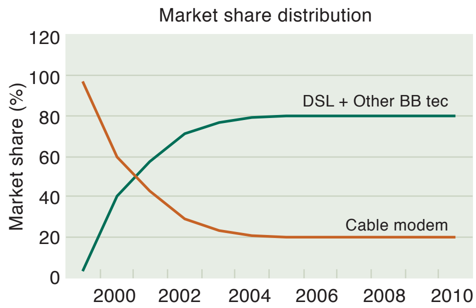


Figure 9 Predicted market share evolution between cable modems (HFC) and DSL + other broadband technologies

4.1 Data Sources and Modelling

Information has been gathered from a lot of different sources. The project partners have collected up-to-date data of the broadband evolution, demographic data and tariff data. Other important sources have been consultant reports from Jupiter [18], Strategy Analytics [19] and OVUM [20]. The Tonic project has developed new forecasts based on the collected information [21–23]. It has been difficult to use the forecasts from the consultant reports since the forecasts predict too high a market share for cable modem and the HFC technology, probably influenced by the situation in North America.

The first step has been to make penetration forecasts for the total broadband demand in the residential market. A four parameter logistic model has been used for the forecasts. The saturation level in the model has been estimated based on coverage for broadband in various countries in Europe. In non-dense rural areas, the expenses in rolling out broadband are too high, because too few households give payback to the necessary investments. The other parameters in the model are estimated based on historical data and also some expert evaluations.

Then predictions of the evolution of market share between different broadband technology have been developed based on a set of Logistic forecasting models. Migration between technologies are handled when VDSL and Fixed wireless broadband are catching market shares from ADSL and cable modem. The penetration forecasts for the broadband technologies are found by multiplying the predicted market share with the total broadband penetration.

4.2 Residential Broadband Penetration Forecasts for Western Europe

Figure 8 shows the long-term Western European residential broadband subscription forecasts. The demand is expressed in percentage of total number of households. The figure shows a penetration of nearly 25 % at the end of 2005.

4.3 Cable Modem (HFC) Market Share Evolution

Figure 9 shows that the market share for cable modems (HFC) starts on nearly 100 % in 1999 but loses about 40 % of the market during the first two years. The long-term forecasts show saturation for cable modem on a 20 % level. Even that level may be a little bit too high for Western Europe. These forecasts contradict the long-term forecasts from various consultant companies, which predict higher cable modem penetration.

4.4 Market Share Evolution for DSL

Figure 10 shows that the market share evolution of DSL reaches a turning point around 2005. Then the DSL market share is predicted to decrease because of other competing technologies.

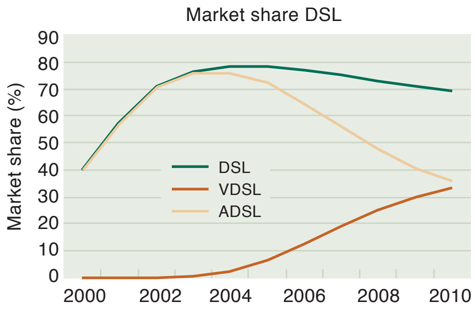


Figure 10 Market share evolution of DSL and the distribution between ADSL and VDSL

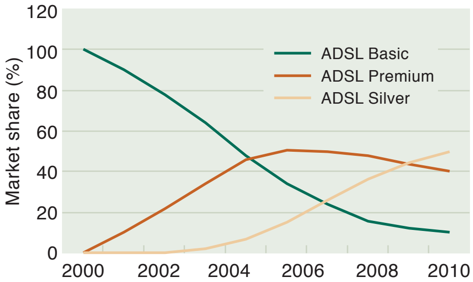


Figure 11 Predicted market share evolution for ADSL basic, premium and silver capacity.

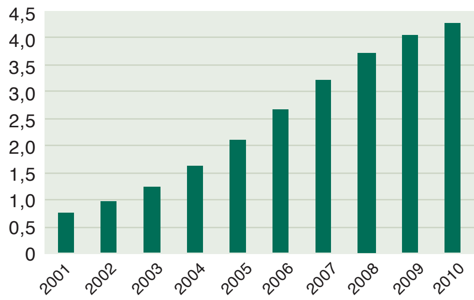


Figure 12 Evolution of predicted average downstream capacity in Mb for ADSL subscriptions

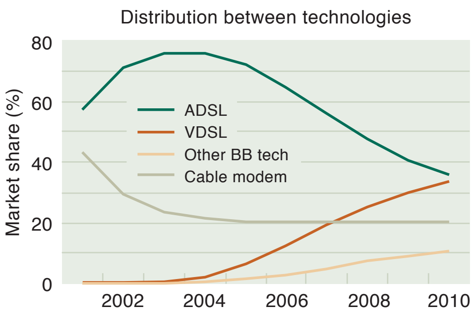


Figure 13 Market share distribution and prediction of ADSL, VDSL, cable modem and other broadband technologies

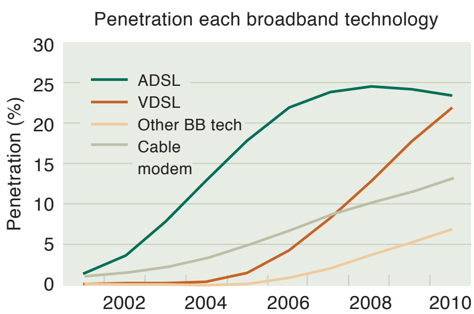


Figure 14 Broadband penetration forecasts for ADSL, VDSL, cable modem and other broadband technologies

Separate forecasts are developed for VDSL market share evolution. The figure shows that VDSL starts slowly in 2003, but increases rather significantly and reaches 30 % penetration in 2010. At the same time VDSL is at the same subscription volume as ADSL. Physical limitations especially the length of the subscriber line influences the market potential for VDSL.

4.5 Market Share Evolution for Different ADSL Access Capacities

The ADSL is divided into the following access capacities:

- Basic-Residential: 512/128kb
- Premium-Residential: 2048/256kb
- Silver-Residential: 6144/640kb

The expected market share evolution is shown in Figure 11. The figure shows that "Basic" is dominating the first years starting with nearly 100 % market share in year 2001. In 2005 "Premium" reaches the same level as "Basic". The demand for "Silver" is expected to start around 2003.

The mean downstream capacity for "Basic" is assumed to be 0.75 kb. For Premium and Silver the respective figures are 3 Mb and 6 Mb. Based on the assumed figures and the market share distribution, the evolution in average downstream capacity for ADSL is described in Figure 12. The figure shows that the average downstream capacity is 0.75 Mb in 2001. The capacity increases to about 2 Mb in 2005 and about 4 Mb in 2009 for ADSL subscriptions.

4.6 Distribution Between Technology

To be able to predict penetrations for each technology, the overall market share for each technology is needed. Figure 13 shows the market share evolution between different technologies.

The resulting penetration forecasts for each technology are given in Figure 14.

4.7 Broadband Forecasts for Country Groups

The TONIC project has also developed segmented country forecasts for Europe. Requirements for the country grouping have been to have reasonable homogeneous country groups and in addition mainly countries represented in the TONIC project. The following country groups were selected both for the fixed and the mobile network services:

- Nordic countries (Finland, Norway)
- Large central European countries (France, Germany, UK)
- Southern European Countries (Greece, Portugal)

4.7.1 Nordic Countries (Finland, Norway)

The Nordic country group is represented by Finland and Norway, since the countries are partners in the TONIC project. *It is important to underline that Sweden and Denmark, which have a rather high broadband penetration, are not included in the presented results*. The broadband evolution in Finland and Norway is rather similar. The number of households in the two countries is 2.45 mill and 2.01 mill, respectively, while GDP per capita is about 27,000 Euro and 38,000 Euro. At the end of 2001 the broadband penetration in Finland was 3.7 % consisting of 2.9 % DSL and 0.9 % Cable modem. At the end of 2001 the broadband penetration in Norway was 3.5 % consisting of 2.0 % DSL and 1.5 % Cable modem.

Figure 15 shows the broadband penetration forecasts for the Nordic country group. It assumed that saturation is lower in the Nordic countries compared with central European countries because the proportion of low density areas is larger in the Nordic countries.

The predicted market share evolution between broadband technologies is shown in Figure 16.

4.7.2 Large Central European Countries (France, Germany, UK)

France, Germany and UK represent the large central European country group. The number of households in the three countries is 27 mill, 38 mill and 26 mill, respectively, while GDP per capita is about 27,000 Euro, 28,000 Euro and 24,000 Euro. At the end of 2001 the broadband penetration in France was 2.6 %, consisting of 2.0 % DSL and 0.6 % Cable modem. At the end of 2001 the broadband penetration in Germany was 6.1 % consisting of 5.8 % DSL and 0.3 % cable modem.

Figure 17 shows the broadband penetration forecasts for the large central European country group. It assumes that the forecasts are close to the European mean forecasts.

The predicted market share evolution between broadband technologies is shown in Figure 18.

4.7.3 Southern European Countries (Greece, Portugal)

The Southern European country group is represented by Greece and Portugal, since the countries are partners in the TONIC project. The broadband evolution in Greece and Portugal is rather low so far. The number of households in the two countries is 3.7 mill and 5.1 mill, respectively, while GDP per capita is about 13,000 Euro and 12,000 Euro. At the end of 2001 the broadband penetration in Greece was 0.4 % consisting of 0.1 % DSL and 0.3 % cable modem.

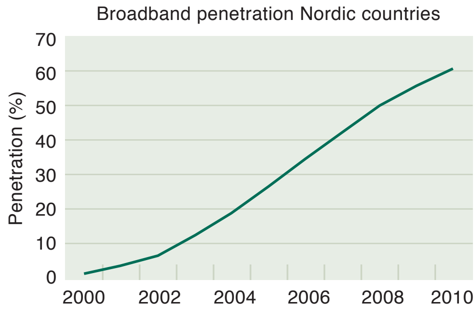


Figure 15 Broadband penetration forecasts

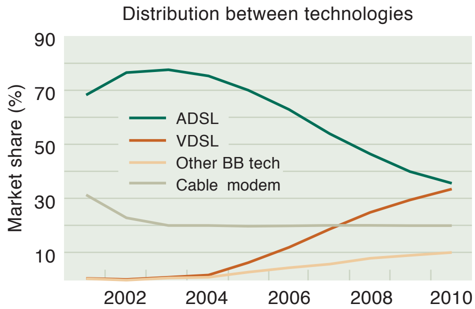


Figure 16 Market share evolution of broadband technology

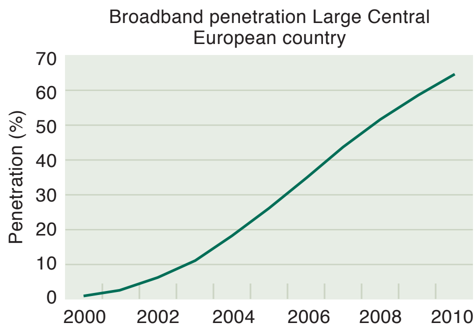


Figure 17 Broadband penetration forecasts

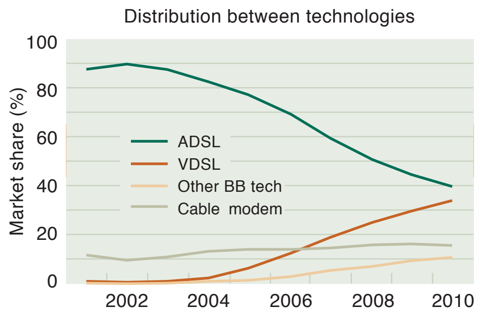


Figure 18 Market share evolution of broadband technology

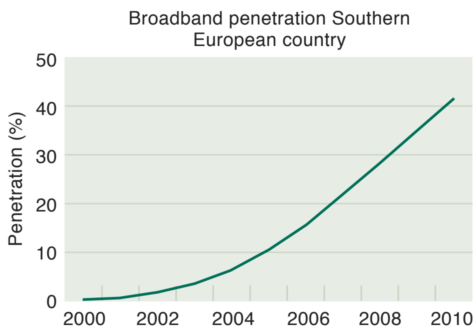


Figure 19 Broadband penetration forecasts

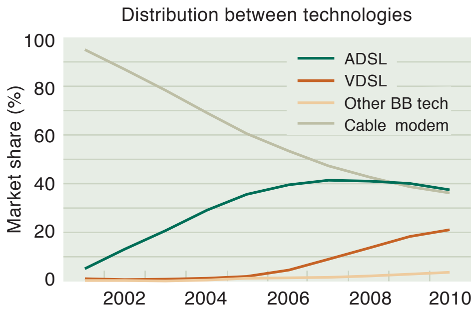


Figure 20 Market share evolution of broadband technology

At the end of 2001 the broadband penetration in Portugal was 1.4 %, consisting of 0.02 % DSL and 1.4 % cable modem. Figure 19 shows the broadband penetration forecasts for the Southern European country group. The figure shows that the evolution is more defensive compared with Central European and Nordic countries.

The predicted market share evolution between broadband technologies is shown in Figure 20.

5 Forecasting Models Used for Mobile Forecasts in TONIC

Demand forecasts for different mobile technologies for Western European countries are presented. The forecasts are established for three different groups of Western European countries. The countries in each group are similar with respect to GDP per capita, GSM penetration today, and forecasted UMTS penetration in 2007. Specific forecasts are developed for each country group.

In particular, after formulating projections on total mobile subscriber penetration, we make forecasts for the different penetration rates for the following mobile system "generations":

- 2G – digital mobile systems such as GSM
- 2.5 G – HSCSD, GPRS, EDGE
- 3G – UMTS
- 3.5G – ubiquitous roaming among 3G and WLAN[4)] systems

It is assumed that a "higher" mobile subscription has interworking access to "lower" mobile subscriptions. 3G have for example possibilities to interwork with 2G and 2.5G. The system generation 3.5G is in fact an UMTS subscription which also has WLAN possibilities. The TONIC Project has developed a set of forecasting models based on extracted external information and on members' expertise for the establishment of basic assumptions. The results of this work are inputs to the forecasting models.

Table 2 Subscriptions and subscribers assumption for mobile penetration in Western Europe

Penetration/year	2005	2010	Saturation
Subscribers	81	90	95
Subscriptions	100	120	130

The demand models and tariff predictions serve as important input to business cases I and II.

5.1 Data Sources and Modelling

Information has been collected from different consultancy reports. The three most important reports are from Strategy Analytics [24], Analysys [25] and OVUM [26]. In addition the TONIC project partners have collected up-to-date information about mobile penetration, demographic data and ARPU levels.

As for the fixed network, a four parameter logistic model has been applied to the forecasts. The saturation level in the model has been estimated based on the number of mobile subscribers and subscriptions. The other parameters in the model are estimated based on historical data and also some expert evaluations.

5.2 Western European Mobile Market Forecast

The statistics show that the 2G subscribers have increased from about 15 % to 70 % during the period 1997 – 2001. One important driver the last years is the prepaid subscriptions, which constitute a significant part. Based on evaluation from the TONIC project and external consultant reports, assumptions of average mobile penetration for Western Europe are assumed, see Table 2.

A four parameter Logistic model is used to generate penetration rates from 1997 to 2010, as shown in Figure 21.

The total subscriber penetration in Western Europe is split into four mobile system generations, namely 2G, 2.5G, 3G and 3.5G. Assumptions about the relative market share for each of the systems were discussed and adopted. We assume that the share of 2G is decreasing to 2 % in 2010, while the respective shares at that time will be 28 % for 2.5G, 37 % for 3G and 33 % for 3.5G. Our assumptions for 3G taking off in 2003 are based on the fact that the initial horizon of early 2002 today appears ambitious, and most operators admit to at least a 6–12 months' delay.

4) Based on the technical architecture developed within the IST-MIND project (WLAN is Hiperlan2).

Based on the assumptions for the evolution of the total subscriber penetration combined with the assumptions regarding each of the mobile systems, we have calculated the penetration forecast for the four different mobile generations. These penetrations are shown in Figure 23.

We can see that the predicted subscriber penetration levels for 2G and 2.5G systems are equal in year 2004/2005. 3G subscriber penetration is 3 % in 2003, increasing to about 33 % in 2010. 3.5G subscriber penetration will reach almost 30 % in 2010.

Figure 24 shows subscription penetration for different mobile systems based on assumptions in Table 1 and the evolution of market shares given in Table 2. It is assumed that mobile subscribers will have more than one mobile subscription.

We see that total mobile subscription penetration will reach 120 % in 2010. 2.5G subscriptions will reach almost 40 % in 2010. 3G subscription penetration is almost 4 % in 2003, increasing to 40 % in 2010. 3.5G subscriptions will increase from 1 % in 2005 to nearly 40 % in 2010.

5.3 European Public WLAN Access in Hot-Spot Areas

The number of hot-spot locations that will be WLAN-enabled is one of the critical uncertainties for the 3.5G subscriber forecasts. Analysys have based their forecasts on the assumption that property owners will react positively to the service propositions currently being in place by operators and that roaming arrangements between public WLAN operators will emerge from 2002 onwards. Analysys have estimated the roll-out in hot spots by considering the number of potential locations by type illustrated in Figure 25.

If these assumptions are correct, the number of hot spots with WLAN access will reach over 90,000 locations across Europe by 2006. Figure 25 shows that the overall value of the market is likely to be highly sensitive to the ability of service providers to persuade the owners of cafés, restaurants and hotels to host public WLAN services.

5.4 Mobile Forecast for Each Country Group

5.4.1 Nordic Countries

The Nordic country group is represented by Finland and Norway.

The mobile evolution in Finland and Norway is rather similar. For a long time Finland has been the country with the highest mobile penetration. In the same period Norway has been among the top three. Because of heavy sale of prepaid

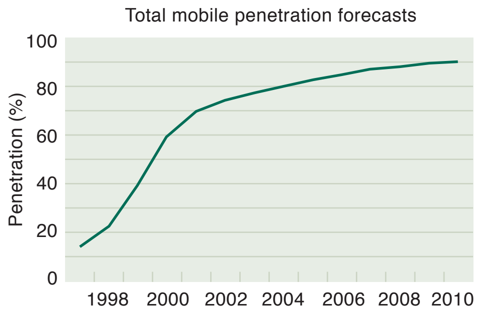


Figure 21 Mobile subscriber penetration forecasts for Western Europe

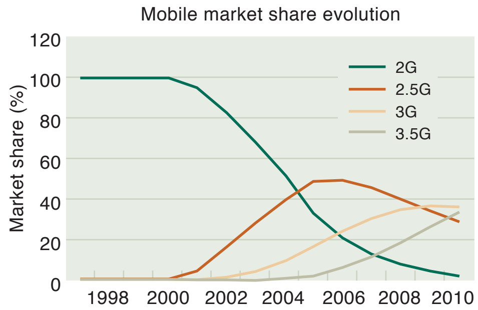


Figure 22 Shares of different mobile systems for Western Europe

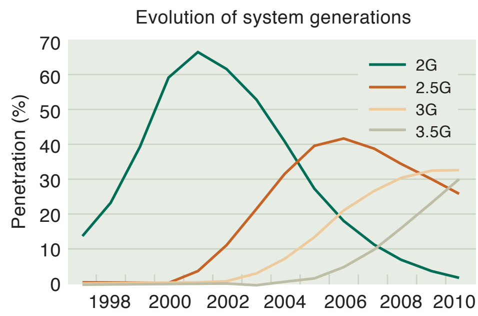


Figure 23 Subscriber penetration forecasts for different mobile systems for Western Europe

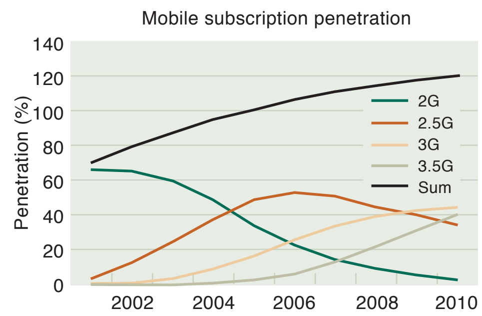


Figure 24 Subscription penetration forecasts for different mobile systems for Western Europe

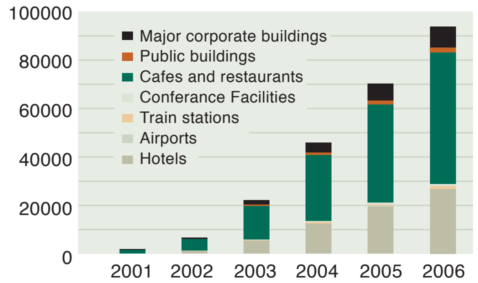


Figure 25 Public WLAN access locations, by type of location (source: Analysys)

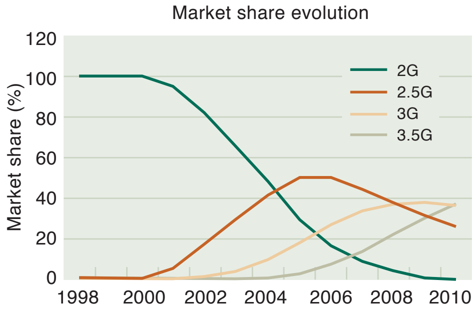


Figure 26 Market share evolution of mobile system generations

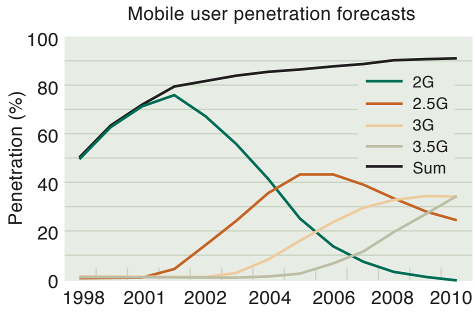


Figure 27 Mobile penetration forecasts for the Nordic country group

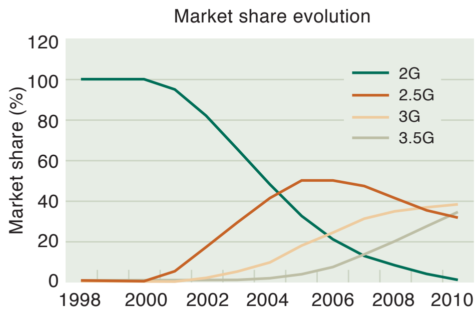


Figure 28 Market share evolution of mobile system generations

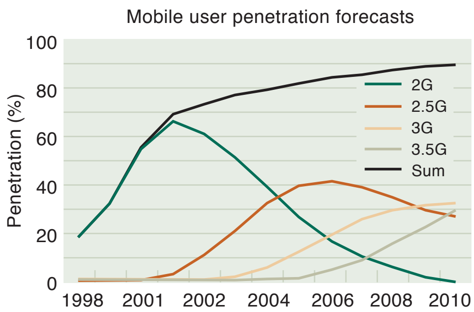


Figure 29 Mobile penetration forecasts

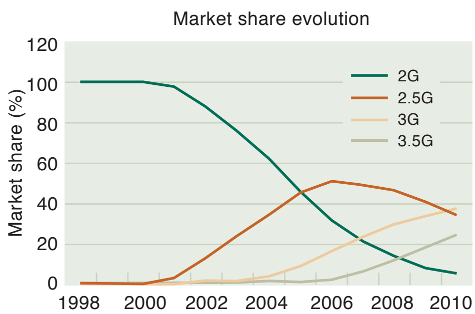


Figure 30 Market share evolution of mobile systems generations

mobile card the mobile penetration starts to be more even in several European countries.

The number of inhabitants in the two countries is 5.16 mill and 4.45 mill, respectively, while GDP per capita is about 27,000 Euro and 38,000 Euro. At the end of 2001 the mobile penetration was 80 % in both Finland and Norway.

Figure 26 shows the market share evolution of mobile system generations for Nordic countries.

Figure 27 shows that the 2G penetrations in 2010 is 0 %, while 2.5G are 25 % and 3.5G is 37 %. The market share is multiplied by the total mobile penetration forecasts for the Nordic countries.

5.4.2 Large Central European Country (France, Germany and UK)

France, Germany and UK represent the large Central European country group. The number of inhabitants in the three countries is 59 mill., 82 mill., and 59 mill., respectively, while GDP per capita is about 27,000 Euro, 28,000 Euro and 24,000 Euro. At the end of 2001 the mobile penetration was 58 % in France, 67 % in Germany and about 75 % in the UK. It is assumed that the mobile evolution for the large Central European countries is close to the evolution for Western Europe.

Figure 28 shows the market share evolution of mobile system generations for large Central European countries. The figure shows that the 2G penetrations in 2010 is 0 %, while 2.5G is 30 % and 3.5G is 33 %. The market share is multiplied by the total mobile penetration forecasts for the Nordic countries. The results are shown in Figure 29.

5.4.3 Southern European Country (Portugal and Greece)

The Southern European country group is represented by Greece and Portugal. The mobile evolution in Greece and Portugal has increased very significantly during recent years. At the end of 2001 the mobile penetration was 70 % in Greece and 79 % in Portugal. The number of inhabitants in the two countries is 10.9 mill and 10.4 mill, respectively, while GDP per capita is about 27,000 Euro and 38,000 Euro.

Figure 30 shows the market share evolution of mobile system generations for the Southern European country group.

Figure 31 shows that the 2G penetrations in 2010 is 5 %, while 2.5G is 33 % and 3.5G is 25 %. The market share is multiplied by the total mobile penetration forecasts for the Southern European country group. The results are shown in Figure 31.

6 Conclusions

An overview of broadband forecasting models used during the last eight years in a portfolio of techno-economic projects supported by the European Commission has been presented. The forecasts have mainly been based on expert surveys, especially Delphi surveys, before the broadband services were offered. Also diffusion models are used based on results from Delphi surveys and historical demand data. Table 3 gives a comparison of broadband penetration forecasts for Western Europe in 2005. The table shows that the forecasts are mainly on the same level. One exception is the forecasts done in 1994. However, at that time much higher annual tariffs on broadband were expected compared to what we see today. The main conclusion is that the long term forecasting models used seem to give rather good results. If the flat rate tariff regime is changed during the next years because of heavy traffic in the core network, it may be possible that a level of 20 % penetration will be more probable for year 2005.

The paper presents a methodology to forecast broadband penetration based on migration between the competing broadband technologies ADSL, VDSL, HFC (cable modem) and fixed wireless broadband.

The TONIC forecasts show that DSL access technology within a short time will be the dominating technology in Europe. The situation in Europe is different from North America where forecasts show that cable modem technology based on HFC during the next years will still have more than 50 % of the market. Fixed wireless broadband access based on technologies like LMDS are for the moment rather expensive.

Demand forecasts for different mobile technologies for Western European countries are presented. The forecasts are established for three different groups of Western European countries. The following mobile system "generations" have been considered:

- 2G – digital mobile systems such as GSM
- 2.5 G – HSCSD, GPRS, EDGE
- 3G – UMTS
- 3.5G – ubiquitous roaming among 3G and WLAN[5)] systems

The predicted Western European subscriber penetration levels for 2G and 2.5G systems are equal in year 2004/2005. 3G-subscriber penetration is 3 % in 2003, increasing to about 33 % in 2010. WLAN subscriber penetration is predicted to reach almost 30 % in 2010.

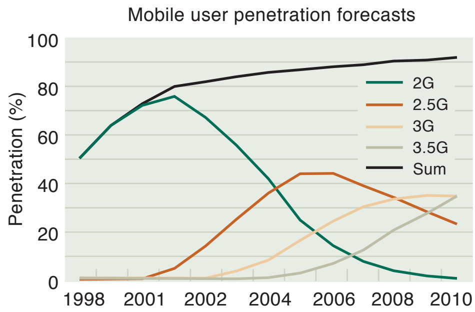


Figure 31 Mobile penetration forecasts for the Southern European country group

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Table 3 Broadband penetration forecasts, Western Europe 2005

	Penetration
TITAN forecasts (Delphi survey, 1994)	11.3 %
OPTIMUM forecasts (Delphi survey, 1997)	20.5 %
TERA forecasts (Diffusion models, 2000)	20.5 %
TONIC forecasts (Diffusion models, 2002)	24.9 %

5) *Based on the technical architecture developed within the IST-MIND project (WLAN is Hiperlan2).*

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Residential Demand for 'Multipurpose Broadband Access': Evidence from a Norwegian VDSL Trial

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1 Introduction

There is no industry-wide accepted definition of the term 'broadband access'. In Norway it is used to describe all access links to networks with capacities in excess of ISDN (128 kbit/s). In this study we will use the term 'multipurpose broadband access' to describe access technologies that facilitate 'very fast' interactive transmission of data *and video*. We will include broadcast in this concept: Hence, a multipurpose broadband access link as hitherto defined will supply the customer with at least one interactive digital TV stream (or VoD), as well as a high-speed Internet connection. Today this bundle of services (high speed Internet and Interactive TV/video) can be offered to residential households by several access network technologies and combinations of technologies, including fibre, coaxial cables with cable modems, xDSL modems on the twisted pair, satellite networks for broadcasting in combination with some link for two-way data transmission etc., see e.g. Ims 1999 for a thorough survey of current broadband access networks.

In Norway, only the cable television companies have a commercial offer of multipurpose broadband access (and services) on a single technology, i.e. cable modems (HFC). Currently the digital set-up boxes allow for one TV stream at the time, as well as a high-speed Internet connection. In a few years set-up boxes equipped with several tuners will permit the households to receive multiple TV streams. Upgrading the Internet speed from the current bandwidths, however, will prove to be costly due to the shared medium property of the network technology.

A handful of Norwegian households today are able to receive multiple digital TV streams through the satellite networks. The usual customer premises (parabol and set-up box) however, only allow for one TV stream at a time. As mentioned above, satellite connection must be combined with some up-link network to constitute a multipurpose broadband access as previously defined.

The telecommunication companies are migrating their existing infrastructure towards a multipurpose broadband access network through deployment of fibre nodes enabling a range of DSL roll-outs. At the moment only ADSL is offered to the residential sector. In principle ADSL permits transmission of one digital TV-stream and a high-speed Internet connection, at least for distances up to 1 km. For the time being, however, no broadcast services are offered on ADSL. To supply multiple simultaneous TV streams on the twisted pair along with a high-speed Internet connection, the telecommunication companies need to upgrade to VDSL (Very high-speed digital subscriber line). The asymmetric VDSL provides capacities up to 26 Mbit/s downstream and 2 Mbit/s upstream. This permits up to three digital TV streams to be transmitted simultaneously along with a very fast Internet connection. As for all DSL alternatives there is a trade-off between distances and capacity, the capacities mentioned above are for distances within 1 km.

This study reports the main results from a willingness to pay experiment designed to estimate the demand for multipurpose broadband access in the Norwegian residential market. It is built on the results in Andersson and Myrvold, 2001. The experiment was conducted in the Stavanger/Sandnes VDSL pilot as part of Telenor's Hybrid Broadband Access project, HB@, see Telenor HB@ Project Deliverable D3 and D10. The experiment data permits estimation of residential demand for high-speed Internet along with the demand for 'capacity to receive TV streams', or simply demand for TV streams[1]. Hence, the results give a first indication of the market size for network technologies enabling multipurpose broadband access, and some of the factors that are likely to affect the future willingness to pay. Since the experiment enables us to study the effect of households' purchase behaviour in both the 'Internet-centric' and 'TV-centric' markets simultaneously, the effect of products that enforce the tendency of *convergence* between traditional telecom and broadcast like a 'TV-portal' is also analysed.

2 The Derived Demand for Broadband Access

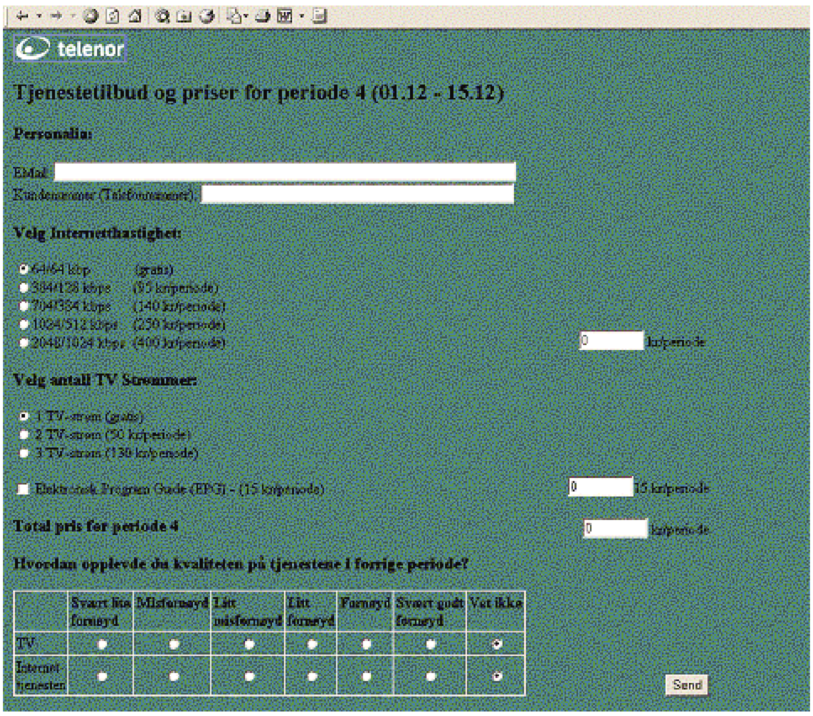
Demand for broadband access is derived from the demand for the content and applications that can be transmitted on the access link, as well as the demand for communication and file sharing

1) *This must not be confused with the demand for a particular TV* Channel.

with other broadband customers[2)]. In the economics terminology, the latter services are complementary to access. Some customers are willing to upgrade to a broadband access simply because this increases the quality of the complementary services they are already consuming, for instance because the broadband access link reduces waiting time on the WWW. However, a major share of the future multipurpose broadband access customers will probably purchase the product because it gives access to services they cannot consume with their current access link.

We have chosen to split the demand for multipurpose broadband access into what we for short label 'demand for Internet access' and 'demand for TV streams'. By the latter we mean demand for capacity to receive multiple digital TV streams. This partitioning reflects the current technology: For most available multipurpose broadband access technologies, the bandwidth allocated to broadcast and Internet is pre-specified, i.e. the customer cannot swap bandwidth allocated to broadcast for Internet-bandwidth or vice versa. In particular this holds for the VDSL configuration used in the VDSL trial that forms the basis for the current study. In the future this may change, and it may make sense to simply model the demand for broadband bandwidth.

Figure 1 Example of the menu offered to the consumers



If both content/applications and access capacity are priced, we can define separate demand functions for content/applications and access. For instance, we can model the demand for capacity to receive simultaneous TV streams and the demand for a particular TV channel or packages of TV channels. Likewise, we can model the demand for Internet connection speed and the demand for payable content and applications that can be downloaded. Due to the complementarities discussed above, these functions would probably be interdependent. In particular we would expect that the lower the price of available content and applications, the higher the demand for broadband access. Content and applications available for free will be reflected in the demand for access; that is, the more attractive, free content is available, the higher will be the demand for broadband access.

Thus any empirical estimates on the willingness to pay and take rates for broadband access, including the present, are conditioned on the quality and range of priced and un-priced complementary services available at the time of measurement. Hence in the interpretation of the results on the demand for TV streams reported from the willingness to pay experiment presented below, it is important to keep in mind that the trial users received 33 digital TV channels for free. To determine the overall willingness to pay in the broadband market we would need to model the demand for both access and payable content and applications.

3 The Willingness to Pay Experiment

Telenor's Hybrid Broadband Access project (HB@) took place during 2000 and 2001 and tested how different access technologies may be combined in order to provide comparable offerings of next generation interactive broadband services in cities, townships and rural areas. In the HB@ project, 'broadband services' are defined as services that enable the customer to simultaneously receive at least two interactive digital TV channels as well as a high-speed Internet connection. In four separate pilots located in Stavanger, Beito, Oslo and Svolvær, the project tested different network infrastructure options for interactive broadband services, with an emphasis on access network solutions. In the Stavanger pilot, the concept of fibre nodes in combination with VDSL was tested. This pilot trial has been in operation in the city of Stavanger, Norway, since November 2000, and now has 750 trial users connected, with an access capacity of 26 Mbit/s. See Ims 2001.

2) *The latter implies that number of other broadband access customers may positively affect the individual demand for broadband access. See Bjørn Hansen in this issue of* Telektronikk *for a discussion of such network externalities.*

The willingness-to-pay experiment took place in the period 15.10.01 – 15.12.01 among 680 trial users in the Stavanger/Sandnes region. Prior to the experiment period, the trial users had freely received a 704 kbit/s Internet access and up to three simultaneous TV streams comprising 33 TV channels. They were informed that from 15.10.01 they would have to pay for the services.

In the experiment period the users were offered a menu of choices of Internet connection speed and capacity to receive simultaneous TV- or video streams. The choices were 1, 2 or 3 simultaneous TV streams labelled TV1, TV2, and TV3, respectively. The Internet choices were (kbit/s down/up): 64/64, 384/128, 704/384, 1024/512 and 2048/1024. In the following these will be labelled IN64, IN384, IN704, IN1024, IN2048. In addition they could choose whether they wanted to buy an electronic program guide, EPG, or not. The prices of the various alternatives changed twice a month. During the experiment period each user chose Internet access and number of TV streams four times. The users received the price menus, and returned their choices, by mail.

Note that one TV stream, TV1, along with 33 TV channels and the 64/64 kbit/s Internet connection, IN64 *were always offered for free*. The results must therefore to some extent be interpreted as willingness to pay for *extra* Internet bandwidth, and *additional* TV streams.

	IN384	IN704	IN1024	IN2048	TV2	TV3
Period 1						
Gr 1	40	150	210	295	60	105
Gr 2	55	125	210	305	90	150
Gr 3	60	150	225	395	60	130
Gr 4	55	130	215	280	50	115
Period 2						
Gr 1	65	140	230	360	75	120
Gr 2	80	120	245	390	85	125
Gr 3	45	105	220	330	75	145
Gr 4	55	115	200	350	80	120
Period 3						
Gr 1	70	140	250	285	90	140
Gr 2	55	145	210	290	55	110
Gr 3	65	135	250	270	80	135
Gr 4	50	145	195	340	55	105
Period 4						
Gr 1	95	140	250	400	50	130
Gr 2	55	135	220	285	60	130
Gr 3	90	155	240	315	75	155
Gr 4	70	165	185	400	85	120

Table 1 The prices

The sample was divided into four groups. Each group received a different set of prices each period. The prices were randomly drawn from a pre-specified interval and rounded. In the specification of the intervals, i.e the level of the pricing, we have taken account of the existence of the free alternatives – the test group hence faces more affordable prices than what would prevail in competitive markets. The experiment was conducted over four subsequent 14-day sessions, starting on October 15, 2001. Table 1 presents the price menus offered to the different groups during the experiment period. Recall that the prices must be multiplied by 2 to get monthly prices.

The sample comprises 678 households located in the Stavanger/Sandnes area. Households are mainly single dwellings and the area may be characterised as 'a middle- to high-end residential market'.

Table 2 lists the percentage of the sample that chose the various access alternatives (and EPG) each period. The most striking observation is that as much as 27 % of the pilot users chose to pay for 2 or 3 simultaneous TV streams. ARPU for TV streams, that is users that purchased at least one additional TV stream, was 156 NOK. This take-rate and ARPU are surprisingly high and quite promising for the business case of VDSL. Further inspection of the data (not shown) reveals that approximately 6 % of the households with only one TV chose multiple streams. This may indicate that many households use the second or third stream for video purposes (or it may be that the number of TV sets in the household is underreported). Approximately 43 % chose to buy an Internet access at 384 kbit/s or higher, with as much as 12 % choosing one of the two highest bandwidth alternatives. ARPU for Internet access was 288 NOK.

Table 3 shows the joint distribution of the choices along with monthly ARPU (in brackets) for the different segments[3)]. 50 % of the sample never chose to pay for Internet bandwidth, nor extra TV streams. 19 % chose to pay for extra Internet bandwidth (IN384 or higher) as well as additional TV streams (TV2 or TV3). This constitutes the natural VDSL segment, i.e. the households that are willing to pay for both high-speed Internet access and multiple TV streams. In interpretating the figures it is important to bear in mind that the prices were deliberately set low because of existence of the free alternatives,

	Period				
	1.00	2.00	3.00	4.00	Total
IN384	15 %	15 %	17 %	18 %	17 %
IN704	12 %	15 %	13 %	13 %	14 %
IN1024	4 %	6 %	4 %	8 %	6 %
IN2048	7 %	5 %	8 %	4 %	6 %
TV2	22 %	23 %	23 %	23 %	23 %
TV3	3 %	4 %	4 %	4 %	4 %
EPG	30 %	32 %	33 %	34 %	32 %

Table 2 Distribution of choices by period

they are not optimised to maximize revenues, and finally, the existence of the large free channel package.

4 The Determinants of Demand for Multipurpose Broadband Access

We model the probability of purchase of each Internet access alternative and each TV stream alternative as a function of the following vector of variables: **X** = AGE012, AGE1319, HHINCO, UNIV, INMTH, TVNUM, PARABOL, NETGEM, **lnPRICES**. The definition of the variables will be explained below. Each of the following probability functions were estimated separately:

$$\text{Prob}(IN384 = 1) = \phi(\beta 1'\mathbf{X}) \quad 1)$$
$$\text{Prob}(IN704 = 1) = \phi(\beta 2'\mathbf{X}) \quad 2)$$
$$\text{Prob}(IN1024 = 1) = \phi(\beta 3'\mathbf{X}) \quad 3)$$
$$\text{Prob}(IN2048 = 1) = \phi(\beta 4'\mathbf{X}) \quad 4)$$
$$\text{Prob}(TV2 = 1) = \phi(\beta 5'\mathbf{X}) \quad 5)$$
$$\text{Prob}(TV3 = 1) = \phi(\beta 6'\mathbf{X}) \quad 6)$$

IN384 = 1 indicates that the household bought the 384 kbit/s Internet access alternative etc., $\phi(.)$ is the cumulative standard normal distribution and β is the coefficient vector to be estimated.

Tables 4 and 5 depict the estimates of the demand equations for Internet bandwidth, 1)–4), and TV streams 5) and 6).

Table 3 Take rates (ARPU)

	Int. free		IN384 or higher	
TV free	50 %	(0.-)	23 %	(288.-)
TV2 or higher	7 %	(157.-)	19 %	(444.-)

The first group of variables comprises the number of household members, HHM; a dummy variable, AGE012, that is 1 if the household comprises children 0 to 12 years old; a dummy variable, AGE1319, 1 if the household comprises teenagers; an indicator of the household's pre-tax income, HHINCO; and finally a dummy, UNIV, 1 if one or more members have attended university for more than 3 years. The second group of variables comprises the number of months the household has been connected to the Internet prior to the experiment period, INMTH; the number of TV sets in the household, TVNUM; a dummy variable, PARABOL, 1 if the household has a parabol; and finally a dummy, NETGEMB, equal to 1 if the household has a NetGem set-up box, a device that facilitates web and e-mail on the TV screen. lnP384 is the natural log of the price of IN384, lnPTV2 is the natural log of the price of.

The variables describing the size and type of the household, HHM, AGE019 and AGE1319, exhibit a non-consistent pattern throughout the equations. For instance, the presence of children in the household seems to have a negative effect on the demand for 384 kbit/s and a positive effect on the demand for 1024 kbit/s. We do not have a good explanation for this, neither of the effect on the pattern of HHM. The presence of teenagers in the household, AGE1319, has a strong and highly significant effect on the household's probability to purchase both 2 and 3 TV streams, probably reflecting that many teenagers have their own TV sets. Finally, quite surprisingly, we see that one or more of the household members holding a university degree, UNIV, has a negative effect on the demand for all bandwidths; significantly so, however, only in the 1024 equation. There is no systematic relation between the amount of money spent on telecom and the household's total income, HHINCO. This finding supports results from other studies of the Norwegian telecom market (including mobile telephony). The lack of relationship between demand and income suggests that the results may be generalized to other market segments.

Turning to the ICT-variables we see that the longer the household has been connected to the Internet prior to the experiment period, INMTH, the higher the demand for all bandwidths. This may reflect that this variable picks up an unobservable preference parameter, or that 'usage creates its own demand'. We also see that INMTH has a strong positive effect on the

[3] *It is a coincidence that the ARPUs in the upper right and low left in Table 3 correspond with the ARPUs for all Internet buyers and all TV streams buyers. What this shows is that those who bought Internet access and additional TV streams on average spend as much on Internet access as those who bought Internet access only, and as much on TV streams as those who bought TV streams only.*

Variable	IN384 Parameter	IN384 t-ratio	IN704 Parameter	IN704 t-ratio	IN1024 Parameter	IN1024 t-ratio	IN2048 Parameter	IN2048 t-ratio
Constant	-1,47	-0,35	0,82	0,18	4,66	0,82	-0,96	-0,17
HHM	0,07	1,92	-0,13	-3,04	-0,03	-0,51	0,08	1,84
AGE012	-0,22	-2,59	0,23	2,35	0,15	1,22	-0,27	-2,42
AGE1319	-0,03	-0,37	0,17	1,88	0,16	1,37	-0,10	-0,93
HHINCO	0,00	-0,55	0,00	1,07	0,00	-2,06	0,00	0,44
UNIV	-0,19	-2,61	-0,13	-1,65	-0,04	-0,39	-0,12	-1,20
INMTH	0,00	3,08	0,01	4,38	0,00	2,73	0,01	5,40
TVNUM	0,13	1,56	-0,05	-0,59	0,14	1,24	-0,07	-0,60
PARABOL	-0,21	-3,18	0,10	1,41	0,09	0,97	0,25	2,59
NETGEMB	0,25	3,43	0,29	3,67	0,16	1,51	0,09	0,86
LnP384	-0,18	-0,75	-0,10	-0,39	0,14	0,43	-0,27	-0,81
LnP704	0,14	0,41	-1,03	-2,92	-0,20	-0,45	-0,27	-0,61
LnP1024	-0,12	-0,23	0,69	1,16	-2,08	-2,96	0,83	1,08
LnP2048	0,16	0,51	-0,06	-0,18	0,87	1,94	-0,55	-1,33
Log-L	-982,97		-836,65		-453,30		-481,08	
Log-L(0)	-1007,80		-868,39		-478,93		-509,25	

Note: Probit estimates

Table 4 Demand for Internet bandwidth

demand for two TV streams, but a negative effect on the demand for three TV streams. We do not have a good explanation for the latter result.

As expected, the number of TV sets in the household TVNUM, has a very strong positive effect on the demand for two TV streams, and also for three TV streams. Calculations show that having more than one TV set in the household increases the predicted probability of purchasing two TV streams by 3.5 percentage points, all other variables set at mean. For comparison it can be mentioned that 5.78 of those with only one TV set purchase more than one stream, as compared to 35 % of those with more than one TV set. For the three-stream the relative importance is huge; the predicted probability increases from 0.006 to 0.035 when moving from one to two or more TV sets.

More surprisingly, PARABOL has a positive effect on the demand for three TV streams. It also has a positive effect on the demand for 2048 kbit/s. Apparently, PARABOL is an indicator of households that want the "full-package" of technology products. Some caution is needed in this interpretation because PARABOL may be measured with error due to missing data.

The NETGEM box has a positive, significant effect on the demand for 384 kbit/s, 704 kbit/s, two and three TV streams. Some caution is needed in interpreting this as a causal effect however, because NETGEM may be endogenously determined with the dependent variables[4)]. We will return to the effect of NETGEM in the next section.

Table 5 Demand for additional TV streams

Variable	2 TV Parameter	2 TV t-ratio	TVSTR3 Parameter	TVSTR3 t-ratio
Constant	-3,313	-2,47	-4,152	-1,86
HHM	0,016	0,45	0,123	2,37
AGE012	0,128	1,57	-0,055	-0,46
AGE1319	0,416	5,49	0,367	3,02
HHINCO	0,000	-0,83	0,000	0,56
UNIV	0,082	1,15	0,007	0,06
INMTH	0,008	6,15	-0,008	-2,73
TVNUM	0,984	9,94	0,694	3,29
PARABOL	-0,142	-2,17	0,334	1,92
NETGEMB	0,160	2,40	0,245	2,13
LnPTV2	-0,145	-0,79	0,169	0,56
LnPTV3	0,168	0,52	-0,089	-0,17
Log-L	-1037,410		-331,943	

Note: Probit estimates

	384 kbit/s	704 kbit/s	1024 kbit/s	2048 kbit/s
Price 384	-0.26			
Price 704		-1.58		
Price 1024		1,06	-3.72	1,45
Price 2048			1,54	-0.97

Table 6 Internet price elasticities

5 Some Implications: Pricing, TV-Portal and Electronic Program Guide

In this section we present the quantitative effect of the key variables that the supplier can affect, i.e. the prices, the TV portal (NetGem) and the EPG, and discuss some corporate policy implications of the results.

5.1 Pricing and Price Elasticities

Table 6 presents the price elasticities for the Internet demand functions. The elasticities are calculated from the regression results presented in Tables 4 and 5 in the previous chapter. Price elasticity gives the percentage change in demand when the price changes by one percent. The own-price elasticity, i.e. the effect on the demand for capacity x when the price of x changes, is shown in the downward diagonal from left to right. The off-diagonal elements give the effect of demand for capacity x when the price of capacity y changes. We have chosen not to display the elasticities that are insignificant *and* very small.

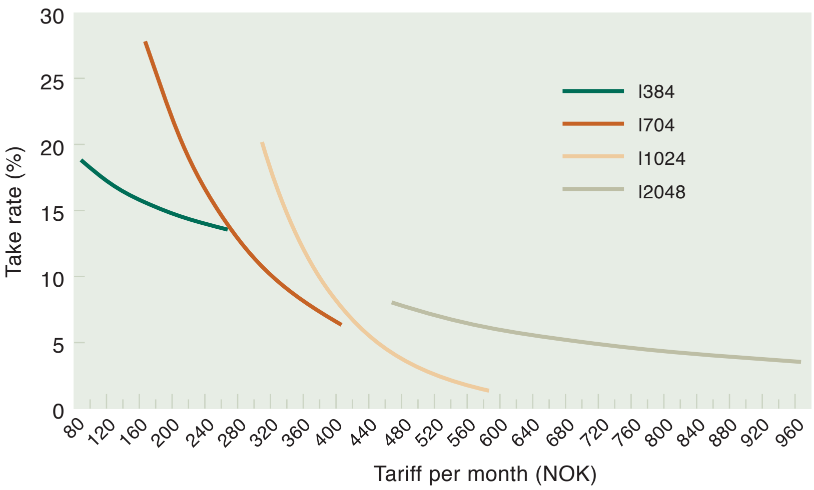
The own price elasticities for the middle alternatives are quite large. For instance, a price increase of 10 % for 1024 kbit/s will decrease the demand by 37.2 percent. Note that the effects are calculated when all variables take on their mean values. Because of the non-linear demand function, the figures may change when prices deviate far from their mean values. The average period (15 days) price of 1024 kbit/s was 222 NOK. The elasticity implies that if the price changes to 244, demand would fall from its mean value of 5.7 % to approximately 3.5 percent. An explanation for this large elasticity is found by looking at the cross-price elasticities. Both 704 kbit/s and 2048 kbit/s have positive and quite large cross-price elasticities of 1024 kbit/s: 1.06 and 1.45, respectively. Thus, when the price of 1024 kbit/s rises, demand is shifted both to 704 kbit/s and to 2048 kbit/s. We see that this substitution effect is particularly strong between 1024 kbit/s and 2048 kbit/s, where the cross-price elasticities reveal that buyers of 1024 kbit/s view 2048 kbit/s as a close substitute, and vice versa. Thus, as is also evident from Table 2, the *total* demand for the two highest bandwidths is quite stable at 11 to 12 % during the experiment period.

The estimated Internet demand curves (demand as a function of own price) are depicted in Figure 2. They illustrate the difference in own-price sensitivity between the two middle alternatives and the extreme alternatives indicated in Table 6. Note that the curves show demand when all other prices of all other alternatives are set at their average values.

Since the effects of prices on TV streams are all insignificant, see Table 5, we do not present a quantitative analysis of the price effects for TV streams. The effects are however very small suggesting that a price increase from the sample monthly averages of 140 and 240 NOK per month for the two TV streams and three TV streams respectively, could be done without affecting demand very much. It is however important to bear in mind that we measure the demand for *additional* TV streams, one stream was offered for free. Based on current market prices, the monthly value of one stream with a basic channel package is about 100 NOK. The results indicating that over 20 % are willing to pay 140 NOK for one *extra* TV stream are quite promising, but we once again emphasize that the users received a large channel package for free.

Increasing the prices of 384 kbit/s and 2048 kbit/s from their sample mean values will increase revenues. The price ranges for 384 kbit/s and 2048 kbit/s during the experiment were 80–190 and 520–800 respectively (per month). The prices for 384 were deliberately set low due to the existence of the 64 kbit/s alternative offered for free. If 64 kbit/s and 384 kbit/s are close substitutes, for instance because they are

Figure 2 Demand curves for Internet bandwidth



4) *This will be further investigated in forthcoming work.*

utilised for equal purposes, 384 kbit/s measures demand for *extra* bandwidth. The price insensitivity of demand for 384 kbit/s suggests that demand price in the range of 300–350 would increase revenues without affecting demand very much (this is admittedly speculations on effects outside the interval in which the prices were drawn).

Simulations show that increasing the price of 2048 kbit/s to the max-level of 800 (holding all other prices at means) will lead to a fall in demand for 2048 kbit/s to about 4 %, and an increase in demand for 1024 kbit/s to about 7.2 %. The price increase at both ends suggested above implies that 704 kbit/s and 1024 kbit/s also should increase from the sample average. The optimal price-combination of 704 kbit/s and 1024 kbit/s is however not that clear cut. However, the strong cross-price effects suggest that the highest bandwidths are close substitutes. Thus, there may be little to gain by fine-tuned optimisation, and indeed perhaps *little to gain by having all four alternatives available*. The results suggest that the four alternatives are (perhaps more than) sufficient to differentiate the product along the speed-dimension, and that product differentiation along other dimensions, different form of usage-based pricing for instance, see e.g. Andersson et al. 2001, is worth exploring.

5.2 TV Portal and Electronic Program Guide

NetGem *seems* to have a strong effect on the demand for additional TV streams. In addition NetGem seems to have a strong effect on the purchase of the two lowest Internet bandwidth classes (but not on the two highest). This suggests that it may be profitable to subsidize the NetGem box or other WeB-on-TV devices.

We stress the seeming effect because there is a potential endogeneity problem here. Prior to the experiment start-up half of the users were offered a NetGem box for free. The caveat was that they had to fetch it themselves. During the second period of the experiment the other half of the sample received the same offer. In the third and fourth period the NetGem box was delivered to anyone who wanted it. Since NetGem to some extent is a choice variable, it may be endogeneous to the choices of Internet bandwidth and TV streams. This means that the *causal* effect may be spurious, the seeming relationship may stem from an unobservable preference for telecom products. Having said that, WeB-on-TV has the potential to have a strong impact since it is likely to increase the value of both Internet access and the value of additional TV streams, through making the web and e-mail accessible via the TV screen.The issues are important because the quantitative effects are large. For instance, having a NetGem box increases the probability of purchasing two TV streams by 7 percentage points.

EPG is strongly correlated with the demand for additional TV streams, but the causal effect, i.e. whether EPG drives the demand for streams, is not determined and needs to be further analysed. About 67 % of those who chose more than one TV stream also bought EPG at a monthly average price of 25 NOK. Correspondingly, only 20 % of those who chose the one free TV stream alternatively bought EPG. We have not included the variable EPG in the regression analyses due to its obvious endogeneity – the choice of EPG was made simultaneously with the choices of TV streams. Hence, we cannot determine whether having EPG *affects* the demand for streams. However, the fact that choosing EPG also correlates strongly with the Internet demand suggests that correlation primarily measures individual innate differences, and not a causal effect.

6 Conclusions

This study reports some initial estimates on the demand functions and willingness to pay for multipurpose broadband access. The study was conducted in a ‘middle- to high-end residential area’ with large single dwellings. Quite surprisingly, as much as 26 % of the participants in the willingness to pay trial chose to pay an average of 156 NOK to get capacity to receive two or three simultaneous TV streams. The main drivers were the number of TV sets, and the presence of teenagers in the household.

19 % of the household chose to pay for extra Internet bandwidth, 384 kbit/s or higher, as well as additional TV streams. This constitutes the natural VDSL segment, i.e. the households that are willing to pay for both high-speed Internet access and multiple TV streams. The main drivers in the Internet access market were prices and previous Internet use. The monthly total (i.e Internet and TV) ARPU in the VDSL segment was 444 NOK. The estimated price elasticities along with the fact that a quite generous basic alternative was offered for free, suggest that ARPU in the total multipurpose broadband access market may be considerably higher in a commercial, targeted offering with optimal pricing without affecting the take rate very much.

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Elements of a Competitive Broadband Strategy for Incumbents*)

BJØRN HANSEN

Incumbent telecom operators are well positioned to enter the broadband market. Before doing so, an incumbent will have to make a number of strategic decisions. In the present paper we take market characteristics into consideration and discuss investment, pricing and content strategy. We argue that incumbents in the investment phase should give network size priority above speed of service. User heterogeneity is considerable in the broadband market and thus we argue that both the incumbent and the majority of customers probably are better off if volume based pricing is introduced. Finally we discuss content strategy for the incumbent and argue that a strategy with standardised interfaces towards the content industry may be preferable as compared to a strategy where the incumbent enters the content market.

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1 Introduction

The core activity of a Telecommunications incumbent (hereafter the incumbent) is basically to distribute digital signals. The development towards broadband can accordingly be analysed as a quality improvement of the core product for an incumbent. As illustrated in other papers in this journal issue the technological development is fast, and there are a number of opportunities for newcomers to enter the market for distributing digital signals as broadband is introduced. Thus an incumbent has to make a number of strategic decisions in order to protect its current revenue stream and possibly increase it.

Firstly, the incumbent has to decide whether to enter the broadband market or not. Secondly, the incumbent must choose technology and bandwidth for the new services as well as determine the targeted geographical market (the geographical footprint of the network). Thirdly, the incumbent has to choose a pricing and a segmentation strategy where both existing (narrowband) and new services are taken into consideration. Finally, the incumbent has to determine a strategy towards a major complementary market, namely content.

The paper is organised as follows: In the introduction we discuss some characteristic features of the broadband market, and then in the proceeding section we discuss the strategic issues outlined above. In the final section we conclude.

1.1 Defining Broadband

From a technical perspective a broadband service may be described along three dimensions (at least), bandwidth, mobility and interactivity. As an example, traditional broadcasting has relatively high bandwidth, is to a certain degree mobile and has no interactivity, whereas an ISDN service has low bandwidth, no mobility and is interactive. In Figure 1 we illustrate expected development paths for mobile services (blue), broadcasting (red) and residential data services (green).

In the present paper we will narrow the scope considerably and focus on two prospective submarkets of the market for broadband services, namely:

- *Turbo Internet distribution*
  Access services with bandwidth exceeding ISDN (128 kbit/s) but below the required bandwidth for high quality video (2 Mbit/s). These services can be provided by a number of access technologies, e.g. ADSL, cable, WLAN.

- *Interactive video distribution*
  Access services with sufficient capacity to carry at least one channel of real time high quality video, typically exceeding 2 Mbit/s. Such services can also be provided by a number of access technologies, e.g. high capacity ADSL, VDSL, Fibre to the home or DTT combined with an appropriate return channel.

Note that the submarkets are not defined as specific technologies. Seen from the consumer's point of view, ADSL and cable based broadband have for example comparable functionality and are accordingly close substitutes. Hence they belong to the same market.

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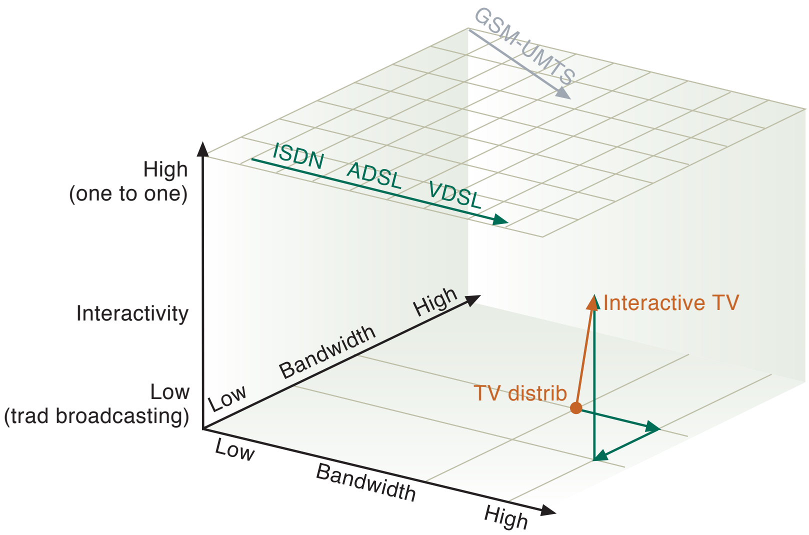

Figure 1 Development paths

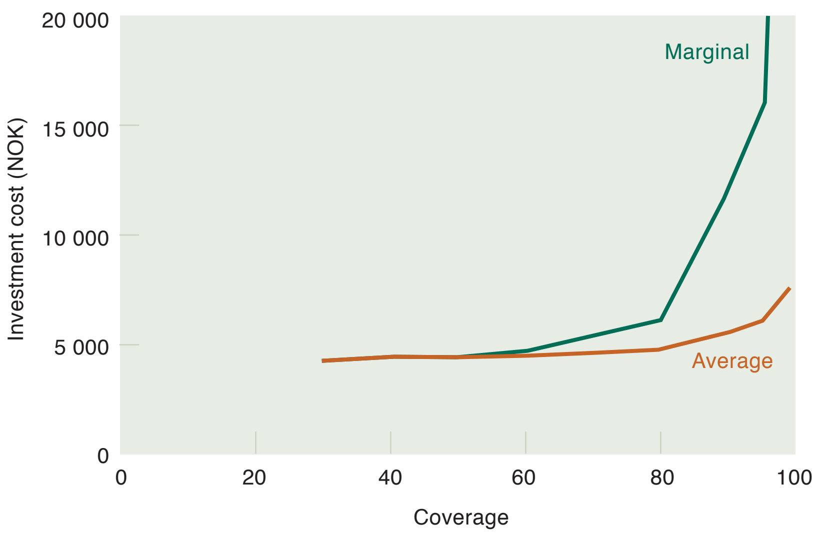

Figure 2 Typical cost structure in the geographical dimension

A turbo Internet service is suitable for applications like home office, streaming low quality video and fast Internet surfing. An interactive video service is suitable for all turbo Internet applications in addition to high quality interactive video. The three services, narrowband, turbo Internet and interactive video are accordingly purely vertically differentiated services. A given service can support all applications carried by services of lower bandwidth. A consequence of this pure vertical differentiation is that substitution, or "cannibalisation", of existing services is an important issue as new services are introduced.[1)] In particular, an upgrade from turbo Internet to interactive video is only profitable if the additional revenues from high quality video exceeds the investment cost of upgrading the network from turbo Internet to high quality video.[2)]

1.2 Broadband Cost Structure

For a given geographical coverage, the operation of a broadband network is typically characterised by significant economies of scale. As an example, an important cost component when building networks is civil works. This cost is independent of capacity being installed, thus there are economies of scale. This is opposed to the cost structure in the geographical dimension. For a number of reasons the cost of investing and running a network depends on geographical factors like population density and topography. A provider will typically start the network roll-out in areas where this can be done at the lowest cost per prospective subscriber, and then expand into areas characterised by higher costs. In Figure 2 we have illustrated a typical pattern of how the average cost and marginal cost, i.e. the cost of adding the last subscriber, increase as the network coverage in the geographical dimension increase from a coverage of 30 % of all households and up to 95 % coverage for a given service.

A characteristic pattern is that the marginal investment cost is relatively constant over an interval and then increases steeply. When comparing the cost structure of two services, one typically finds that the locus of the point where marginal costs start to increase steeply, shifts to the left as the speed of service increases. Thus, as the bandwidth of the service under consideration increases, the interval with constant marginal cost decreases. Furthermore, as the service offer is upgraded from turbo Internet to interactive TV, there will typically be a considerable additional cost per subscriber stemming from the need for customer premises equipment such as set-top boxes, digital TVs, cabling, etc. In order to penetrate the market, a supplier will typically have to carry a fraction of these costs. Thus the cost of obtaining a particular coverage and market penetration is considerably higher for interactive video as compared to turbo Internet.

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1) *Hausman et al. (2001) find that the price of narrowband services has insignificant effect on the price of turbo Internet services in their empirical study of the US Cable and DSL market. Thus they conclude that the narrowband and the turbo Internet market are separate markets for antitrust purposes. This result is however not implying that narrowband and turbo Internet services are not substitutes. The result in Hausman et al. may be driven by the particular strategic interaction in the markets under consideration.*

2) *In the presence of competition, the additional revenues from upgrading to interactive video may include revenues from existing services. This is the case if (and only if) the existing revenues will be lost to competitors unless the network is being upgraded.*

1.3 Economies of Scale on the Demand Side

There are also economies of scale and scope on the demand side. Utility from network participation may depend directly or indirectly on the number of potential communication partners and the quality of this communication. In such cases, the willingness to pay for network participation is an increasing function of network size. Such externalities were first given a theoretical treatment by Rohlfs (1974). The strategic effects of network externalities on competition was recognized by Katz and Shapiro (1985). In an analysis of the emerging broadband market it can be useful to distinguish between direct and indirect network externalities.

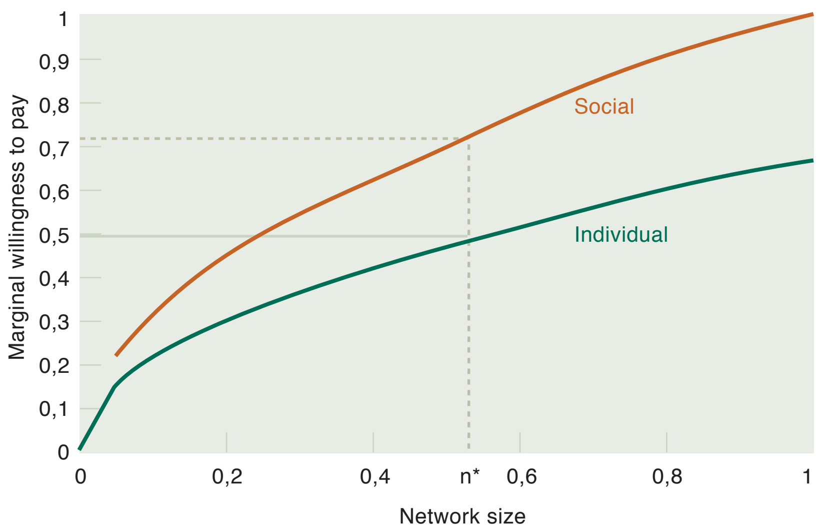
Direct network externalities are present if users derive utility directly from the number of subscribers to the network. A classical example is the fax machine. The very first fax in the world was hardly useful, but as the number of faxes grew this changed. In general, direct network externalities are typically of significance if subscribers communicate directly with each other. In a broadband context such externalities may be important in a number of ways. If the network is used for real time video conferencing, then the utility, or willingness to pay for the service, is an increasing function of the number of potential conferencing partners. Likewise, if the network is used for exchanging content directly between end users (peer to peer networking), e.g. exchanging holiday videos, the willingness to pay increases in the network size.

Indirect network externalities are present if the availability of complementary goods or services increases as the size of the network increases. The most obvious example in a broadband context of such a complementary good is content. There is no economic incentive for content providers to use the broadband network as a distribution channel if there are too few broadband subscribers since such subscribers constitute the entire potential customer base. As the number of broadband subscribers increases, this may change. At the same time the incentive for becoming a subscriber is low in the absence of content. Thus the availability of content is low if there are few subscribers, and there are few subscribers if the availability of content is low. Then we obtain a utility structure similar to what we described for direct externalities. The utility (or willingness to pay) for being a subscriber increases in the size of the network. The link is however via the content market as described above.

As argued above, both direct and indirect externalities lead to markets with network effects. In Figure 3 we have illustrated how individual utility and thus willingness to pay increase as the network size increases. For simplicity we have assumed that all consumers have an identical utility structure. For a given network size, the solid line depicts the individual willingness to pay for network membership for all connected customers. A consumer contemplating to join the network will compare the willingness to pay with the price of network membership. If he joins the network, willingness to pay for *all* network members will increase, due to the network externality. In the figure we have illustrated a price for network membership of 0.5. If the size of the network initially is zero, a consumer will find that his willingness to pay for network membership is below this price and he will accordingly not join. A zero network size is accordingly an equilibrium for any strictly positive price in this market. If the network size is above *n** in Figure 3, consumers will find that willingness to pay exceeds the price and they will join the network. In this stylised market it is accordingly also an equilibrium that all consumers are network members. Thus there are two equilibria, either that everybody are network members, or that nobody are network members. In more realistic models where consumers are heterogeneous one obtains similar, but more realistic results; an equilibrium with network size zero and an equilibrium where "almost" everybody is connected to the network (see e.g. Economides, 1996 for a discussion of such markets).

In Figure 3 we have also illustrated the social (i.e. the sum over all network members) marginal willingness to pay for network expansion. As stressed above, as one more subscriber is connected, the utility or willingness to pay for all existing customers increases. Thus the social marginal willingness to pay for network expansion consists of both the willingness to pay for

Figure 3 Willingness to pay for network expansion as a function of network size



the marginal consumer as well as the added willingness to pay for the other network members.[3)] When the marginal social willingness to pay exceeds the individual willingness to pay, market equilibrium will in general yield a network size below the social or welfare maximising network size unless the market equilibrium is a corner solution, characterised by everybody joining the network.

2 Investment Strategy

Several papers in the present issue of *Telektronikk* discuss broadband investment strategies.[4)] In this section of the paper we will focus on two particular aspects of the investment strategy; relevant revenues and network externalitites.

2.1 Relevant Revenues and the Speed of Service

An upgrade to broadband requires considerable up front investments. Before committing to such investments the supplier has to determine the desired bandwidth of the upgraded services (turbo Internet or interactive video) and the desired coverage of the network ("footprint" of the networks or number of "homes passed"). Investment cost increases in both dimensions. Thus for a given investment budget one can upgrade to turbo Internet in a large area or one can upgrade to interactive video in a considerably more limited area. The discussion in this section aims at discussing the key strategic effects of trading off turbo internet coverage for coverage in interactive video.[5)] Furthermore we will discuss the timing of investments.

As argued above, and documented in other papers in this issue, investment costs are significantly higher for an upgrade to interactive video as compared to an upgrade to turbo Internet. These broadband services can be provided by a number of technical solutions which typically require that the reach of the fibre network has to come closer to the customer as the bandwidth is increased, i.e. the reach of the fibre network is expanded out into the access network. These additional investment costs of going from a turbo Internet upgrade to an interactive video upgrade has to be compared with the relevant or additional revenues from the interactive video services. The additional revenues[6)] consist of two parts, direct and indirect revenues.

The direct revenues are the revenues directly caused by the ability to carry services and applications with bandwidth requirements in the high quality interactive real-time video range. There is considerable uncertainty with respect to the size of such revenues and it is far from obvious that the size of the direct revenues is sufficient to carry the additional investment cost required, given current technology.

It is possible that an incumbent can protect existing revenue streams (e.g. telephony and turbo Internet) by offering interactive TV services. This will be the case if other prospective players are deterred from investing in broadband infrastructure when the incumbent is the first mover in a geographical area. Currently, there are no competitors with plans of massive broadband upgrade in the Norwegian (or Nordic) marketplace and thus this effect can hardly be of significance. There is one other possible source of indirect revenues. In areas where broadband competition is established, the incumbent may gain a competitive advantage by bundling interactive TV with other services (e.g. telephony and turbo Internet). Consumers may be willing to pay a premium for such bundled services, e.g. for convenience (functionality or due to a single invoice). Bundling may also in principle raise rivals' up-front costs. This is particularly the case if the services in the bundle are not sold separately. In such cases the prospective rivals must have a complete portfolio of services in order to be competitive. Incumbents are however subject to strict regulation in this area. In particular it will typically be mandatory to offer basic services like telephony unbundled at regulated prices. Then consumers can buy the services from different providers and thus broadband rivals can, successfully, serve the market with only broadband services given that the price is competitive. An assessment of the profitability of an upgrade to interactive video based on current knowledge indicates accordingly that a roll-out on a large or medium scale is hardly profitable.

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3) *Let u(n) denote the individual utility of a network of size n, then total (social) utility is W: = nu(n), then marginal social utility becomes* $\frac{\partial W(n)}{\partial n} = u(n) + n\frac{\partial u(n)}{\partial n}$. *The particular utility function used in the illustration above is* $u(n) = \frac{2\sqrt{n}}{3}$.

4) *See Kalhagen and Elnegaard and Elnegaard and Stordahl.*

5) *In the absence of capacity constraints in investment activities no such trade-off exists. There are however typically capacity constraints both with respect to the size of the investment budget and with respect to the capacity to physically carry out the upgrade (which requires planning, civil works, etc). Thus in reality most telecom operators face such trade-offs.*

6) *The definition of additional revenues in this context is that these revenues cannot be extracted unless the network is upgraded to interactive video.*

As stressed above, we have limited knowledge of the willingness to pay for interactive video services. Thus there is a considerable value in gaining more information on the profitability of such services. Trials and small scale rollout in low cost areas (cherry picking) may accordingly have a positive net present value due to the value of gaining more accurate information (the option value). Such effects are discussed in Kalhagen and Elnegaard (2002) in the present issue of *Telektronikk*. The obvious limitation to such trials is that it can be problematic to reveal the willingness to pay for services where network externalitites are important since the size of a trial typically is too small.

2.2 Target Market and Externalities

Both turbo Internet services and interactive TV is characterised to some extent by network externalities. As indicated in Figure 3, the willingness to pay for services is relatively low in small networks where externalities are of significance. Thus the provider cannot apply a traditional market penetration strategy where one initially only addresses the prospective subscribers with a high willingness to pay. Initially there are no customers in this category. The willingness to pay will not be high until the network reaches a certain size, "critical mass". Small scale rollouts, in the presence of externalities, will accordingly have a low average revenue per user as compared to large scale rollouts. In the following we will call this the problem of critical mass.

As indicated in the introduction of this paper, the type, extent and significance of network externalities depend on the type of applications used by the customers. Thus one strategy to overcome the critical mass problem is to initially profile the service such that externalities are less important. This can be achieved by hooking up to networks that already exist. As an example, in the mobile phone market, the mandatory interconnection with the fixed network solved the critical mass problem immediately. The number of subscribers to the fixed network served as an installed base. In the market for turbo Internet services the initial problems of critical mass can to some extent be solved by focusing on home office customers. Then the relevant network consists of only two nodes. One node in the relevant network is at the residence of the home worker and the other one node is at the data network at the workplace. Thus by offering home office packages to employers the critical mass problem is reduced. Once the number of broadband customers increases one can introduce, and start focusing on, services where externality effects are of importance.

If the network externalities are of the indirect kind then an active content strategy by the access provider may solve the problem of critical mass, e.g. by committing[7] to offer content services, the access provider will in effect reduce the size of the externality. In such cases the availability of content is initially less dependent on network size and thus the critical mass problem is to some extent solved. In Section 4 of this paper we will discuss possible content strategies for incumbents more closely.

Finally, if the externalities are of the direct kind, then only a massive network rollout will solve the critical mass problem. However, seen from the consumer's side, a massive network rollout is not sufficient. As indicated in Figure 3, willingness to pay is low for small network sizes, so in the initial phase the network service has to have a low price, i.e. penetration pricing. As the number of subscribers increases, the price can be increased.

Notice that the proposed strategies both under direct and indirect externalitites have important implications for the investment strategy. A slow, step by step network rollout implies that the period where consumer willingness to pay is low, is significantly longer as compared to a more massive rollout. Thus the incumbent will incur higher losses due to unprofitable content activivites, and/or unprofitable penetration pricing. Thus if there is a trade-off between speed of service and target market, the presence of network externalitites makes it relatively more profitable to give a large target market priority.

3 Pricing and Segmentation Strategy

Pricing of network services under imperfect competition is a complex matter and a proper discussion of all aspects is outside the scope of this paper. In the following we will however point at some factors that deserve attention in the broadband market.

The ultimate objective of most firms is to maximise profits or value for the owners within the boundaries given by competitive pressure, legislation and regulation. Profits are, by definition, the difference between revenues and costs. Pricing decisions will affect both revenues and costs. The effect on revenues is obvious, for a given number of units sold, a price increase will

[7] *Such a commitment has to be credible. For a supplier with a very good reputation an announcement of intentions to engage in the content industry may be sufficient. Most incumbents will however only be credible if they indeed are present in the content industry and demonstrate their services.*

increase revenues. The effect on costs is more indirect. By changing the pricing of the service portfolio some consumers will change their usage pattern. When usage patterns change, it will in general affect costs. Thus production and investment costs are affected by pricing.

Optimal pricing is accordingly aiming at two objectives, to extract as much willingness to pay as possible and at the same time give users incentives such that production costs are minimised. In order to reach the first objective, prices should be correlated with consumers' willingness to pay, and in order to reach the second objective, prices should be correlated with the production costs.[8)]

In a broadband context there are several factors making the pricing decisions more complex than what we find in the straightforward textbook case, in particular economies of scale, extreme consumer heterogeneity, network externalitites, and finally complementarities. The effect of economies of scale on prices is well covered in the literature, complementarities will be covered in the last section of this paper, so in this section we will focus on some aspects related to heterogeneity and network externalities.

Before we proceed with a discussion of pricing it can be useful to introduce some terminology. Uniform (or linear) prices refer to cases where the total price paid by consumers is strictly proportional to the quantity purchased. Thus the pricing of broadband is uniform, e.g. if it is only based on download volume or if it is of the flat rate type[9)], whereas any combination of subscription fee and volume (and/or time) is nonlinear pricing. Furthermore quantity rebates will result in prices becoming nonlinear since the average price per unit becomes a nonlinear function of the purchased quantiy. A uniform and a nonlinear price are illustrated in Figure 4.

Figure 4 Uniform and non-linear pricing

In the figure, the total price for the service for a single customer is measured along the vertical axis. An overview of nonlinear pricing can be found in Wilson (1993).

In the introduction to the paper, we argued that investment in, and operation of broadband networks typically are characterised by economies of scale. With such cost structures, intense competition cannot be sustained over time. The competitive pressure will drive prices down to marginal cost. Then (some) firms will go bankrupt until the competitive pressure is reduced sufficiently such that prices are allowed to exceed average costs.[10)] Thus, the broadband market will be characterised by monopoly or imperfect competition. There are however few robust results in the literature on markets characterised by imperfect competition and nonlinear pricing. Such markets are difficult to analyse, and results in the literature are diverging. (For examples see Jensen and Sørgard, 2001, Gibbens et al. 2000.)

3.1 User Hetereogeneity and Pricing

We can expect to find a great variety in both the applications being used and the intensity of use among different customer groups. One extreme group of broadband customers are teenagers downloading mp3 files day and night and thus generating huge volumes in the network. At the other end of the scale we may also find "extreme" groups of broadband customers, e.g. executives, exchanging mail once or twice a day in relatively small volumes.

Data from various broadband trials indicate that there is indeed significant heterogeneity among customers of broadband networks. The extent of the heterogeneity is illustrated in Figure 5.

[8)] *To be more specific, a typical result is that* marginal *prices should be correlated with* marginal *willingness to pay and* marginal *costs.*

[9)] *Note that the interpretation of* quantity *is not the same for volume and flat rate pricing respectively. Under a (uniform) volume price, the total price paid by consumers is proportional to the total download volume. Under flat rate pricing, the total price paid by subscribers is proportional to the number of subscribers.*

[10)] *Economies of scale is defined as a situation where average cost decreases as produced quantity increases. This can only be the case if average costs exceed marginal costs.*

In the figure customers of Telenor's HB@ trial are sorted after network usage (download volume). The heaviest consumers are on the left of the figure. On the vertical axis (normalised) accumulated network usage is measured. The figure shows that the heaviest 3.3 % of users are responsible for roughly 50 % of the network usage. Given this heterogeneity it is puzzling that a majority of the users apparently prefer undifferentiated flat rate charging of such services. By introducing a nonlinear tarriff (in particular subscription and download volume), and not changing revenues for the provider, 96.7 % of the users would get a reduced total broadband price, whereas 3.3 % of the users would experience a price increase given that the HB@ users are representative.[11)] Other Internet trials have obtained quite similar results with respect to hetereogeneity although the results are less extreme, see Altman et al.

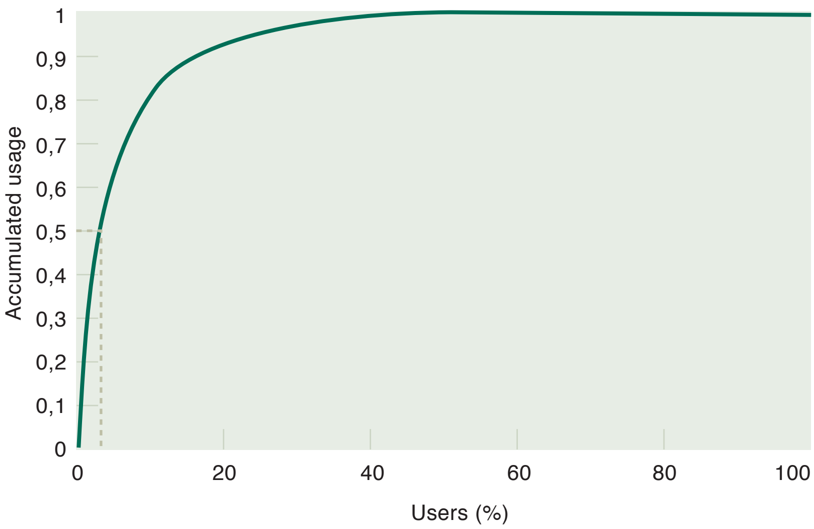

Figure 5 HB@, accumulated usage 2048 kbit/s down

3.2 Network Externalities and Pricing

The presence of network externalities will in general affect the optimal pricing policy. First of all, in order to penetrate the market, prices will initially have to be sufficiently low such that the first users find it individually rational to join the network. Moreover, as illustrated in Figure 3, the social or aggregated willingness to pay for network expansion will in general exceed the individual willingness to pay. Thus networks will tend to be "too small". This issue can to some extent be solved by nonlinear pricing. Marginal users can be attracted by designing pricing plans with a low subscription fee and a correspondingly high usage fee. Then the network size will increase towards the optimal size.

Although there are several arguments why nonlinear tariffs in the broadband market is preferable, consumers apparently still indicate that they prefer flat rate pricing. Thus the introduction of two part tariffs or "volume based pricing" may drive some consumers to choose other providers. This will have severe negative effects since network externalities will lead to a reduction in the willingness to pay for the consumers that initially were comfortable with the new pricing scheme. One possible strategy for the incumbents to overcome this obstacle is to offer optional pricing plans where the flat rate offer is one option in addition to a menu of two-part tariffs. Over time consumers will learn their usage pattern and hopefully some of them will find that they are better off choosing a pricing plan dependent on download volume. Notice that such a strategy represents a two-sided trial and error process. It represents a learning process towards customers, i.e. what customers choose which tariff, but it will also represent a learning process towards competitors. Since there are hardly no robust results in the literature on equlibria in markets with menus of tariffs, the strategic response from competing firms as multipart tariffs are introduced is hard to predict. Thus a main objective has to be to gain knowledge by applying a flexible pricing strategy where prices are allowed to change as a response to choices made by customers and competitors.

4 Complementarities and Content Strategy

In this section we will focus on the content industry. Seen from the incumbent or the digital distributor, the content industry is of particular importance if indirect externalities are present. We will accordingly focus on indirect network externalities in this section.

Content is basically defined as anything that can be digitised (see Shapiro and Varian, 1998). Subscribers or customers of a broadband service are not interested in the connection or digital pipe per se, it is the ability to communicate (exchange digital signals) with someone or something that the consumer is willing to pay for. Thus customer willingness to pay is attached to a "system" consisting of digital distribution,[12)] content and the necessary terminal.

The providers of content and the provider of digital distribution are in one respect partners. They

[11)] *This calculation presupposes that download volumes are unchanged as volume pricing is introduced. This is of course not realistic. Nevertheless, at least 50 % of the customers will be at least as well off with volume based pricing as under flat rate charging in the sense that the outlay for buying broadband decreases.*

[12)] *Either narrowband distribution, turbo Internet distribution or interactive video distribution.*

Figure 6 The system of strict complements

have to cooperate, or in other ways coordinate their actions in order to maximise the total value of the system. Digital content is without value unless there is a network to distribute the content to the customers. Likewise, the distribution network is of limited value unless there is some content to transport on it. Products or services with such characteristics are called strict complements. Furthermore an upgrade of one element without upgrading the other may be without value, e.g. an upgrade of the bandwidth capacity in one element and not the other. In this respect content providers and the distributor must coordinate their actions.

At the same time, customer willingness to pay is for the whole system and not for one of the elements, thus if one party is able to extract a relatively large portion of the customer's willingness to pay, then there is less to extract for the other party. In this respect content and distribution providers are competitors. The tension between cooperation and coordination on the one side, and competition on the other makes it a challenge to find an optimal content strategy for incumbents.

4.1 Competing for the Value

A chain of monopolies will in general be worse than a single monopoly. This argument dates back to Cournot in 1838. The same mechanism as Cournot studied may also be of relevance in our broadband context. The total price of using the system illustrated in Figure 6 will, under a set of assumptions, be too high if the content provider and the distributor set their price independently. When determining their own margins, neither will take into account that a price increase will decrease the volume and thus profits of the complementor. Then the total price for access to the system becomes too high.

In other competitive environments similar effects may occur. As argued above, there is only a single value attached to the total system (and not a specific willingness to pay for each component) and thus one potential monopoly rent.[13)] In particular, if the content provider for some reason is able to extract the entire monopoly rent of the system, then no margins at all are left for the distributor.

In order to be able to set a content price that is sufficiently high to have adverse effects on the distributor's profits, the content provider has to have market power in the content segment. In the absence of such market power, the content provider trying to raise its price will be bypassed. Customers will choose alternative content providers with low price. Thus a key to obtaining a high fraction of the total value is to make sure that there is sufficient competition in the complementing segment. The distributor can accordingly discipline the content market by entering it and set competitive prices. By being a low price competitor the other content providers will have to reduce their own prices in order to be competitive and the distributor can accordingly protect his margins on the distribution activity by entering the content market. The distributor can alternatively enter into contracts with content providers in order to avoid the adverse pricing effects.

Currently the content business is however characterised by quite intense competition (in particular in the Internet), most services are for free, and thus there is no reason for the distributor to enter this market in order to get the prices right. New systems for digital rights management (DRM) may change the picture by making it easier to distribute and make money from copyrighted material distributed over the Internet. If – or when – such systems come into place, pricing on the content side becomes an issue for the distributor. This may be an argument for entering the content business. Then the incumbent will be positioned in the content industry prior to the introduction of DRM.

4.2 Creating the Value

In the previous section we focused on the sharing of the total willingness to pay among the content providers and the incumbent. This discussion presupposes that there is a value to share. However, in immature and growing markets the providers will have to create the value before they can start to distribute it.

First of all the providers will have to solve the pure coordination problem as described above. Thus, content providers, in cooperation with the incumbent, will have to assure that there is sufficient availability of (relevant) content in the initial phases of the rollout of a new service. For example for turbo Internet services there is huge availability of content requiring narrowband speed, but the availability of content requiring broadband is limited. Consumers will presum-

13) *The monopoly rent in this context is the difference between willingness to pay and the sum of production costs for the content provider and the distributor.*

ably find it more attractive to upgrade their access service if there is some content out there which they find interesting and which is unavailable by narrowband. Content providers will however not find it profitable to introduce content services requiring broadband before there are sufficiently many broadband subscribers (see Foros and Hansen 2000). Seen from the incumbent, he can choose between heavily underpriced access services to attract consumers or alternatively to provide some content directly and thus make the access service more attractive for subscribers. Then the underpricing can be reduced. This may be the main explanation why some incumbents have entered the content business. Since content activity is far outside the core business of an incumbent, an alternative, and perhaps less costly strategy, would be to pay one or more content providers in order to make them offer content services requiring broadband.

In the previous subsection we discussed how the incumbent could make sure that content profits would remain bounded. An incumbent with a reputation for being effective in restricting profits in complementary segments may discourage content providers from entering the broadband business. Given a reputation for restricting profits in complementary segments, content providers will expect that their long term profits in the broadband market will be limited and thus they will be less willing to take risks and invest in content services requiring broadband. An incumbent strategy where content activity initially is established in order to create value, but where the presence in the content industry in later phases will be used to discipline the content market, may accordingly turn out to be counterproductive.

As an alternative to direct engagement in the content industry, the incumbent may focus on creating standardised interfaces towards the content industry. The interface includes both a technical interface and a set of standardised contracts.[14] This model will however only work if there are some rather obvious and sustainable business models for the content providers. In the initial value creation phases, the incumbent may have to subsidise the content providers, but as the size of the installed base increases the content providers must have a business that is profitable per se.

It might be the case that incumbents find it impossible to design the required obvious business models. If this is the case, then one cannot but ask the question: Is broadband really profitable? In cases where the answer to this question is yes, it will in general be possible to design contracts between the incumbent and the content providers such that the content side also becomes profitable.

5 Conclusions

In this paper we have taken economies of scale on the supply side, network externalities and complementarities into consideration when discussing investment-, pricing- and content strategy for incumbents in the broadband market.

On the investment side we have argued that incumbents should give network size priority above speed of service, i.e. it is better to roll out ADSL in a (very) large area than to roll out VDSL in a limited area. In some areas one can however upgrade to VDSL at relatively low cost and one should take advantage of this opportunity to carry out small scale experiments and trials in order to learn more about the willingness to pay for interactive video. The knowledge obtained in small scale experiments is however of limited value if network externalities are important.

We have argued that both the incumbent and the majority of broadband customers will be better off if volume based pricing is introduced instead of the current flat rate charging for broadband. However, both theoretically and empirically the effects of such a move is not obvious. One possible strategy for the incumbents is to offer optional pricing plans where the flat rate offer is one option in addition to a menu of two part tariffs. Over time consumers will learn their usage pattern and hopefully many of them will find that they are better off choosing a pricing plan dependent on download volume.

An incumbent introducing broadband will have to have an active content strategy. We have argued that several factors indicate that the preferable strategy for an incumbent is to establish a standardised contractual and technical interface towards the content industry. A main focus has to be on establishing profitable business models for the content providers.

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[14] *The standard contracts may also include clauses limiting the pricing of the parties involved such that the possible adverse double marginalisation is avoided.*

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Assessing Broadband Investment Risk Through Option Theory

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This paper presents the different economic challenges and uncertainties a telecom operator is faced with deploying broadband services in different geographical market segments. It is argued that in sub-urban and rural areas, where the incumbent operator faces no or little competition, it is important to take into account the flexibility in the timing of the investment decision. The economics and risks associated with an incumbent's investment decisions in suburban and rural areas are analysed using a real option approach. Option-pricing methodologies capture the value of flexibility while NPV does not. The question to be answered is: how will this flexibility influence the value of such projects?

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1 Introduction

A telecom operator's challenges providing profitable deployment of broadband services differ a lot with respect to urban, suburban and rural settlements. In urban areas the battle between DSL operators and cable operators has started and the question is how the market shares will evolve. The challenge for the incumbent operator is to roll out ADSL and VDSL at the right time. The timing for xDSL rollout depends on HFC coverage and penetration, and additional factors like infrastructure, area characteristics, component costs, mass production of network components, applications offered, expected tariff evolution, willingness to pay, demand forecasts and evolution of expected market shares.

In comparison to the dense urban area case, which is the focus of [1], suburban areas are characterised by lower subscriber densities, longer loop lengths, lower duct availability and therefore higher infrastructure costs compared to dense urban areas. Suburban areas are not likely to be the prime focus of the incumbent and OLOs in a "first wave" VDSL rollout but may become interesting markets and sources of revenue in a "second" rollout wave. Therefore, there is an inherent flexibility in such investments compared to the situation in dense urban areas where there is a high level of competition already present and where the operator must act faster in order to get a competitive advantage. The question to be answered is: how will uncertainty influence the value of such a project?

In rural areas the incumbent faces no or little competition from cable operators or other network operators. This is because the economic prerequisites for offering broadband services are not fulfilled under pure market criteria. These areas are sparsely populated and high investment costs will be incurred promoting broadband. In many countries, there is a high level of political interest to provide broadband access in areas and sectors where the economic prerequisites for offering broadband services are not fulfilled under pure market criteria [2].

This article examines the economics and risks associated with an incumbent's broadband rollout in a typical Nordic country, by taking into account the flexibility in timing of the investment decision. This is highly relevant for rollout of broadband infrastructure in suburban and rural areas. In these areas the incumbent is often the only provider of broadband infrastructure and therefore has the possibility to possess staged investment plans without worrying about lost market shares to competitors.

Section 2 gives an overview of the real option framework.

In Section 3 a study on the incumbent's decision whether to invest or not in a VDSL upgrade based on remote fibre nodes in suburban areas is presented. The extra revenue stemming from new services available over VDSL must be balanced against the large upgrade investment necessary.

In Section 4 we are looking at an incumbent's decision to invest in a new cost effective technology, Digital Terrestrial Television (DTT), to provide broadband services to rural areas. ADSL has proved to be too costly in these areas. However, there are some technical and practical problems that have to be solved before DTT can be launched on a fully commercial basis. Therefore the operator has to invest in a DTT pilot to resolve the problems, before deciding upon a commercial rollout.

Section 5 summarizes the main findings from the two case studies presented. How is the value of the project influenced taking real option theory into account?

Section 6 gives an overview of relevant references and Section 7 is a mathematical presentation of the real option methodology.

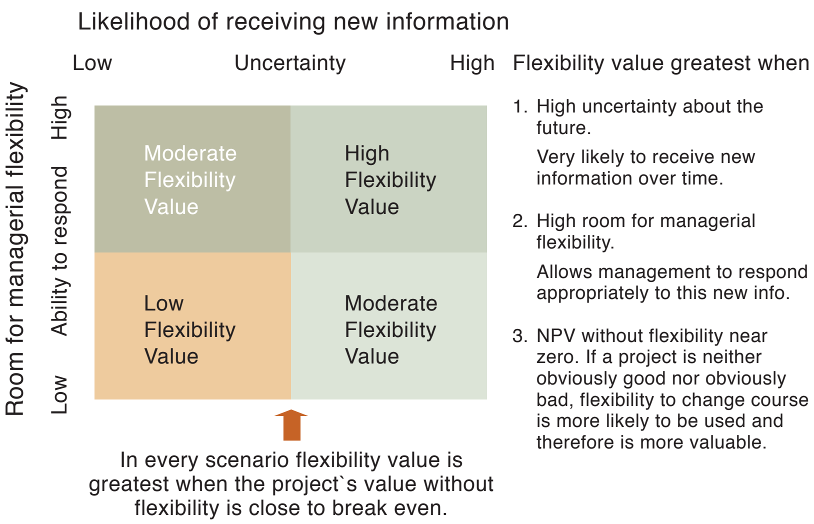
An overview of acronyms is presented in Section 8.

2 Real Option Methodology

While traditional NPV forces a decision based on today's expectations of future information, option valuation allows the flexibility of making decisions in the future contingent on the arrival of information. The possibility of deferral that is captured in the option methodology gives rise to two additional sources of value. First we would always rather pay later than sooner, all else being equal, because we can earn the time value of money on the deferred expenditure. Second, while we are waiting, the world can change. Specifically, the value of the operating assets we intend to acquire may change. If their value goes up, we have not missed out; we can still acquire them simply by making the investment (exercising our option). If their value goes down, we might decide not to acquire them. That is also fine because by waiting, we avoid making what would have turned out to be a poor investment. In other words, we have preserved the ability to participate in good outcomes and insulated ourselves from some bad ones.

For both of these reasons, being able to defer the investment decision is valuable. Traditional NPV misses the extra value associated with deferral because it assumes that the decision cannot be put off. In contrast option *presumes* the ability to defer and provides a way to quantify the value of deferring. While traditional NPV forces a decision based on today's expectations of future information, option valuation allows the flexibility of making decisions in the future contingent on the arrival of information. This is illustrated in Figure 1.

Figure 1 When is managerial flexibility valuable?



The value of a project using option pricing will always be greater than the value of a project using NPV. Sometimes the difference in value between the two approaches is small. This is usually the case when the project has such a high NPV that the flexibility is unlikely to be used, or conversely when the NPV is very negative. The biggest differences occur when the NPV is close to zero; that is, when the decision about whether to undertake the project is marginal.

The three basic criteria for a real option similar to the investment problem are the following:

- Uncertainty in the future cash flows resulting from the project rollout at time *T*;
- A large discretionary and irreversible investment at time *T* (new network components and civil works costs);
- Flexibility in timing. The operator can decide to invest or not depending on the information he gets until time *T*.

Over time, uncertainty will be resolved and the achieved knowledge is used to either proceed with an aggressive strategy or defer/discard the investment opportunity if market conditions are not favourable, technology not available, etc. It is exactly this value (in some situations) of deferring the investment which is not included in the "good old" discounted cash flow (DCF) and NPV calculus. The value of deferral stems from two factors:

- uncertainty is resolved over time;
- the time value of money, that is the interest earned on money that could have been invested from the start.

The higher the level of uncertainty, the higher the option value because the flexibility allows for gains in the upside and minimizes the downside potential. The total discounted operating cash flow[1)], in the following called the asset value, generated by the optional future investment is modelled by a lognormal stochastic variable. The uncertainty is modelled by a volatility commonly used for financial call options.

Note that an important difference between financial and real options is that management can affect the value of the underlying risky asset (a physical project under its control) while financial options are side bets owned by third parties that cannot affect the outcome of the underlying asset (e.g. a share of a telecom operator).

[1)] *Operating cash flow = revenue – all OA&M, sales and other costs – variable follow investments (line cards etc.).*

Table 1 shows the mapping of the investment problem into option valuing parameters.

- An increase in the present value of the project will increase the NPV (without flexibility) and therefore the option value will also increase.
- A higher investment cost will reduce NPV (without) flexibility and therefore reduce option value.
- A longer time to expiration will allow us to learn more about the uncertainty and therefore it will increase option value
- An increase in the risk-free rate of return will increase option value since it will increase the time value of money advantage in deferring the investment cost.
- In an environment with managerial flexibility an increase in uncertainty will increase option value.

As will be demonstrated in the following, the mapping of the investment project into a call option is direct, once the DCF analysis is available.

Investment Opportunity	Variable	Call option
Present value of a project's operating assets to be acquired	S	Stock price
Expenditure to acquire the project's assets	X	Exercise price
Length of time the decision may be deferred	T	Time to expiration
Time value of money	r_f	Risk-free rate of return
Riskiness of project assets: 20 % – 60 %	$\sigma\sqrt{T}$	Cumulative volatility

Table 1 Mapping the rollout investment problem into a call option

3 Suburban Area

3.1 Background

Incumbents worldwide are faced with increased competition from various sides such as cable operators and other licensed operators (OLOs). Cable operators in Europe and North America have for a while offered broadband Internet services bundled with TV and telephony. In order to be competitive, incumbents face large investments in the coming years. It is therefore imperative for the operator to develop methodologies for valuing the flexibility of optional future investments: which rollout investment projects should be launched in the short, medium and long term? – And equally important: – Which rollout projects should never be launched?

In this paper, we propose the use of option pricing widely applied in financial theory as a means to capture the value of flexibility in future VDSL rollout investments. This value is not incorporated in the static traditional discounted cash flow (DCF) approach used ubiquitously. In real life projects, management will most often have flexibility to make decisions along the way as conditions change. Surprisingly, the use of option pricing or real options in telecommunications is still in its infancy.

We show that when uncertainty and the flexibility of timing are taken into account, the impact on the NPV can be dramatic and result in different decisions compared to decisions based on conventional NPV criteria.

Rolling out VDSL implies heavy investments for an incumbent due to the requirement of optical fibre deeper in the access network caused by the shorter reach for VDSL compared to ADSL. A 26 Mb/s asymmetric VDSL access connection requires that the total copper line distance to the subscriber does not exceed 1,000 m. The cost levels and customer potential can vary significantly from one central office area to another. The following parameters are key: line density and therefore the number of potential customers within the reach of an optical node, existing ducting/fibre infrastructure as well as the operator's market share.

The focus of this study is the incumbent's decision whether to invest or not in a VDSL upgrade based on remote fibre nodes in suburban areas during a ten year period. It is assumed that the incumbent launches ADSL services from the first year and onwards. The extra revenue stemming from new services available over VDSL must be balanced against the large upgrade investment necessary.

In comparison to the dense urban area case, which is the focus of [3], suburban areas are characterised by lower subscriber densities, longer loop lengths, lower duct availability and therefore higher infrastructure costs compared to dense urban areas. Suburban areas are not likely to be the prime focus of the incumbent and OLOs in a "first wave" VDSL rollout but may become interesting markets and sources of revenue in a "second" rollout wave. Therefore, there is an inherent flexibility in such investments compared to the situation in dense urban areas where there is a high level of competition already present and where the operator must act faster in order to get a competitive advantage. The question to be answered is: how will uncertainty influence the value of such a project?

Scenarios	Penetration 2002	Penetration 2006	Penetration 2010
Sc 1	1 %	15 %	60 %
Sc 2	3 %	20 %	60 %
Sc 3	3 %	30 %	65 %

Table 2 Broadband service take-up scenarios

3.2 The Case Study

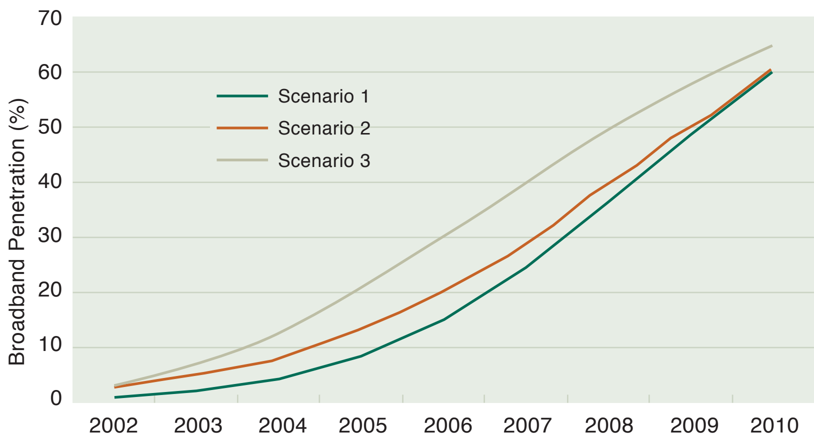
We consider an incumbent operator facing the decision on a VDSL upgrade based on fibre nodes in a suburban central office area at a future point in time, namely 2004. A nine years study period, 2002 – 2010, is assumed. The incumbent offers ADSL services from the first year and an OLO is assumed to enter the ADSL market in 2002 basing his business on local loop unbundling. In 2004, the incumbent invests (or not) in a VDSL upgrade in order to be able to offer VDSL services from 2005.

The total penetration of broadband services over xDSL is modelled by an S-curve and the market share of the OLO is 25 %. The suburban area considered covers 12,000 telephone subscribers and the subscriber density is equal to 1000 subscribers per km^2. The central office area is assumed to have a local exchange with 4000 telephone subscribers and four remote subscriber units with 2000 lines each. It is assumed that a VDSL offering requires five nodes per km^2. This gives a total of 60 node locations of which only five of them are at existing exchange/RSU locations.

Remote outside cabinets including powering and cooling systems are required for all the new nodes. The costs of digging, pulling new fibre and restructuring of the copper lines at remote nodes have been taken into account in the analysis.

We consider three forecast scenarios of the total xDSL service take-up versus time, see Table 2. The resulting S-curves, based on a four parameter logistic model [4], are shown in Figure 2.

Figure 2 Resulting S-curves



3.3 Technical Description

ADSL services are delivered from DSLAMs at the local exchange and RSU locations – each DSLAM shelf can handle up to 32 line cards of 8 customers each. VDSL services are delivered from optical network units (ONUs) placed in outside cabinets as well as at the local exchange. Different vendors use different names for the ONU – sometimes 'DSLAM' is used. Up to 128 users per ONU is assumed. No passive splitters are used in the architecture. An optical fibre cable carrying 24 fibres feed each ONU. Twisted pair copper is used for the remaining path to the

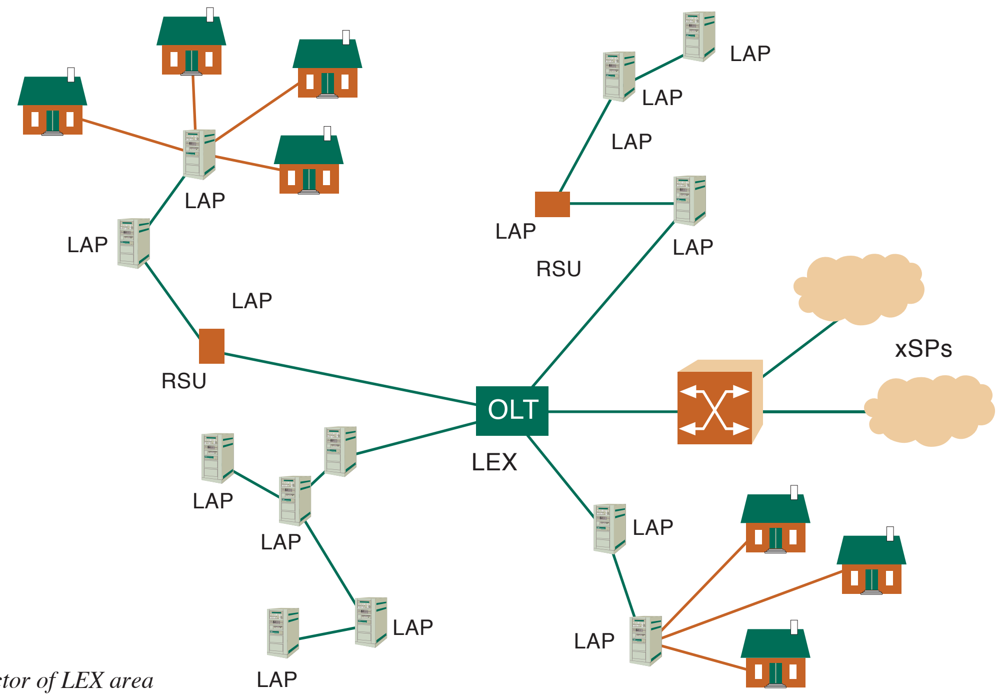


Figure 3 VDSL archictecture, sector of LEX area

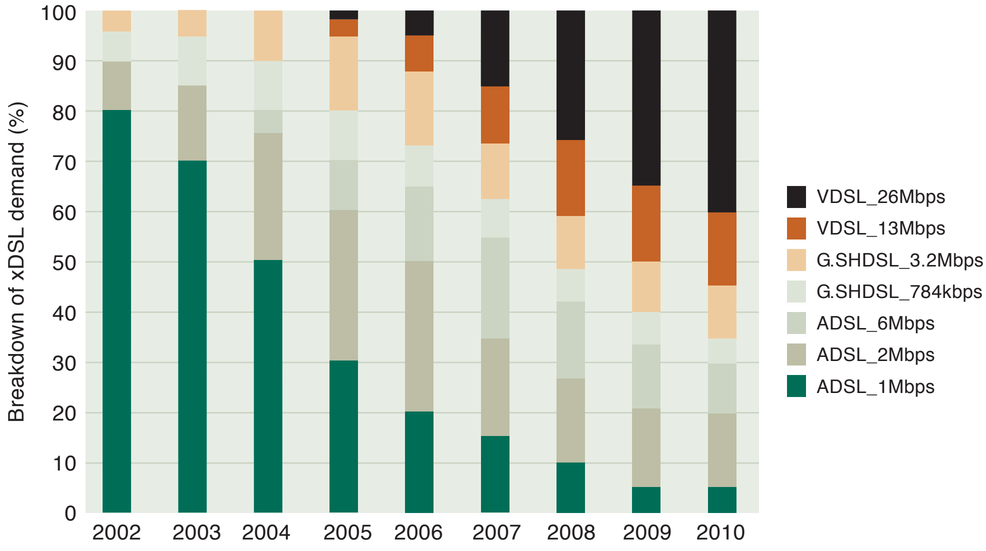


Figure 4 Breakdown of xDSL service demand

customer. If the operator decides to invest in a VDSL upgrade, all services will eventually be delivered over VDSL. In order to secure economy of scale and easier operation, a "multi service DSLAM" type of ONU is chosen. In this study, there has been no analysis of crosstalk (NEXT and FEXT) between xDSL sources. At the local exchange, an OLT (optical line transmitter) system is installed to feed the ONUs. The OLT has a built-in ATM cross-connect functionality. An OLT can handle up to 2048 customers. Normally one extra OLT for hot stand-by is required.

Figure 3 shows a sector of an exchange area with remote VDSL nodes. The ONU locations are labelled "LAP" (local access point).

3.4 Service Description

In 2002, the operator launches ADSL services in the area with up to 2 Mb/s downstream capacity as well as symmetric DSL services with up to 2.3 Mb/s capacity. For the symmetric DSL services, G.shdsl is used as it has far better spectral characteristics than "standard" SDSL. The DSLAM equipment at the local exchange and RSU locations handles both ADSL and G.shdsl line cards.

In 2004, 6 Mb/s ADSL service is offered, and asymmetric VDSL services of 13 and 26 Mb/s capacity are offered in 2005.

Figure 4 shows the breakdown of the different xDSL services during the time period as a percentage of the total number of subscriptions. The substitution effect over time is clearly seen. When more applications become available, more customers will be willing to pay for a 6 Mb/s ADSL service or a VDSL service.

The underlying business case assumptions are as follows:

3.5 Business Case Assumptions

Market share:
75 % (25 % for the LLUB operator)

Discount rate:
12 %

Content costs:
10 % of ADSL revenues and 20% of VDSL revenues

Sales costs:
ADSL type of service and symmetric DSL service: 50 % in 2002, 40 % in 2003, and 20 % 2004 – 2010 VDSL services: 50 % in 2005, 40 % in 2006, 30 % in 2007 and 20 % 2008 – 2010

Provisioning:
100 Euro per subscriber (one time cost)

General overhead:
10 % of total revenue

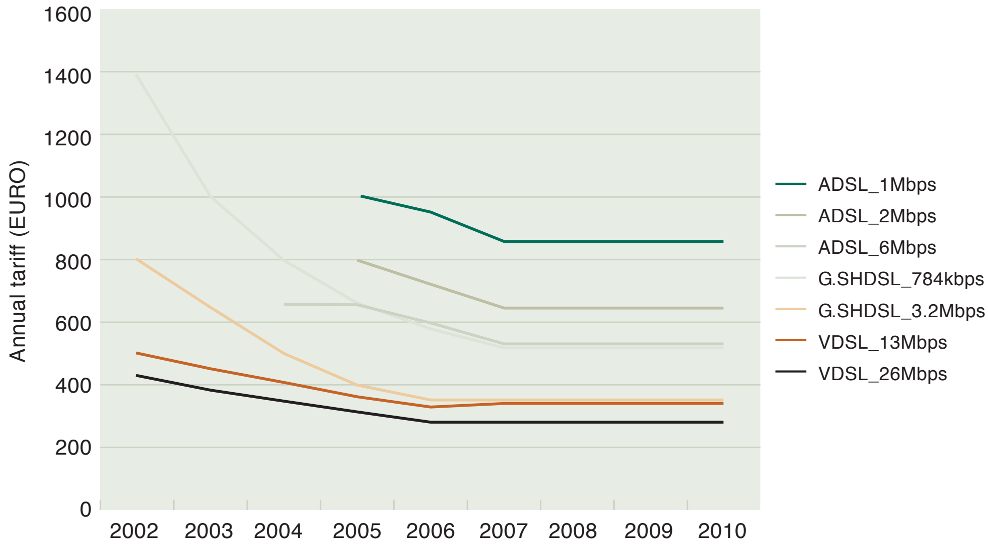
Infrastructure costs per remote node:
45,000 Euro: digging, ducting, cabinet incl. powering, copper network restructuring and all installations

The annual subscription tariffs are given in Figure 5.

3.6 Results – DCF Approach

For each take-up scenario, NPVs have been calculated both with and without a VDSL upgrade in 2004. In the latter case, the operator only offers ADSL and symmetric DSL services over G.shdsl throughout the period.The latter case will be named "ADSL only" in the following.

Figure 5 Annual tariffs



Scenario	Phase 1	Phase 2 ADSL only	Total ADSL only	Phase 2 VDSL	Total VDSL
1	–466.7	1,420.4	953.7	416.3	–50.4
2	–476.9	1,463.0	986.2	588.5	111.6
3	–508.7	1,682.5	1,173.8	1,234.8	726.1

Table 3 Net present values

The net present values (NPV) for the three take-up scenarios are given in Table 3 with and without VDSL upgrade.

For later use, the total NPVs have been split into two phases:

- NPV of the first phase: "ADSL only" cash flows 2002 – 2004
- NPV of the second phase:
  - Large discretionary VDSL investment in 2004, cash flows from full xDSL service set 2005 – 2010;
  - "ADSL only" cash flows 2005 – 2010 in case of no VDSL upgrade.

As seen in Table 3 the decision with *today's* information is not to go for a VDSL upgrade in the area in 2004: for every take-up scenario, the NPV is higher when sticking to the "ADSL only" path and avoiding the VDSL upgrade.

The methodology of real options in Section 2 explained the analogy between a financial call option and an investment project. We will now use the framework on the already established cash flows of the VDSL investment project.

As we will demonstrate in the following, the mapping of the investment project into a call option is direct, once the DCF analysis is available.

The formula of Black and Scholes is used to calculate the adjusted NPV.

Table 4 shows the cash flows of the entire xDSL project in the period 2002 – 2010 shown for Scenario 3. The unit in the following is 1000 Euro.

We see that the resulting cash flow has a large negative value in 2004 due to the investment in VDSL basic infrastructure and electronics.

Table 4 Cash flows, Scenario 3

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Revenues	65.9	181.1	344.6	674.9	1,026.6	1,495.7	2,132.9	2,768.8	3,318.6
COGS	5.0	14.6	28.3	55.8	100.1	173.7	292.3	417.6	531.2
Revenue margin	*60.9*	*166.6*	*316.2*	*619.1*	*926.5*	*1,322.0*	*1,840.6*	*2,351.2*	*2,787.4*
OA&M costs	58.8	124.3	177.3	337.9	509.1	676.4	818.4	1,008.9	1,185.0
CAPEX	243.9	79.1	3,327.1	468.0	203.5	56.4	92.0	9.6	10.3
CF BIT	(241.8)	(36.8)	(3,188.2)	(186.7)	213.9	589.2	930.2	1,332.8	1,592.1
Terminal Value									3,683.8
DCF	(241.8)	(32.9)	(2,541.6)	(132.9)	136.0	334.3	471.3	602.9	2,130.8
NPV	**726.1**								

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Revenues	65.9	181.1	344.6						
COGS	5.0	14.6	28.3						
Revenue margin	*60.9*	*166.6*	*316.2*						
OA&M costs	58.8	124.3	177.3						
CAPEX	243.9	79.1	432.5						
CF BIT	(241.8)	(36.8)	(293.6)						
DCF	(241.8)	(32.9)	(234.0)						
NPV	**(508.7)**								

Table 5 Cash flows, Scenario 3 – initial phase

The cash flows of the two phases are given in Tables 5 and 6.

The traditional NPV value of the VDSL phase would actually be much lower, namely 440.5k Euro. This is so because the large discretionary VDSL infrastructure investment in 2004 is discounted at the same 12 % as the uncertain operating cash flows governed by highly uncertain revenues and operating costs. This is the common mistake of over-discounting future investments. Although the infrastructure costs are high, the uncertainty is minimal. As a result, Table 3 gives too optimistically biased values for the NPVs!

In Table 7 the large discretionary infrastructure investment X and the total discounted operating cash flow S have been isolated.

The option calculation formula is given in the Appendix. Using a volatility of 60 %, the NPV of the second phase is 2,628.1. For the total NPV of the project we get 2,119.4 kEuro. This value is far from 726.1 kEuro and even further from 440.5 kEuro (with correct discounting) using DCF! And most important: it is much higher than the NPV of sticking to the “ADSL only” path (1,173.8 kEuro). The large uncertainty therefore makes it more probable that a VDSL upgrade investment will be incurred in 2004.

The options-based NPV is the expected value with uncertainty and flexibility included – given in today’s money.

Results – Real Options Approach

A summary of NPVs is given for three different scenario forecasts and for two different values of the volatility: 60 % (high uncertainty) and 20 % (low uncertainty).

For all take-up scenarios, the options-based NPV is significantly different from – and higher than – the NPV of the “ADSL only”case.

However, a low volatility of 20 % means that the expected deviance from the default assumption on expected return is small. The NPV of the second phase is only marginally larger than for the “ADSL only” case, e.g. 1,455.3 versus 1,420.4 kEuro.

As expected, the difference between traditional NPV values and the options-based NPVs is small for a small volatility: there is little likelihood of new information that can skew the default “bad” case of the VDSL investment in 2004 towards the upside. The probability of a VDSL upgrade investment is therefore vanishing which means that the value of flexibility is insignificant.

Table 6 Cash flows, Scenario 3 – VDSL phase

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Revenues				674.9	1,026.6	1,495.7	2,132.9	2,768.8	3,318.6
COGS				55.8	100.1	173.7	292.3	417.6	531.2
Revenue margin				*619.1*	*926.5*	*1,322.0*	*1,840.6*	*2,351.2*	*2,787.4*
OA&M costs				337.9	509.1	676.4	818.4	1,008.9	1,185.0
CAPEX			2,894.6	468.0	203.5	56.4	92.0	9.6	10.3
CF BIT			(2,894.6)	(186.7)	213.9	589.2	930.2	1,332.8	1,592.1
Terminal Value									3,683.8
DCF			(2,307.6)	(132.9)	136.0	334.3	471.3	602.9	2,130.8
NPV_2	**1,234.8**	Total NPV,	’02 – ’10	=	(508.7)	+	1,234.8	=	726.1

	0 2002	1 2003	2 2004	3 2005	4 2006	5 2007	6 2008	7 2009	8 2010
Revenues				674.9	1,026.6	1,495.7	2,132.9	2,768.8	3,318.6
COGS				55.8	100.1	173.7	292.3	417.6	531.2
Revenue margin				*619.1*	*926.5*	*1,322.0*	*1,840.6*	*2,351.2*	*2,787.4*
OA&M costs				337.9	509.1	676.4	818.4	1,008.9	1,185.0
CAPEX – initial			2,894.6						
CAPEX – follow-up				468.0	203.5	56.4	92.0	9.6	10.3
Operating CF				(186.7)	213.9	589.2	930.2	1,332.8	5,275.8
CF BIT			(2,894.6)	(186.7)	213.9	589.2	930.2	1,332.8	5,275.8
DCF			(2,307.6)	(132.9)	136.0	334.3	471.3	602.9	2,130.8

$T - \sigma\sqrt{T} = 60\ \% \times \sqrt{2} \approx 0.85$ $\qquad r_f$ 5.5 %

X – To be discounted at the risk-free rate

S – 3,542.4 (by discounting by 12 % to 2002)

PV of Phase 2 in "ADSL only" case $\qquad V$ – 1,682.5 (by discounting by 12 % to 2002)

"Hurdle cost" to be exceeded in 2004 is therefore equal to $X'' = X + (1 + r_D)^2\ V$ $\qquad$ 5,005.1

Adjusted NPV for Phase 2: $\mathbf{NPV_{adj,2}}$ $= c = \upsilon(S, X'', r_f T, \sigma\sqrt{T}) + N(-(\ln(S / X') + r_f T - \sigma^2 T / \sigma\sqrt{T}))V$

Total NPV is therefore: $\mathbf{NPV_1 + NPV_{adj,2}} =$ (508.7) + 2,628.12 = **2,119.4**

Table 7 Identifying the option parameters

Scenario	Total VDSL DCF, corrected	Phase 2 VDSL RO: σ = 20 %	Total VDSL RO: σ = 20 %	Phase 2 VDSL RO: σ = 60 %	Total VDSL RO: σ = 60 %
1	-335.9	1,455.3	988.6	1,986.7	1,520.0
2	-173.9	1,516.1	1,039.2	2,106.7	1,629.9
3	440.5	1,843.8	1,335.1	2,628.1	2,119.4

Table 8 NPV – real options versus traditional DCF approach

4 Rural Area Case Study

4.1 Background

There is a high level of political interest to provide broadband access in areas and sectors where the economic prerequisites for offering broadband services are rather poor. TONIC, an international research programme funded by the EU where Telenor is participating, has analysed the ADSL, LMDS, DTT, RCST and even VDSL technology for different country groups and country areas characteristics in Europe and quantified the additional costs required to build broadband network in these areas compared to the densely populated and competitive areas. The results provide valuable information for policy makers and for the EU Commission concerned with the additional support measures for offering broadband communication to these areas/sectors.

In rural areas in the Nordic countries, household densities typically vary from 3 to 15 households per km^2. Techno-economic calculations have shown that it is generally unprofitable to promote ADSL services without substantial subsidisation from government/local government in these areas. This is also illustrated in Figure 6. The investment levels for VDSL, LMDS and ADSL increase enormously when we go from Villages to Rural areas.

Many people see Digital Terrestrial Television as an alternative technology for providing broadband services to rural areas. From the figure above we can see that the increase in investment levels is significantly lower for DTT than for other technologies, when moving from Villages to Rural areas. With DTT, broadband Internet access can be provided on a more general basis to consumers in rural areas using the DTT

Broadband small-cell technique (IP Unicast over DVB). This can be accomplished in a cost-effective manner, covering large geographical areas in a short time without digging new cables or fibres. In addition, this technology can provide portable and even mobile broadband Internet Access.

DTT is well suited for providing TV services to large areas, both to fixed and portable receivers. The cost for the head-end and the transmitting network is the same whether one or several million viewers receive the signals simultaneously.

The home installation includes one digital set-top box. A dedicated PC card is used in a PC at the receiving end. An ISDN line was used for the return channel. GSM/GPRS works just as well. The home network solution is illustrated in Figure 7. Since the transmitting method is based on the DVB standard the PC also displays the TV channels.

However, a lot of uncertainties are associated with a commercialisation of this product:

- Licence application for use of broadcasting frequencies;
- Price models and market for broadband access;
- New technology, and little experience from commercial rollout;
- The evolvement of equipment prices;
- Network planning, to avoid overlap and cannibalisation of ADSL customers.

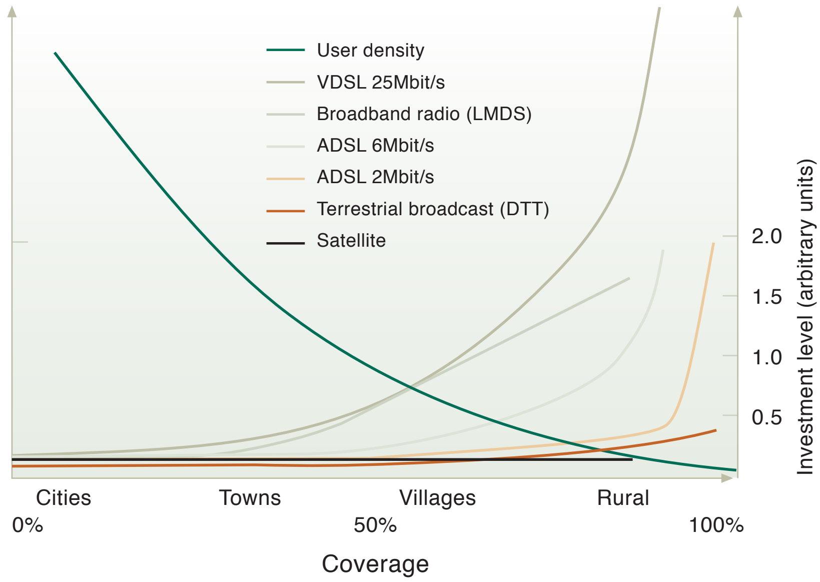


Figure 6 Comparisons of technologies, cost and coverage

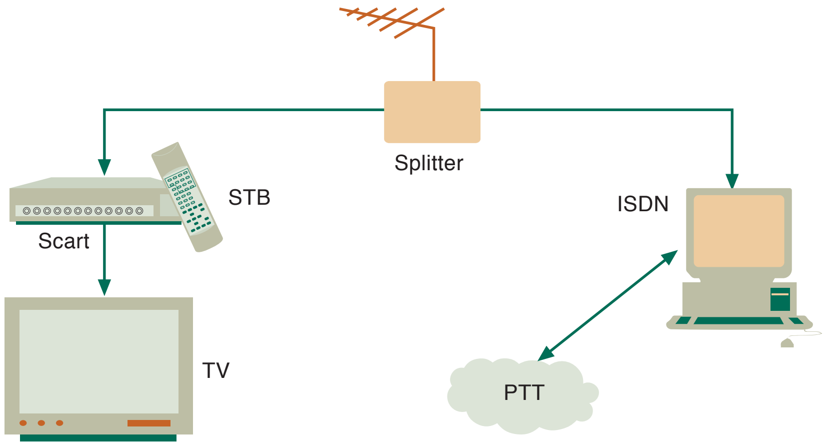


Figure 7 Home network

4.2 The Case Study

To resolve the technical uncertainties mentioned above, the operator has to run a pilot covering a representative rural area in either 2002 or 2004.

In scenario 1 this pilot is assumed to start up in 2002 and run for one year. Commercial rollout will take place in 2003. In scenario 2, the pilot is postponed until 2004 and commercial rollout will start in 2005.

The cost of running a pilot is 700,000 Euro. The number of pilot users is approximately 200. The very high cost of establishing and running a pilot is due to large investments in DVB multiplexers. No revenues are collected from the one-year pilot period.

The possibility of deferral of pilot gives rise to two sources of values. First, we would rather pay later than sooner, all else being equal, because we can earn the time value of money on the deferred pilot investment costs. Second, while we are waiting, the world can change. Specifically, the present value of the operating cash flows may change. Penetration, willingness to pay and service and application development are far more uncertain than cost of equipment.

4.3 Business Case Assumptions

Figure 8 illustrates how the subscriber penetration levels will increase from 2 % in 2002 to almost 25 % in 2010. The potential number of households that may subscribe to DTT services, given our assumptions about coverage and household density are approximately 100,000. A 25 % penetration means that about 25,000 households will have a DTT subscription in 2010.

The average revenue per user, ARPU, is increasing from 480 Euro in 2003 to almost 700 Euro in 2010. This is due to the assumption that devel-

Assumptions	Value	Description
Cost of pilot	700,000 Euro	Cost of establishing and running pilot for one year. 200 pilot users are assumed
Commercial rollout	1 year after pilot start	4 geographic areas similar to the pilot area
ARPU in 2003	540 Euro	3 % annual growth
Cell radius	35 km	Radius of cell in km
Household density	5 household	Number of households per km^2
Households per cell	19,200	Potential households covered by each cell
Discount rate	12 %	Pre-tax discount rate
Capex elements		Access cost (Transmitters, combiners, GPS receivers, antennas, installation) Backbone cost (Network adapter, radio link equipment, installation cost) Head-End cost (DVB Multiplexers, IP-encapsulator)
Opex elements		ISP-rental cost, call-center, network monitoring, transmitter consumption, return channel (ISDN) cost

Table 9 Assumptions

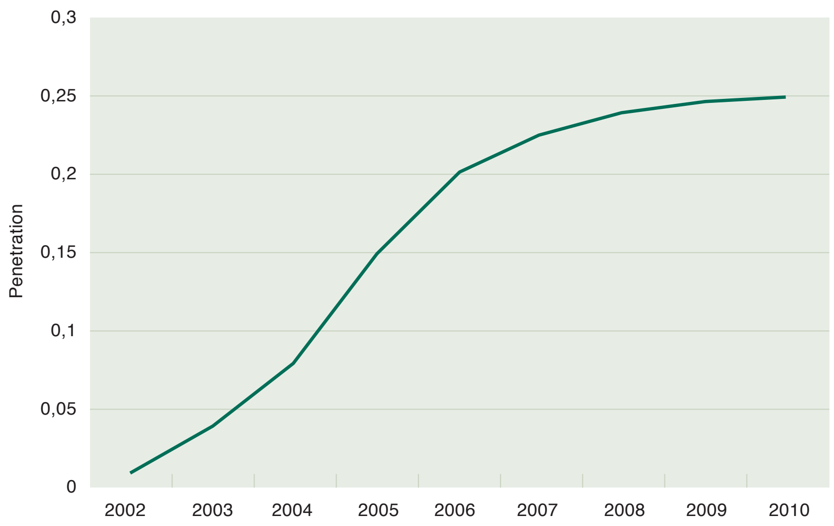
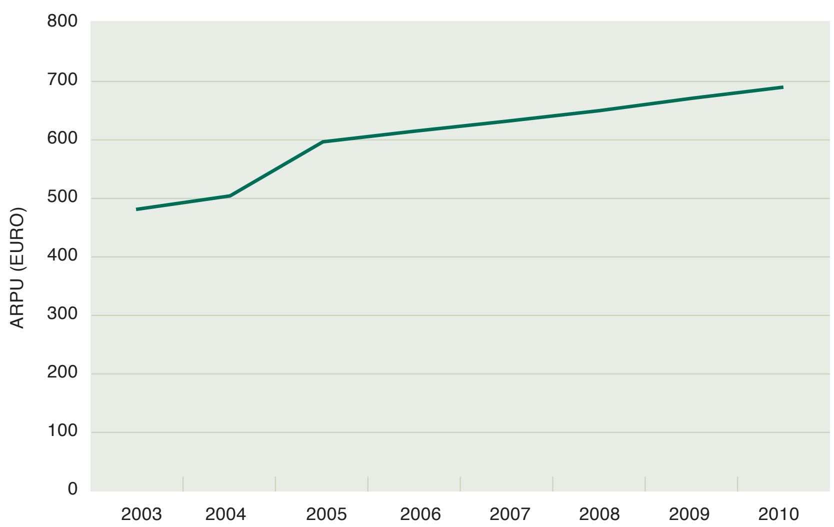


Figure 8 Subscriber penetration assumption, DTT services

Figure 9 ARPU assumptions



opment of new applications and content will increase usage and thereby ARPU. We have assumed an annual increase of 3 % in ARPU from 2005 to 2010.

4.4 Results

During the pilot phase of one year, no revenues are received. The total cash flows are calculated for two choices of the pilot launch, 2002 and 2004. The results are shown in Tables 9 and 10.

Using the right discounting of the pilot upfront investment in 2004, the NPV would be only 270,477 Euro. As in Section 3.6, we will incorporate the value of flexibility hidden in the two years postponement of the pilot start-up. The option pricing parameters are calculated as in Section 3.6. The "strike price" X is the total investment in 2004, which is 720,750. The "asset value", S, is equal to the present value of the uncertain cash flow, which in this case is the operating cash flow minus the follow-up investments (investments governed by number of subscribers 2005 – 2010). We get S = 911,942 Euro.

In Table 12 the traditional NPV is compared to the adjusted NPV (including the value of flexibility) for different values of the volatility.

For the highest value of volatility, the value of flexibility is more than 20 % of the NPV of the entire upfront investment in 2004!

For the lowest value of volatility, the value of flexibility is low and therefore the difference between tradition and adjusted NPV is small.

The NPV is extremely sensitive to the ARPU assumption. For higher ARPU values, the case will turn highly profitable resulting in a vanishing flexibility value even for high volatilities.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Revenues		923,160	2,907,954	6,579,919	10,313,308	12,899,002	14,536,416	15,696,985	16,499,543
OPEX	101,735	1,837,991	3,648,681	6,820,983	9,095,128	10,246,575	10,934,568	11,285.752	11,398,022
EBITDA	(101,735)	(914,831)	(740,727)	(241,064)	1,218,180	2,652,427	3,601,848	4,411,233	5,101,521
CAPEX	720,750	873,750	1,747,500	1,747,500	1,747,500	873,750	873,750	0	0
Cash flows, CF	(822,485)	(1,788,581)	(2,488,227)	(1,988,564)	(529,320)	1,778,677	2,728,098	4,411,233	5,101,521
DCF	(822,485)	(1,596,947)	(1,983,599)	(1,415,421)	(336,392)	1,009,269	1,382,139	1,995,418	2,0060,419
NPV	**1292,401**								

Table 10 Cash flows, total operation: Scenario 1, pilot in 2002, rollout 2003

5 Conclusions

We have shown that a considerable impact on the NPV of future infrastructure investments can be expected when taking the uncertainty and the flexibility in timing into account. This will inevitably alter the way by which an operator should plan medium- and long-term infrastructure rollouts. Using conventional NPV calculus can therefore give misleading results and a wrong focus with respect to investment portfolios. Rollout projects that might turn out to be a valuable part of future project portfolios might be abandoned completely using a conventional NPV methodology. This is an important learning as the competition between investment projects and funding within large companies is often high.

In case of lack of flexibility due to high competition or if a project is highly profitable with default (read: conservative assumptions), then there is no/insignificant option value. The real options approach does therefore not alter the conclusions found from the conventional NPV approach in such cases.

The real options methodology has the strength to be applied directly in already prepared detailed cash flow statements found everywhere. The methodology does not, therefore, discard the "old" framework but augments it in order to capture new insight, which is of great importance in decision-making under high uncertainty.

6 References

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2 Kalhagen, K O (ed.), Olsen, B T et al. *Provision of Broadband Services in Non-competitive Areas in Western European countries*. ISSLS 2002, Seoul, Korea, Apr. 14–18, 2002.

3 Kalhagen, K O, Elnegaard, N K. *The Economics and Risks of 3rd Generation Mobile Service Deployment*. 3G 2002, Amsterdam, 20–23 May 2002.

4 Stordahl, K, Rand, L. Long term forecasts for broadband demand. *Telektronikk*, 95 (2/3), 34–44, 1999.

Table 11 Cash flows, total operation: Scenario 2, pilot in 2004, rollout 2005

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Revenues				4,005,168	9,723,976	12,443,743	14,223,805	15,455,493	16,416,631
OPEX			98,860	6,328,779	8,646,049	10,022,035	10,710,029	11,173,482	11,398,022
EBITDA			(98,860)	(2,323,611)	1,077,927	2,421,707	3,513,776	4,282,010	5,018,609
CAPEX			720,750	4,368,750	1,747,500	873,750	873,750	0	0
Cash flows, CF			(819,610)	(6,692,361)	(669,573)	1,547,957	2,640,026	4,282,010	5,018,609
DCF			(653,388)	(4,763,490)	(425,525)	878,353	1,337,519	1,936,964	2,026,932
NPV	**337,364**								

Traditional NPV	Adjusted NPV, σ = 10 %	Adjusted NPV, σ = 20 %	Adjusted NPV, σ = 40 %	Adjusted NPV, σ = 60 %
270,477	290,902	283,406	340,778	411,691

Table 12 Adjusted NPVs for different values of volatility: Scenario 2, pilot in 2004

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7 Appendix: A Mathematical Presentation of the Real Option Methodology

The model of stock behaviour is a so-called geometric Brownian motion. The discrete time version of the model is given by

$$\frac{\Delta S(t)}{S(t)} = r_f \Delta t + \sigma \varepsilon \sqrt{\Delta t}$$

The variable ΔS is the change in stock price, S, or asset in a small amount of time, Δt. σ is the volatility, r_f the drift rate – here the risk free rate of return, and ε is a random number drawn from a Normal distribution with zero mean and a standard deviation of 1. It can be shown that $S(t)$ is lognormal distributed with mean value

$$\mu_t = \ln\left(S(0)\right) + \left(r_f - \frac{\sigma^2}{2}\right) t$$

and a standard deviation of $\sigma_t = \sigma\sqrt{t}$.

The asset, in our case the total discounted value of the operating cash flow of a VDSL infrastructure rollout in the future, T, is estimated at $S(0) \equiv S$ with today's information. During the time leading up to decision time T, the operator will receive information on market potential, technology, competition etc., and the asset value will therefore move up or down with accumulated volatility $\sigma\sqrt{t}$.

The investment is only incurred if $S(T) \equiv S_T > X'' = X + (1 + r_D)^2 V$, X being the initial investment at time T in the VDSL infrastructure rollout, V the NPV of Phase 2 if VDSL is not offered, i.e. "ADSL only", and r_D is the discount rate of 12 %.

The NPV at time T is therefore defined as: NPV = $E\{\max(S(T) - X,(1 + r_D)^2 V)\}$. We get:

$$E\left\{\max\left(S_T - X, (1+r_D)^2 V\right)\right\} =$$

$$\int_{X''}^{\infty}(S_T - X)p(S_T)dS_T + \int_0^{X''}(1+r_D)^2 V p(S_T)dS_T$$

where $p(S_T) = \frac{1}{\sigma_T\sqrt{2\pi}S_T}\exp\left[\frac{-(\ln(S_T)-\mu_T)^2}{2\sigma_T^2}\right]$

After straightforward but tedious algebra[2], one gets:

$$\text{NPV} = \exp(-r_f T)\left(SN(d_1)e^{r_f T} - XN(d_2)\right) + V\left(1 - N(d_2)\right)$$

where

$$d_1 = \frac{\ln(S/X'') + (r_f + \sigma^2/2)T}{\sigma\sqrt{T}},$$

$$d_2 = \frac{\ln(S/X'') + (r_f - \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

where $N(y)$ is the cumulative normal distribution with zero mean and a standard deviation of 1.

8 Acronyms

ADSL	Asymmetric digital subscriber line
ARPU	Average revenue per user per year
CAPEX	Capital Expenditure
COGS	Cost of goods sold
DCF	Discounted cash flows
DSLAM	Digital Subscriber Line Access Multiplier
DTT	Digital Terrestrial Television
EBITDA	Earnings before interest, taxes, depreciation and amortization
FEXT	Far end cross talk
HFC	Hybrid Fibre Coax
LAP	Local access point
LEX	Local exchange
NEXT	Near end cross talk
OA&M	Operations and maintenance
OLO	Other licensed operators
OLT	Optical Line Transmitter
ONU	Optical network unit
OPEX	Operating expenditures
VDSL	Very high-speed digital subscriber line
xSP	Service provider

[2] *By making use of the substitution* $w = \ln(S_T) \Rightarrow S_T = e^w$, $dS_T = e^w dw$.

Deciding on Optimal Timing of ADSL and VDSL Rollouts for Incumbents

NILS KRISTIAN ELNEGAARD AND KJELL STORDAHL

The battle between DSL operators and cable operators has started and the question is how the market shares wil evolve. This paper analyses a set of different broadband access rollout scenarios for an incumbent operator in dense urban areas where the cable operator has the possibility of upgrading the cable network to an HFC architecture. The focus is on the residential market and SOHO markets. The challenge for the incumbent operator is to roll out ADSL and VDSL at the right time. The timing for xDSL rollout depends on HFC penetration and rollout and additional factors like infrastructure, area characteristics, component costs, mass production of network components, applications offered, expected tariff evolution, willingness to pay, demand forecasts and evolution of expected market share.

Net present value (NPV), payback period and internal rate of return (IRR) have been calculated by use of a techno-economic tool developed in the projects AC 226/OPTIMUM, AC 364/TERA and IST 2000-25172 /TONIC in order to estimate each rollout alternative. To establish a robust optimal rollout strategy, a risk simulation tool, Crystal Ball, has been used together with techno-economic modelling. For each rollout alternative, a Monte Carlo simulation of 1000 runs is performed for the risk analysis.

Risk analysis takes into account the uncertainties in the critical factors demand, tariffs, market share, and cost evolution of specific equipment. Instead of using single values as input to the calculations, probability distributions of each critical factor are used as input. The probability distributions characterise the uncertainties of the predictions to each factor. The "optimal" ADSL/VDSL rollout strategy is developed, taking into account both the mean values of the NPV and IRR, and the risk involved.

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Kjell Stordahl (57) received his M.S. in statistics from Oslo University in 1972. He worked with Telenor R&D for 15 years and with Telenor Networks for 15 years, mainly as manager of Planning Department Region Oslo and then Market analysis. Since 1992 he has participated in various techno-economic EU projects (TITAN, OPTIMUM, TERA, TONIC) analysing rollout of different broadband technologies. Kjell Stordahl has been responsible for working packages on broadband demand, forecasting and risk analysis in these projects. He has published more than 130 papers in international journals and conferences.

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1 Introduction

During 1999 – 2000, ADSL was launched by most of the European incumbent operators as well as a number of ISPs.

As the first European incumbent operator Telenor introduced a large VDSL pilot with 700 subscribers, medio 2001. In parallel, some Western European cable operators have started to upgrade their networks deploying HFC solutions. The incumbent operators face further competition from Local Loop Unbundling and in the future, LMDS and UMTS operators. The incumbent operator will meet the competition by starting to roll out ADSL and after some years VDSL with the potential of a much broader spectrum of services including video-on-demand and multimedia applications. This paper examines various rollout and market share scenarios for the incumbent operator. The timing for rollout of ADSL and VSDL is crucial.

2 The Rollout Case Study

The rollout case study analyses a dense urban metro area consisting of 65,536 POTS/ISDN lines (four local exchange areas with 16,384 lines each). The penetration of POTS and ISDN is ~100 % and the average density of the metro area is 2,000 households per km^2. A cable operator is deploying an HFC network with cable modems, while the incumbent operator is expanding the network to a DSL network.

The cable operator already offers ordinary TV distribution to their customers in the area under study, while the incumbent operator offers POTS/ISDN and Internet. The introduction of ADSL gives the possibility to offer a large set of new applications like high-speed Internet, various home office applications and multimedia applications, but not high quality interactive entertainment applications. VDSL and HFC are assumed to be competitive solutions, which in addition offer high quality broadband like interactive entertainment applications, etc. The churn rate for HFC and VDSL customers is rather low compared to the churn rate for ADSL customers as the former are strongly linked to the operators by service bundling.

We consider the service offering as shown in Table 1.

3 Technical Description

ADSL is delivered to the customers from DSLAMs at the local exchange or RSU location – each DSLAM handles up to 768 customers. VDSL is delivered from optical network units (ONUs) placed in outdoor cabinets as well as at the local exchange.

Different vendors use different names for the ONU – sometimes 'DSLAM' is used. Up to 128 users per ONU is assumed. No passive splitters are used in the architecture. An optical fibre cable carrying 24 fibres feed each ONU. Twisted pair copper is used for the remaining path to the customer. In this study, there has been no analysis on crosstalk (NEXT and FEXT) between xDSL sources.

Table 1 Capacity classes

Downstream Capacity [Mb/s]	Upstream Capacity [Mb/s]	XDSL Technology
1.024	0.256	ADSL
2.028	0.512	ADSL
6.144	0.640	ADSL
24.576	4.096	VDSL

4 Prediction of Network Component Costs

The extended learning curve for prediction of component costs has been developed in the RACE 2087/TITAN project and further developed in the ACTS 226/OPTIMUM and ACTS 364/TERA projects. The cost prediction curve depends on a set of parameters: the reference cost at a reference time, learning curve coefficient which reflect the type of component, initial product volume and growth in production volume of the component. The TONIC cost database contains estimates of these parameters for all components and generates cost predictions based on the extended learning curve. The cost prediction of each network component is described by expansion of the learning curve given as a function of the parameters:

$f(0)$ the predicted costs at time 0;

$n(0)$ the relative proportion of produced components at time 0;

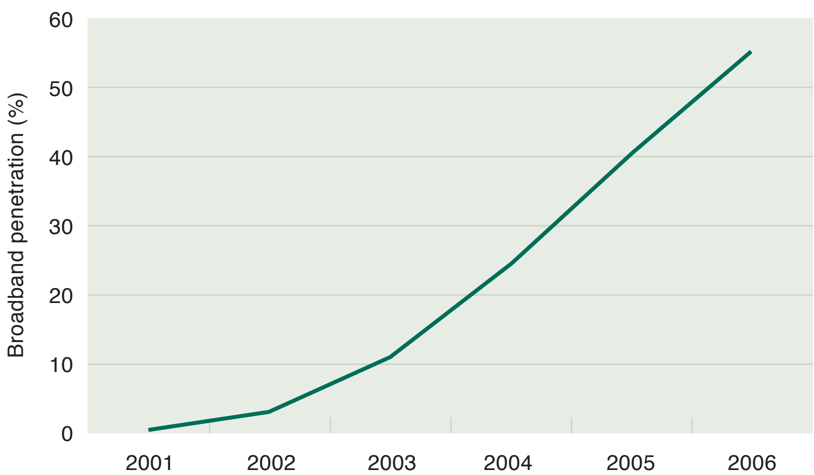
ΔT the time interval between 10 % and 90 % penetration;

K the learning curve coefficient (relative decrease in the cost by doubling of the production volume).

The extended learning curve function is:

$$f(t) = f(f(0), n(0), \Delta T, K, t) = f(0)\,[n(0)^{-1}(1 + \exp[\ln(n(0)^{-1} - 1) - 2\,t\,\ln 9/\Delta t])^{-1}]^{\log_2 K}$$

Figure 1 Total broadband penetration forecasts



5 Total Broadband Penetration (Demand)

The broadband forecasts are based on a Delphi survey and additional forecast demand data from the TERA project and the TONIC project [1, 2, 4, 5, 8]. The forecasts show the demand evolution in a highly competitive residential market where two broadband operators are rolling out a broadband network infrastructure. The broadband penetrations in these competitive areas are expected to be high. The cable operator is expected to have a significant part of the broadband market in these areas because of heavy investments, ownership to the CATV customers and performed marketing activities. An extended Logistic model with four parameters fits the total broadband demand forecasts:

$$Y_t = M / (1 + \exp(\alpha + \beta t))^{\gamma}$$

where Y_t is the demand forecast at time t; M is the saturation level; and α, β, γ are additional parameters.

The total broadband forecasts are split up by technology (operators) and access capacity. The market share evolutions are described in scenario 1 – 6, depending on different rollout strategies.

6 Tariff Evolution/Prediction

The broadband tariff structure is rather complex. In this case study the following tariffs are included: Connection tariff, access tariff, LLUB tariff and tariff for content.

Only some few European operators have so far introduced a traffic tariff when the monthly traffic volume exceeds a given limit. Because of heavy load in the transport network and the significant increase of streaming applications, there are reasons to believe that the incumbent operators have to adjust the broadband tariff regime. We assume a flat rate profile in 2002 and 2003 and introduction of traffic tariffs from 2004. In the tariff model is assumed a 10 % reduction of the access tariffs in 2003, 5 % in 2004 and then a constant “charging” level for the sum of access and traffic charges.

The annual charge for having a 1 Mb/s is set at 480 Euro in 2002. The tariff model is constructed in the following way: The basic tariff for 1 Mb/s is given (480 Euro). The model predicts an increase of 20 % for each doubling of the downstream capacity. The connection tariff is set at 150 Euro for 1 Mb/s, while the tariff is 200 Euro for higher capacities.

Figure 2 shows the erosion of the monthly subscriber tariff, which includes access tariff, service provider tariff and the traffic tariff. Expenses for content delivery are difficult to estimate. In this business case, it is assumed that content expenses constitute a mean 20 % of the VDSL tariff and 5 % of the ADSL tariff.

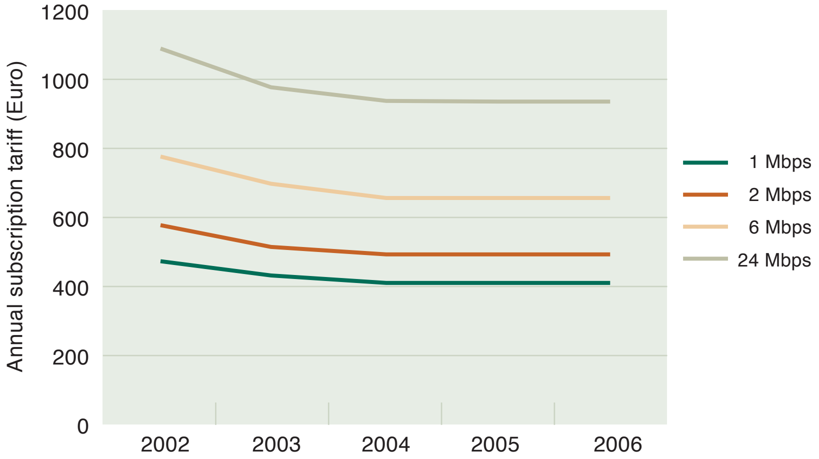


Figure 2 Tariff evolution for access capacities

7 Rollout Scenarios/ Market Share Scenarios

The competitors are classified as:

- Incumbent operator
- Cable operator
- LLUB operators
- Wholesale actors

It is assumed that the LLUB operators catch 20 % of the DSL market and keep that level during the study period. In the techno-economic calculations, revenue for leasing the copper lines is included for the incumbent operator. The risk analysis examines the consequences when the DSL market share deviates from 20 %.

Six different scenarios are studied. In scenario 1 and 2, the incumbent starts to roll out ADSL in 2001 and VDSL in 2002. Scenario 3 and 4 are based on a VDSL rollout in 2003 and ADSL in 2001/2002. In scenario 5 and 6 the VDSL rollout starts in 2004 and ADSL in 2001/2002. The cable operator starts to roll out the broadband infrastructure either in 2001 or 2002.

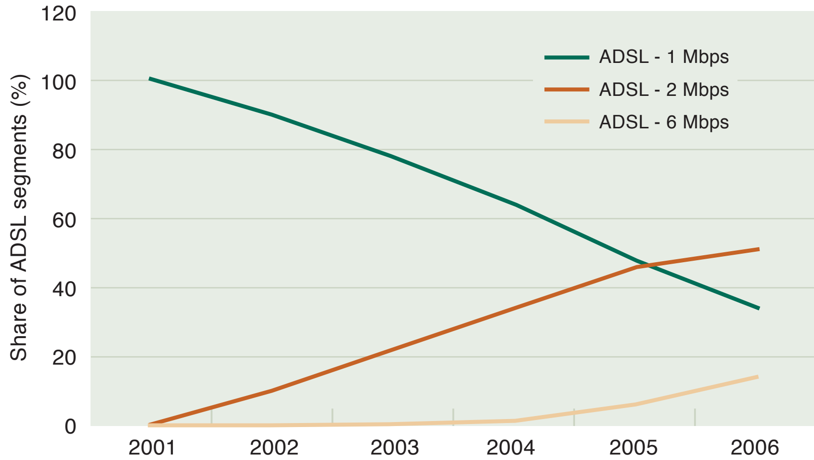


Figure 3 Prediction of market share for ADSL access capacities

Figure 3 shows the prediction of access demand distributed on the access capacities 1 – 6 Mb/s in the period 2001 – 2006. The figure shows that there will be a continuous demand for higher capacity. The demand is generated by new and enhanced broadband applications and the operators have to meet the capacity demand.

7.1 Scenario 1

The incumbent operator offers ADSL in 2001. The cable operator meets the challenge by deploying HFC and cable modems in 2002. In the same year the incumbent operator offers VDSL. Figure 4 shows the market share evolution. The ADSL market share is reduced from 100 % to less than 50 % from 2001 to 2002. The figure shows that the market share for ADSL gradually decreases. In spite of introducing VDSL at the same time as the cable operator, the incumbent operator has to fight very hard to get a high VDSL market share. It is difficult for the incumbent operator to win larger parts of the market since most of the subscribers have a TV channel subscription with the cable operator.

7.2 Scenario 2

Scenario 2 shows that the cable operator introduces broadband in 2001, while the incumbent operator is offering ADSL. The cable operator gets 70 % of the market and is able to hold the level during the study period in spite of the introduction of VDSL in 2002. Figure 5 shows the market share evolution.

7.3 Scenario 3

The incumbent operator offers ADSL in 2002. The cable operator meets the challenge by deploying HFC offering broadband subscriptions the same year. One year later the incumbent operator offers VDSL in the same area.

Figure 6 shows the market share evolution. The cable operator gets 50 % of the broadband market the first year since he has a more advanced

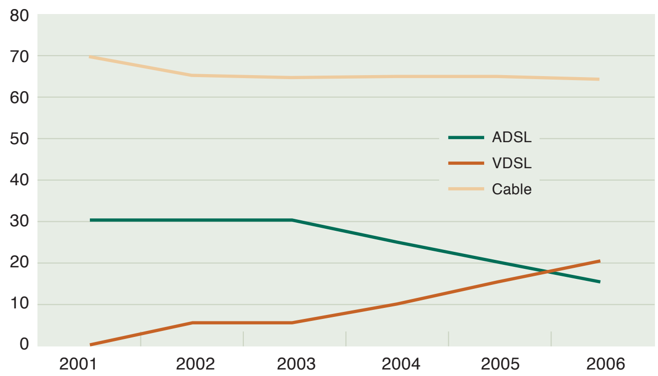


Figure 4 Scenario 1: Market share evolution ADSL, VDSL and cable modems in %

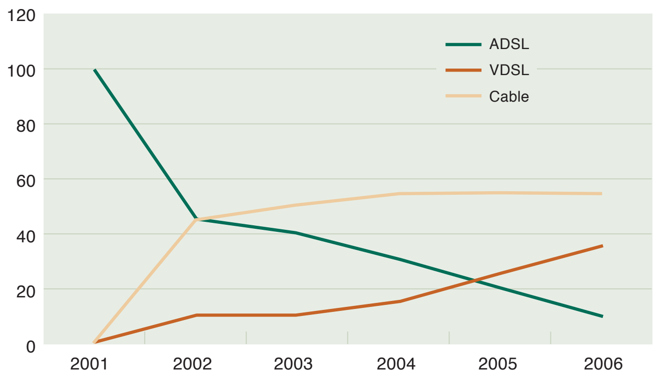


Figure 5 Scenario 2: Market share evolution ADSL, VDSL and cable modems in %

product. The operator takes more market share during the coming years by the introduction of VDSL.

7.4 Scenario 4

The incumbent operator offers ADSL in 2001. The cable operator meets the challenge by deploying HFC and cable modems in 2002. One year later, the incumbent operator offers VDSL in the same area. Figure 7 shows the market share evolution. The ADSL market share is reduced from 100 % to 50 % when the cable operator introduces broadband. The figure shows that the market share for ADSL gradually decreases during the study period. At the same time it is difficult for the incumbent operator to take a larger part of the broadband market.

7.5 Scenario 5

Scenario 5 describes the market share evolution when the cable operator starts to offer broadband services based on their HFC solution in 2001. The incumbent operator has installed an ADSL network in 2001 being able to offer the customers broadband and always-on Internet services. VDSL deployment is delayed and introduced in 2004.

Since the cable operator has delivered TV distribution for a long period, it is assumed that the cable operator starts with a market share around 80 %. The market share decreases slightly when the incumbent operator starts to offer VDSL. The evolution of market share is shown in Figure 8.

7.6 Scenario 6

The cable operator introduces broadband in 2001, while the incumbent operator is very defensive offering ADSL in 2002 and VDSL in 2003. The cable operator gets 100 % of the market the first year. Since the incumbent operator introduces VDSL two years later than the cable operator's broadband solution, in a market where the cable operator has delivered TV distribution to a large customer segment for a number of years, it is very hard to take market share. The incumbent operator ends up with a rather small market share at the end of the study period. Figure 9 shows the market share evolution.

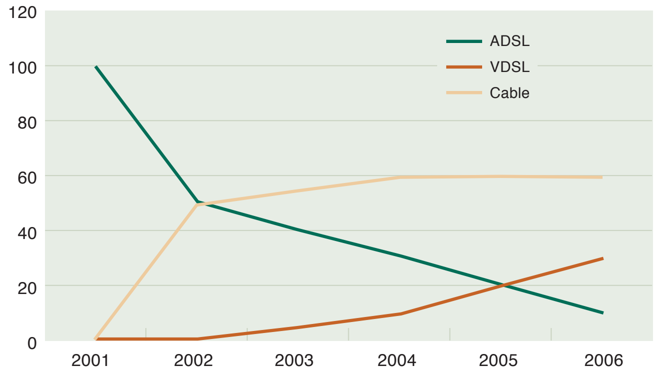


Figure 6 Scenario 3: Market share evolution ADSL, VDSL and cable modems in %

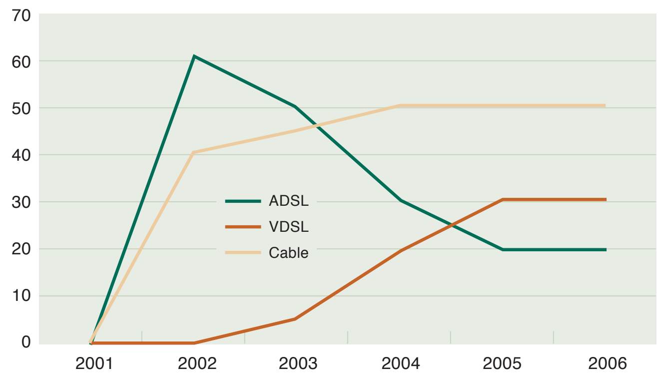


Figure 7 Scenario 4: Market share evolution ADSL, VDSL and cable modems in %

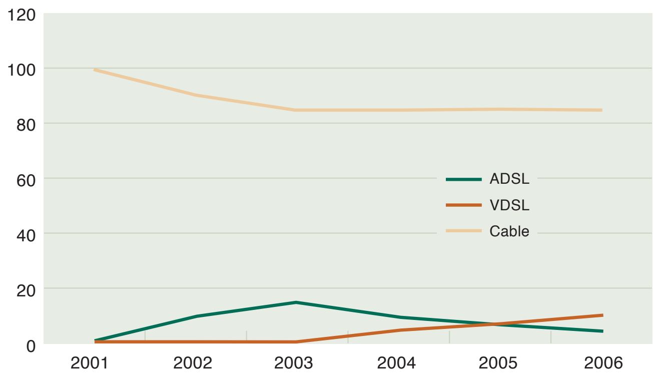


Figure 8 Scenario 5: Market share ADSL, VDSL and cable modems

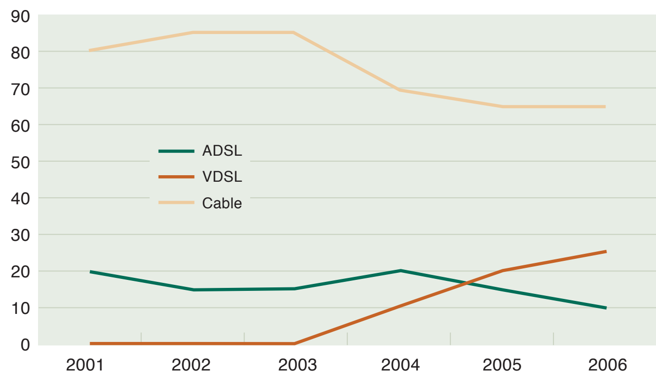


Figure 9 Scenario 6: Market share ADSL, VDSL and cable modems

8 Results

Within the European programs ACTS and IST the projects AC 226/OPTIMUM, AC364/TERA and IST 2000-25172 TONIC have developed a methodology and a tool for calculating the overall financial budget of any access architecture. The tool handles discounted costs of capital investments, operations, maintenance costs, life cycle costs and revenues, as well as net present value (NPV) and internal rate of return (IRR). The tool has the ability to combine low level, detailed network parameters of significant strategic relevance with high level, overall strategic parameters for performing evaluation of various network architectures [3, 6–7, 9–16].

The tool has been used to evaluate techno-economic results of the described scenarios. Figure 10 shows the calculated net present values for each scenario.

Figure 10 shows that the incumbent operator has to fight rather hard to get a positive net present value when the cable operator starts to roll out broadband in 2001 (Scenario 2, 5 and 6). The only possible way to get a significant part of the broadband market and acceptable net present values is to introduce ADSL and VDSL at the same time as the cable operator. In addition the incumbent operator to a certain degree has to meet the access tariffs of the cable operator. Scenario 6 represents a very defensive broadband rollout strategy for the incumbent resulting in a significant negative net present value. The reason is a too late rollout of broadband and as a result a too low market share.

The cable operators have not enough financial strength to roll out a broadband structure in all cable network areas during a short time. Hence, scenarios 1, 3 and 4 describe better possibilities for the incumbent. Figure 10 shows that the incumbent operators get rather good economic results by rolling out a broadband DSL network in parallel to or earlier than the cable operator.

Figure 11 shows that the internal rate of return for scenarios 1–5 is estimated to be in the 20 % – 30 % interval, while the net present values are in the 0.7 – 2.1 mill Euro interval.

9 Uncertainties and Risk Modelling

A series of risk analyses have been carried out – one for each of the six scenarios. 12 “uncertainty” variables are examined. The variables are divided into the following groups:

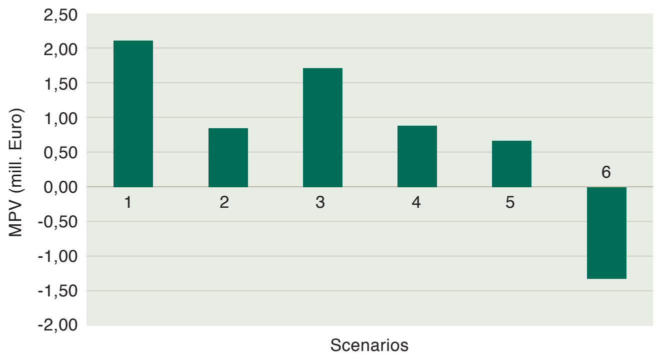


Figure 10 Net present value [mill Euro] for scenario 1–6

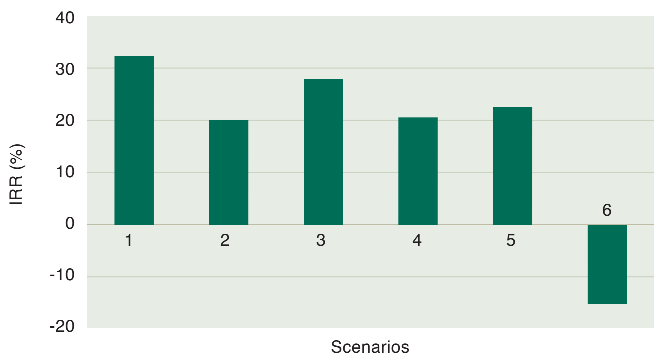


Figure 11 Internal rate of return for scenario 1–6

	Min value	Low conf. limit	High conf. limit	Max value
Total broadband penetration	0.73 P_t	0.82 P_t	1.09 P_t	1.18 P_t
Market share DSL (Scenario 1)	0.67 P_t	0.78 P_t	1.22 P_t	1.33 P_t
Relative share ADSL/VDSL in 2006	0.33 P_t	0.60 P_t	1.27 P_t	1.33 P_t
Relative share LLUB/DSL	0.50 P_t	0.75 P_t	1.25 P_t	1.50 P_t
General tariff changes in tariff level	0	0.25 ($P_t - P_{t-1}$)	1.25 ($P_t - P_{t-1}$)	1.50 ($P_t - P_{t-1}$)
Content cost VDSL	0.50 P_t	0.75 P_t	2.00 P_t	2.50 P_t
Content cost ADSL	0.3 P_t	0.8 P_t	2.00 P_t	3.00 P_t
Sales, marketing, billing	0.33 P_t	0.67 P_t	1.33 P_t	1.67 P_t
Provisioning	0.40 P_t	0.60 P_t	1.60 P_t	2.00 P_t
Network operations	0.43 P_t	0.71 P_t	1.43 P_t	1.71 P_t
Maintenance	0.70 P_t	0.80 P_t	1.20 P_t	1.50 P_t
Network component prices [1)]	–	0.86 P_t	1.20 P_t	–

[1)] *A Lognormal distribution has been used for the extended learning curve to simulate the time constant of the production volume curve.*

Table 2 Maximum and minimum values and 90 % confidence limits for input distributions in risk simulations

Penetration and market share uncertainty
- Total broadband penetration
- Market share DSL
- Relative share ADSL/VDSL
- Relative share LLUB/DSL

Tariffs
- General tariff erosion
- Content costs VDSL
- Content cost ADSL

Service provider costs
- Sales, Marketing, Billing
- Provision

Investments, maintenance
- Network operations
- Maintenance
- Network component costs

A Monte Carlo simulation with 1,000 trials is performed for each scenario. In each trial, a random number is picked from the predefined probability distributions; one for each of the uncertainty variables. The simulation gives as output the cumulative distribution of the NPV and the ranking of the uncertainty variables. This uncertainty ranking is based on the percentage to the contribution to the variance of the NPV or the rank correlation with the NPV. From the cumulative distribution, the probability that the project will produce a negative NPV is calculated. A commercial spreadsheet application Crystal Ball has been integrated with the techno-economic tool. A graphic interface in Crystal Ball makes it possible to specify the distribution functions directly from a palette type of menu inside the techno-economic model.

The risk methodology presented in this paper is based on the generalised Beta distribution of a variable in the closed interval [a, b] instead of the Normal distribution in order to avoid negative values in the simulations for variables that can only take non-negative values.

Given a and b as well as the 90 % confidence interval [c, d], the Beta distribution is fully described. A procedure that calculates the parameters for the Beta distribution given a, b, c and d has been developed.

Let P_t be the predicted value for an uncertainty variable at time t. Table 2 shows the maximum and minimum values and 90 % confidence interval used for the uncertainty variables in the risk model.

"Network component prices" in Table 2 are modelled by a Lognormal distribution, while the remaining variable are modelled by a Beta distribution.

The impact of the uncertainties on the NPV is of course highly dependent on the assumptions shown in Table 2 as well as the default values of the variables. It is important to underline that the broadband penetration is significantly increasing in the study period, while the prices on network components move the opposite way with large reductions.

10 Risk Analysis

For each trial in the Monte Carlo simulation, random values are generated for 12 specific variables based on the described risk model. For each trial a complete set of techno-economic calculations are performed including first installed

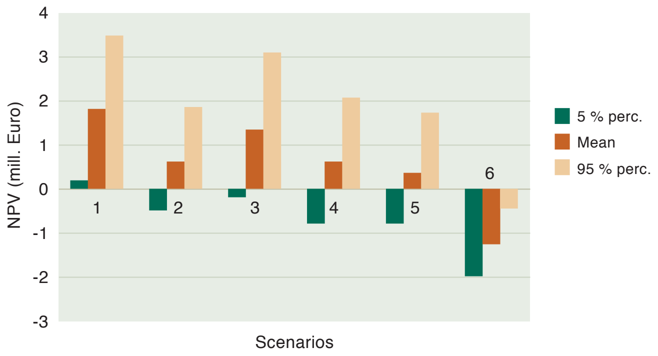


Figure 12 Probability to get a negative NPV

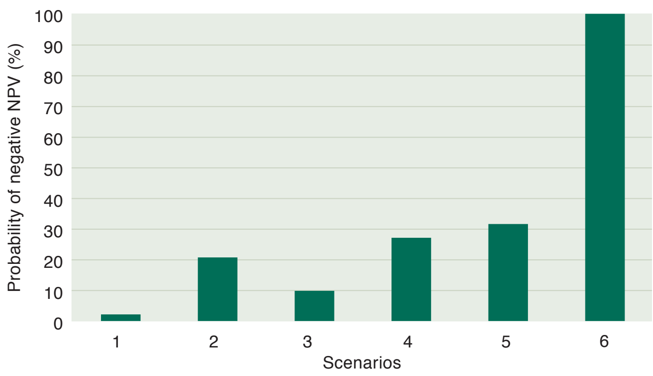


Figure 13 Critical NPV levels (5 % percentile, mean and 95 % pecentile)

costs, OAM costs, revenues, cash flow, IRR, NPV, payback period, etc. The set of 1,000 simulations generate an accumulated distribution for each output variable, e.g. NPV. The accumulated distributions are used to evaluate the risk; i.e. to calculate the probability for the variable to exceed given limits. Figure 12 shows for each scenario the probability to have a net present value less than 0.

Figure 13 shows that the probability of a negative net present value for Scenario 6 is close to 100 %, while the probability for Scenario 1 is close to 0 %. For the incumbent operator, Scenarios 2, 4, 5, 6 have significant risks of negative net present values. The 5 % percentile of NPV distribution says that there is a 5 % probability to achieve that value or lower values. Again, the conclusion is to speed up the introduction of broadband before the cable operator takes the main part of the broadband market.

The question is which of the above-mentioned variables that gives the highest contribution to the net present value uncertainty. Figure 14 answers the question for each scenario. The figure shows that uncertainty in the total broadband penetration and market share for the incumbent are the dominant factors, which explain 40 % to 55 % of the variation of net present value. The tariffs contribute with 20 % – 35 %, while the service provider costs contribute with 15 % – 25 %. The investments and maintenance have a more limited contribution to the uncertainty.

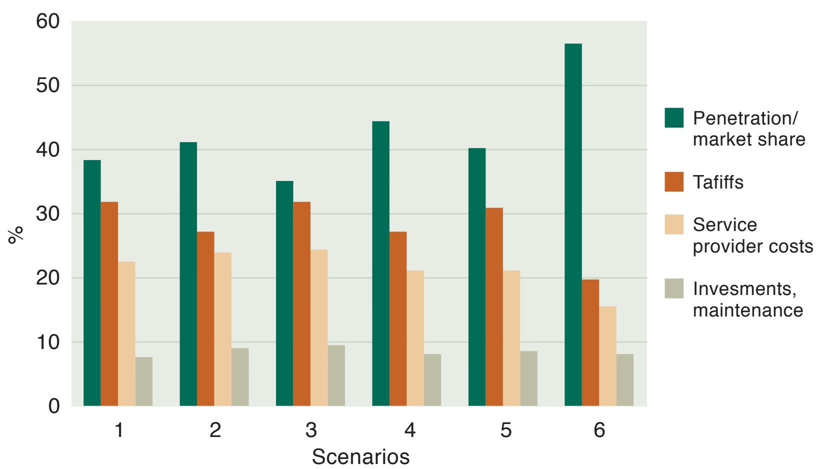
The broadband penetration and market share consist of the following variables: Total broadband penetration, market share DSL/cable, relative market share ADSL/VDSL and relative market share LLUB/DSL. Risk evaluation shows that the total broadband penetration and the incumbent's DSL market share contributes significantly more to the NPV variations than ADSL/VDSL market share and LLUB/DSL market share. The relative low influence of LLUB/DSL can be explained by the fact that the copper leasing revenue is not so far from the access revenue in these calculations. On the other hand there will be other losses for the incumbent by offering LLUB, which is not quantified in this analysis.

The tariffs consist of the following variables: General tariff changes, content costs VDSL, content cost ADSL. The content cost VDSL gives the influence. It is assumed that VDSL content cost constitutes 20 % of the access tariff shown in Figure 2. A significant variation of the VDSL cost will have a significant impact on the net present value. In addition the tariff level also creates uncertainty.

The service provider costs consist of the following variables: Sales/Marketing/Billing and Provision. The analysis shows that Sales/Marketing/Billing had an important impact on the NPV variations.

The investment, maintenance costs consist of the following variables: Network operations, maintenance and network component costs. These variables do not contribute as much the others. One main reason is that the price level of DSL equipment is much less uncertain compared to the other uncertainty variables.

Figure 14 Ranking the sensitivities. Contribution (%) to the net present value uncertainty



11 Conclusions

A competitive battle between a cable operator and an incumbent is going on to capture broadband market share. *The areas considered are highly competitive areas where a CATV network is already deployed*. Both actors aim to upgrade their networks to a two-way interactive broadband network, but investment capital limitations force the actors to roll out their networks stepwise. In some areas the incumbent will be the first actor to offer broadband services, in other areas the cable operator will be the first.

Hence a set of different rollout scenarios have been examined. The analysis shows that the incumbent operator has to fight rather hard to get a positive net present value when the cable operator starts to roll out broadband early. To get acceptable net present values the incumbent's broadband rollout must not be delayed significantly compared to the cable operator's rollout. The cable operators do not have enough financial strength to roll out a broadband structure in all cable network areas during a short time. The incumbent operator should utilise this opportunity with a fast rollout to get good economic results.

However, there are different uncertainty factors. By performing risk analysis the impact of the uncertainties has been quantified. The uncertainty factors have been grouped into four main groups: Penetration and market share uncertainty, tariffs, service provider costs and investments/operation and maintenance. A low risk strategy for the incumbent operator is to roll out broadband in areas where the cable operator has not been able to offer broadband services.

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Provision of Broadband Services in Rural Areas in Western European Countries

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1 Introduction

Interactive services, broadband communications, digital broadcast and flexible tele-working solutions are considered to be strong drivers for the development of rural and peripheral regions. Health, education, tourism and commerce are among the activity sectors that most significantly can benefit from improved communication services. Introduction of broadband services will certainly help to improve the general quality of life and favour the modernisation of less developed zones. For these reasons, there is a high level of political interest to provide broadband access in areas and sectors where the economic prerequisites for offering broadband services are not fulfilled under pure market criteria (3, 4).

Why does broadband matter? This question is discussed in Chapter 2 of this paper. It is argued that key areas like business and consumer e-commerce, education, health care, entertainment, and e-government will benefit from the availability of broadband services.

Chapter 3 gives an overview of relevant technologies for providing broadband to rural areas. ADSL will probably be the most applied technology in rural areas in Europe as a basic technology for most of the households. ADSL can be combined with Direct To Home (DTH) satellite, using the ADSL as a return channel for interactive television in addition to the main data or home office use. VDSL (Very high bit rate Digital Subscriber Line) will probably only in limited cases be a solution in rural areas. Digital Terrestrial TV with return channel over fixed or mobile narrowband network is a strong candidate for rural areas, since the cost of such systems is low compared to other solutions. Also LMDS could be a relevant technology in parts of rural areas, if mass productions of such systems will take place. Satellite based solutions (Return Channel Satellite Terminal – RCTS) are planned for consideration at a later stage.

The definition of rural and non-competitive areas is characterised by income level, cost of infrastructure related to settlement patterns or density in an area. A study performed on the provision and use of telecommunications differences between the rural and urban areas has revealed that there is an observed difference between Northern and Southern Europe. The main findings from this report are presented in Chapter 4.

In Chapter 5 the first results from a techno-economic evaluation of deployment of broadband to rural areas, conducted within the TONIC-project[1)], are presented. Three generic types of Western European countries in terms of population size, socio-economic and demographic characteristics are studied. They are, a Southern European country, a large Central European country and a Nordic country (1).

An overview of the different countries' goals and ambitions to promote broadband to rural areas is presented in Chapter 6. In addition is presented an attempt to calculate the necessary funding required by the telecom operator in a typical Nordic country, deploying broadband to rural areas.

Finally, conclusions and recommendations are drawn in chapter 7.

2 Benefits of Broadband[2)]

Why does broadband matter? Broadband is characterised by high-speed, "always-on" connection and two-way capability. It is capable of supporting many applications. For example, broadband can be used to stream audio and video over the Internet at a much higher quality than narrow band. It provides a platform in which service providers have the ability to develop and deliver new content, software and technology. Not only new applications, but also existing services can be accessed more quickly and conveniently by virtue of broadband technologies. Higher speeds improve the overall online experience of broadband users, encouraging them to explore more applications and spend more time online (Cyberatlas, 2001a). Broadband has been viewed as having a significant impact on economic activity and is considered by some as being an accelerator for economic development. Although it is difficult to make an exhaustive list of broadband applications, key areas will be business and consumer e-commerce, education, health care, entertainment, and e-government.

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1) *TONIC: TechnO-ecoNomICs of IP optimised network and services, An international IST-project.*

2) *This chapter is based on A. Umino, "Broadband Infrastructure Deployment: The role of government assistance", Directorate for science technology and industry, OECD report 22.05.2002.*

Although many of the potential applications will provide user benefits, broadband is often a substitute – in most cases a much-improved substitute – for an existing work process. It would be difficult, however, to make a case that in the short term shows that some of these services were crucial. On the other hand, it is much easier to argue that broadband has the capacity of improving the quality of work and life.

2.1 E-commerce

As e-commerce is becoming an increasingly integrated part of the operation of large businesses, the most likely demand for broadband applications will be from those business users. It is expected that e-commerce will enable companies to lower costs such as procurement, production, selling and distribution, which will lead to the development of new markets and services. This process has the potential to reshape the supply chain by removing the need for intermediaries between suppliers and customers.

However, most large businesses use directly connected leased circuits for broadband applications. For small and medium-sized enterprises, technologies such as DSL and cable modems are likely to be in high demand as they represent the first opportunity these businesses have to obtain affordable, high speed and permanent connections. Broadband networks can also enable new e-commerce activities including services that are not feasible for small businesses over narrowband networks, such as electronic trading communities.

2.2 Education

Broadband technologies have the capabilities to enable distance-learning applications that deliver optimum real-time audio and video to the classroom. In addition to many public schools that are, or will be, connected via broadband networks, there is a growing commercial market for education services offered by private companies. Broadband can also enable online learning systems via public libraries and provide improved access to information for rural and remote areas.

2.3 Health care

Broadband capabilities are already used in telemedicine applications, which require high-quality video imaging. They enable, for example, specialist doctors to provide advice to general practitioners or nurses in rural and remote areas and can be utilised for "distant diagnosis" directly with patients. Telemedicine can potentially provide health care workers in rural areas with an extensive network of specialists from whom to get support and provide patients with improved medical attention no matter where they are located.

2.4 Entertainment

Entertainment is an area that may prove popular for broadband applications. For example, online games and video are often cited as potential areas for growth in broadband demand.

It might be anticipated that consumers are likely to pay more for broadband connectivity when it is bundled with broadcasting services. In this context, the applications with the most potential in the residential community will be non-pay TV-based video applications such as streaming video and audio services, which could be major drivers behind broadband adoption. Services such as "movie on demand" offerings by the major movie studios would be an excellent example of the next generation of technology-enabled entertainment. Most of the attention with regard to broadband entertainment has been focused on the growth of the residential market, but the large number of Internet users who have broadband at work represents another potential market for streaming audio and video providers. Radio and television broadcasters can possibly extend their brands and provide content to consumers in new ways.

2.5 E-government

Broadband technology can be used to deliver government services directly to citizens, as well as business users. Such applications reduce the cost of providing government services and facilitate access to these services by citizens and residential households. Such services can range from information services, administrative documentation, renewal of a range of licences, tax submissions, etc. In geographic areas where no government offices are available such services allow for real-time dialogue with administrative officials at low cost.

3 Broadband Technologies

It is very important to emphasise that broadband networks are relatively new in terms of deployment and still subject to development. The likelihood that we will se important improvement in broadband technologies in the future is very high in view of the telecommunication development so far.

3.1 ADSL

The ADSL (Asymmetric Digital Subscriber Line) technology can transmit high data rates by using advanced digital modulation over standard copper pairs. Data signals can simply be added on the existing PSTN or ISDN lines using passive splitters (filters) at the subscriber and central office ends. The ADSL system consists of four major components:

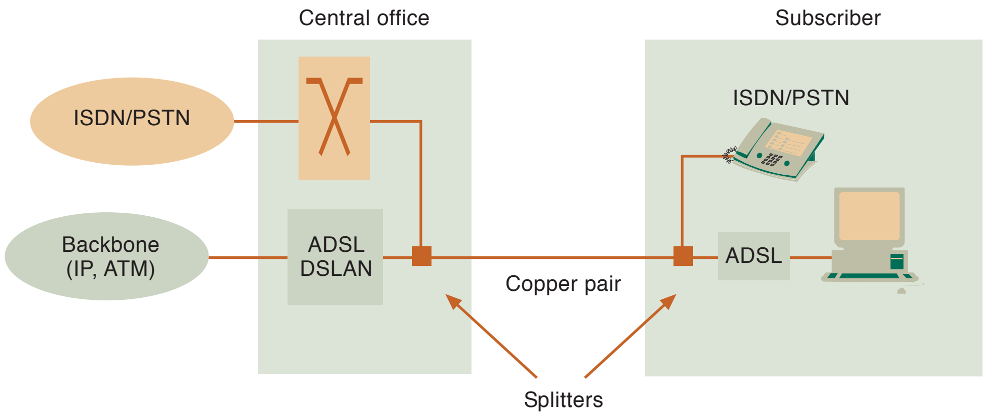


Figure 1 The major components of an ADSL system

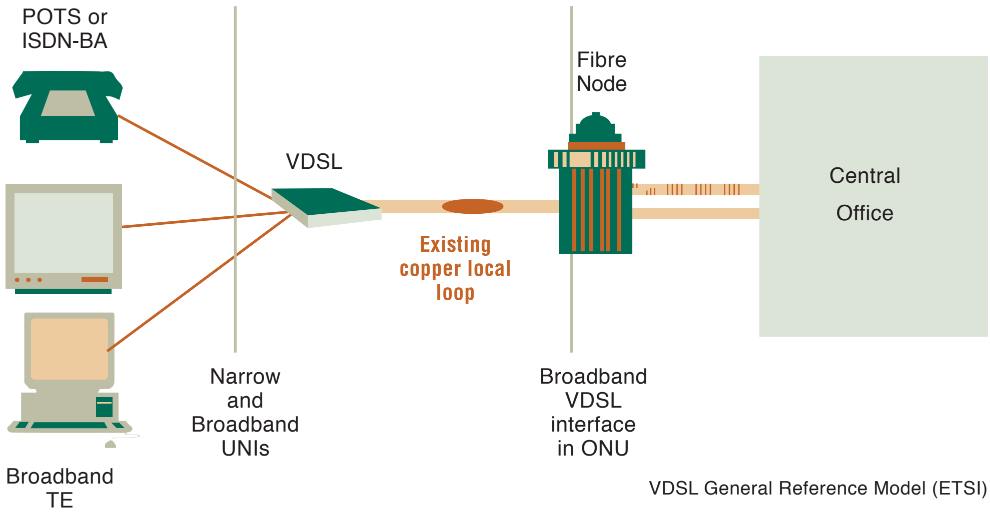


Figure 2 The major components of a VDSL system

- DSLAM (Digital Subscriber Line Access Multiplexer) with ADSL line cards and network interface cards;
- Central office splitter shelf;
- Subscriber splitter unit;
- Subscriber ADSL modem. The ADSL modems are available with 10BaseT Ethernet and/or 25.6 Mbit/s ATMF user interfaces.

Deployment of ADSL can be done rapidly and no great initial infrastructure investments are needed. ADSL has limitations: max speed downstream 8 Mbit/s, in practise max 4–5 Mbit/s over 2 km and 2 Mbit/s over 3 km copper lines. That means one high quality TV channel and fast Data-Internet simultaneously. The service offered is usually fast Internet access.

3.2 VDSL

The VDSL (Very High Speed Digital Subscriber Line) is an enhancement of ADSL technology. The main difference is that VDSL can offer higher bitrates over shorter distances. This limitation usually makes it necessary to establish new nodes closer to the customer premises in order to shorten the subscriber lines. These new nodes need fibre optic feeding. In some of the non-competitive (rural) areas studied the total area of an village/small town is so small making VDSL a possible solution, since no more nodes are needed compared to ADSL.

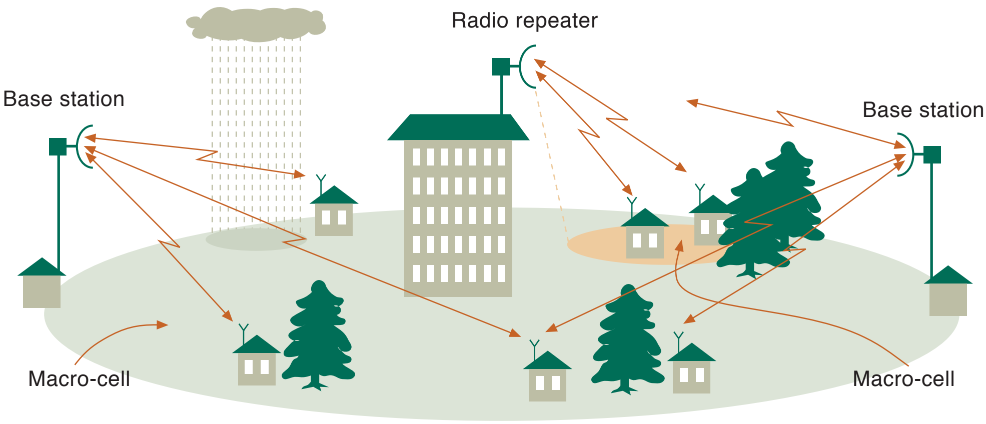
It is important to note that the standardisation process for VDSL is not finished. Availability of commercial systems is still limited.

In this first study VDSL has not been taken into account but in the next phase of TONIC this solution will be considered.

3.3 LMDS

Local Multipoint Distribution Systems (LMDS) is an emerging interactive asymmetrical point-to-multipoint radio access technology able to deliver multi-services to either residential (TV, Internet access, POTS) or business customers (leased lines, Internet access). LMDS is a fixed access technology; mobility of the terminal is not included. LMDS is implemented as a cellular system connecting the end-users to a base station in a star or point-to-multipoint topology. A typical LMDS cell configuration is shown in Figure 3. The range of such systems is typically 2–5 km

Figure 3 LMDS cell configuration



and line-of-sight conditions must be established to provide reliable operation. In some cases a nested star or tree topology may be implemented using radio repeaters. The information bit rates on the uplink typically cover 1–10 Mbit/s whereas the downlink covers 10–50 Mbit/s. The radio medium is shared between the different customers in a cell providing a flexible bandwidth-on-demand functionality.

LMDS systems operate in either 26/28 GHz or 40/42 GHz radio frequency band. The lower frequency band is normally used for business solutions, mostly as a substitute for leased lines. The higher frequency band is intended for residential services, including TV. Several countries have applied licenses for LMDS radio frequencies. It has been difficult to obtain a worldwide frequency allocation for LMDS. There are today several manufacturers with commercial LMDS products, but they are focusing on the business market in the 26/28 GHz frequency band.

LMDS has clearly the potential of becoming the broadband access technology also for the residential market, but for the moment the cost of LMDS equipment (e.g. radio terminal and NT) is prohibitive for that purpose.

LMDS is a fairly new technology and the first large-scale deployment for commercial operation started in 1999 in USA and Canada. In Europe a lot of pilots are in operation at 26 GHz and at 42 GHz. Mainly technical trials are being conducted.

3.4 Return Channel Satellite Terminal (RCST)

Satellite is optimised for broadcast where enormous amounts of users share the same signals. Satellite solutions are very expensive for individual use of bandwidth due to the high upfront cost of satellites with a limited number of transponders. In view of this only single user terminals for the high end users in the rural areas will be studied. This emerging technology called Return Channel Terminal Satellite (RCTS) is packet based and utilises the transponder capacity better for data applications. DVB-RCS is an extension of the DVB digital platform specification to include return channel by satellite. The return link traffic does not necessarily use the

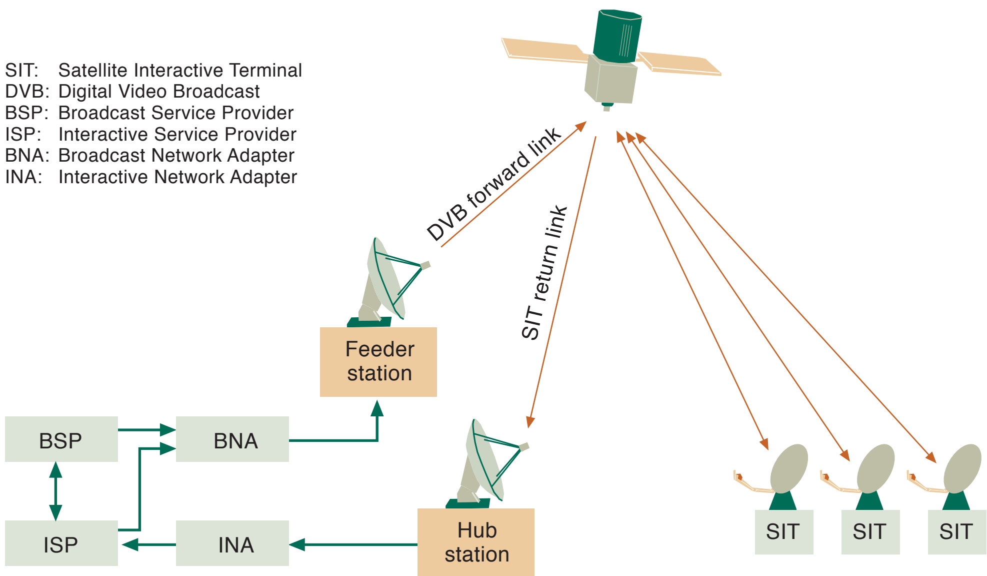


Figure 4 Return Channel Satellite Terminal (RCST) architecture

same satellite as the forward link. Combining satellite feeder with local WLAN or LMDS solutions has been proposed but the total costs of the combined systems will probably be unreasonably expensive compared to WLAN and LMDS with fixed (fibre) feeder to the base stations; therefore only single user terminals will be analysed.

In this first deliverable RCST has not been studied but in the next phase of TONIC this solution will be analysed. The current status of the RCST technology is that the terminal costs are very high and the individual use of transponder capacity quite expensive, making this solution most suitable for the business users and high-end residential market.

3.5 Digital Terrestrial Television (DTT)

With DTT broadband Internet access can be provided on a more general basis to consumers in rural areas using the DTT Broadband small-cell technique (IP Unicast over DVB). This can be accomplished in a cost-effective manner, covering large geographical areas in a short time without digging new cables or fibres. Broadband Internet Access IP over DVB networks (small cells) can give a very positive synergy effect to the High-Power DVB-T (DTT) network (the home network cost can approach nil for this additional broadband Internet service), and can also be bundled with DTH (satellite DVB) networks. This new broadband network can cost-effectively cover consumers in rural areas with broadband Internet access (hybrid approach, using fixed and radio access technologies). In addition, this technology can provide portable and even mobile broadband Internet access.

DTT is well suited for providing TV services to large areas, both to fixed and portable receivers. The cost of the head-end and the transmitting network is the same whether one or several million viewers receive the signals simultaneously.

The home installation includes one digital set-top box. A dedicated PC card is used in a PC at the receiving end. An ISDN line or GSM/GPRS may be used as return channels. Since the transmitting method is based on the DVB standard the PC also displays the TV channels.

However some regulatory issues are related to the commercialization of DTT. Firstly a concession from NRA for the management of the relevant frequency bands is required. These bands are today reserved for TV-centric use. Secondly a concession from the Mass Media Authority (Statens Medieforvaltning) is needed for distribution of Internet services within certain geographical areas.

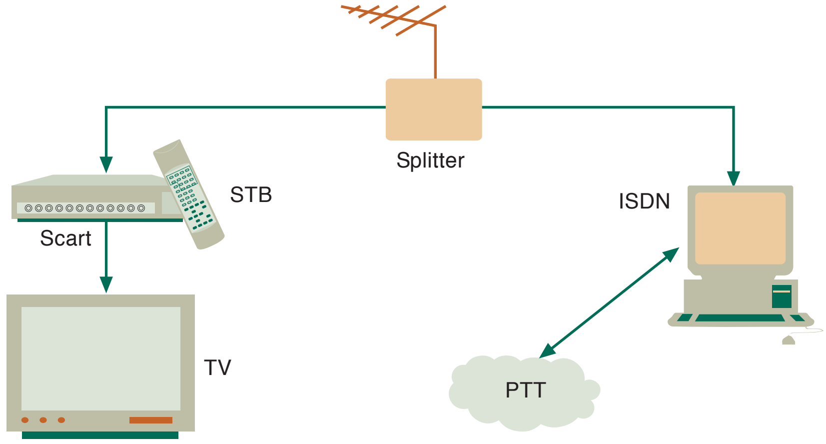


Figure 5 Home network

4 Characterisation of Rural Areas in Western Europe

The definition of rural and non-competitive areas is characterised by income level, cost of infrastructure related to settlement patterns or density in an area. A study performed on the provision and use of telecommunications differences between the rural and urban areas revealed that there is an observed difference between Northern and Southern Europe (2). In Northern Europe, the differences between rural and urban areas in the consumption of telecommunication are relatively small while the difference in Southern Europe is significant. However, rural areas of Northern Europe have a very low population density and as a consequence very high costs of infrastructure supply. The reverse takes place in Southern Europe. Rural densities are significantly higher and thus the disadvantages regarding the provision of infrastructure are smaller. But, because there are substantial social and economic differences between rural and urban areas, disadvantages related to insufficient demand are important.

4.1 Southern European Country – Segmentation Based on Population Densities and Settlement Pattern

Portugal was chosen for this case study. In spite of being a small country, it contains areas with quite different geographic and demographic characteristics. Three regions are considered corresponding to some of the more representative socio-territorial patterns:

- Area A: Occupies the middle south of the country; is mostly flat. Mediterranean agriculture and tourism are the main activities.

- Area B: Corresponds to the north-eastern part of the country. Irregular terrain with mountains. Wine and tourism are the main activities.

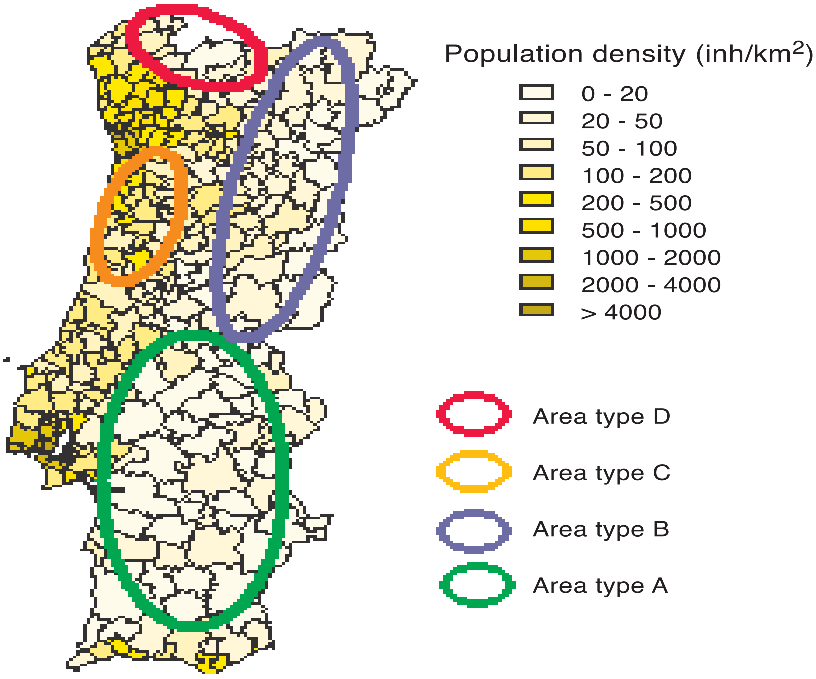


Figure 6 Classification of rural areas

Total Area	Area A	Area B	Area C	Area D
Population size	470,000	670,000	630,000	670,000
Area (km^2)	27,000	22,000	5,500	4,200
Population density (inh/km^2)	18	30	114	160
Clusters (average values)				
Area (km2)	0.35	0.4	0.9	
Population density (inh/km^2)	7,200	1,820	2,840	
Households density (hou/km^2)	3,750	1,240	1,050	125
Distance between clusters (km)	10.5	4.4	2.7	

Table 1 Population density for selected rural areas

	Min no. of subscribers per km^2	Max no. of subscribers per km^2	Avr. no. of subscribers per km^2
Downtown area	2,300	9,200	5,750
Urban area	570	2,300	1,435
Suburban area	250	570	410
Rural area	17	250	134

Table 2 Classification of service areas with minimum, maximum and average densities

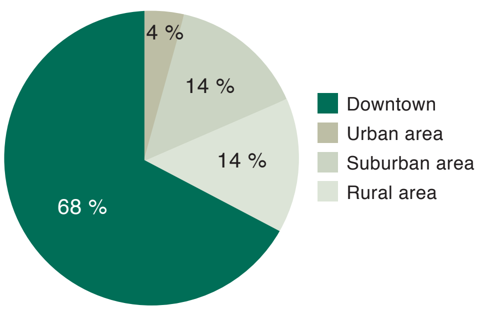


Figure 7 Example: Classification of service areas in a large European country

- Area C: Occupies part of the central west of the country. Small industrial settlements are interspersed with residential and rural zones.

- Area D: Occupies part of the north-west of the country. This area was not analysed due to lack of input data, but represents the most rural area with the most scattered population

For each category of rural areas a representative sample of municipalities was selected. Generalising the results obtained in the sample, which combine statistical and cartographic data, it is possible to make a characterisation of each type of area in terms of: total area, total population, population density, average size of rural clusters and average density of population and households in each cluster. Table 1 shows the main geographic characteristics of each one of the four rural areas identified

4.2 Large Central European Country – Segmentation Based on Exchange Area

The telecommunication infrastructure in the Central European country studied is based on a fixed exchange area. All cables and duct systems lead to the local exchange, which is usually located in the centre. The telecommunication network of the large Central European country studied is segmented in approximately 8000 exchange areas. A segmentation model based on the variation of maximum, minimum and average number of subscribers per km^2 is shown in Table 2.

The total distribution of service areas in a large Central European country using the classification described above is shown in Figure 7.

4.3 Nordic Country – Segmentation Based on Non-Dense Area Samples

For the Nordic country studied we have used a definition of dense areas (Central Bureau of Consensus) as a group of houses with more than 200 people living there and with less than 50 m between the houses. About 3/4 of the total population is settled in such areas. The rest 1/4 of the population lives in non-dense areas. This non-dense area population lives in three different types of municipalities according to typically Nordic geography. These three types are the valleys, the flat land and the fjords. We have selected three sample municipalities, which have less than 10 % of the inhabitants living within dense areas. With the help of maps the three municipalities were manually studied regarding the clustering of houses. By covering the buildings/houses in the map with circles of either 700 m or 3 km radius the number of households within the circles is counted. Based on the distri-

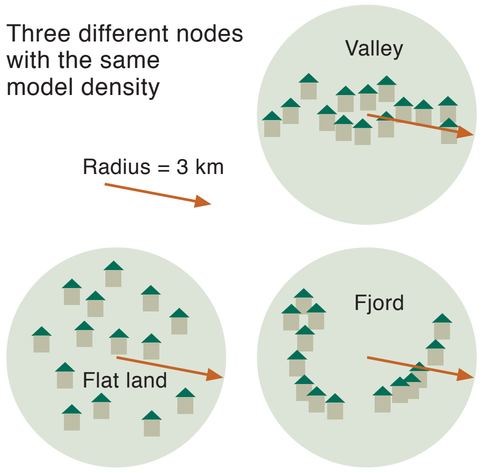


Figure 8 Three types of rural municipalities

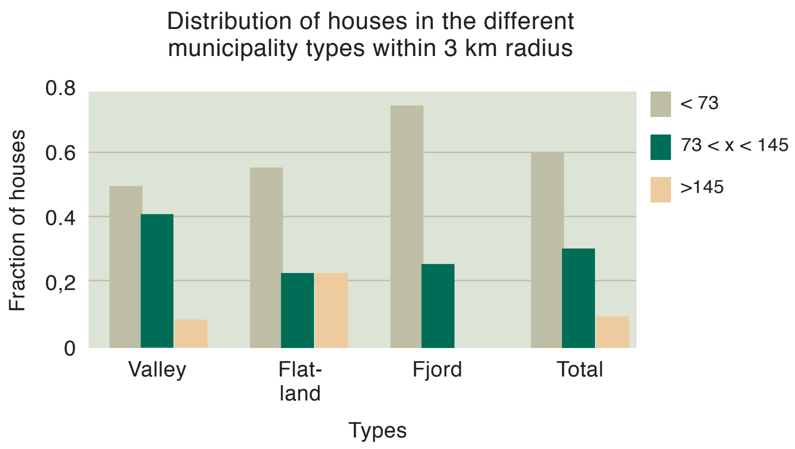


Figure 9 Distribution of number of households

bution of the houses, we can estimate the potential number of households which can be served by different broadband technologies. Both for ADSL and LMDS the 3 km is a typical reach, and for VDSL 700 m could fit quite well. Remember that the copper cable lengths of the twisted pairs for telephony are longer than the straight lines between a node and the houses. For LMDS there is no very good simple model due to the required line of sight and other propagation properties. The three types of municipalities are shown in Figure 8 and the number of households within the circle of 3 km radius is given in Figure 9.

5 Techno-Economic Analysis

In this section we will present business models for studying the economic viability of broadband services in rural areas for the selected countries from an access operator's point of view. No distinction has been made between business market and residential market. ADSL is considered as the basic technology for broadband provision in rural areas. First, the different cost components as functions of time for ADSL are presented. The cost of the different components is assumed to be identical for the different countries. Secondly, the model assumptions are presented. Thirdly, the techno-economic analysis for the three selected country types are presented. Sensitivity analysis is performed, and critical tariffs, household densities and cable lengths are calculated.

5.1 Cost assumptions

Cost assumptions are shonw in Table 3.

5.2 Demand Forecasts and Take Rates in Rural Areas

In general, forecasting is a complex process since the forecasts depend on many different factors. Forecasting broadband demand in rural areas is even more complex because forecasts are developed for new services without historically known time series. In addition the infrastructure for broadband will be rolled out in the areas with high subscriber density before less dense areas.

It is important to distinguish between potential demand and prognosis for penetration of the services. The potential demand in rural areas may be rather high, but since there will be a more limited offer of broadband services due to lim-

Table 3 Cost assumptions for ADSL (Euro)

Component/Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fibre cable/metre	20	20	20	20	20	20	20	20	20
DSLAM 50	10,000	9,324	8,696	8,112	7,570	7,066	6,599	6,166	5,765
DSLAM 100	15,000	13,987	13,044	12,168	11,354	10,599	9,898	9,249	8,647
DSLAM 250	20,000	18,649	17,392	16,224	15,139	14,132	13,197	12,331	11,530
DSLAM 500	25,000	23,311	21,741	20,281	18,924	17,665	16,497	15,414	14,412
DSLAM 1000	40,000	37,298	34,785	32,449	30,279	28,264	26,395	24,663	23,060
Card & Modem	250	233	217	203	189	177	165	154	144

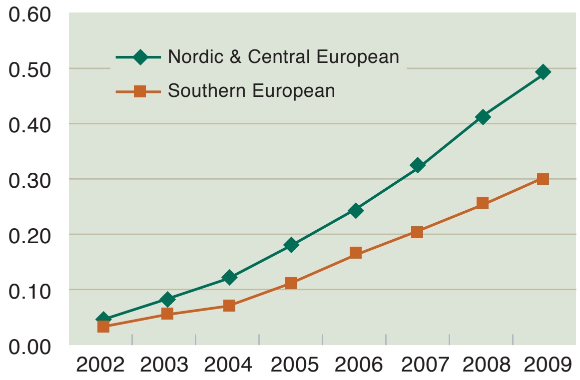


Figure 10 Subscriber penetration forecast

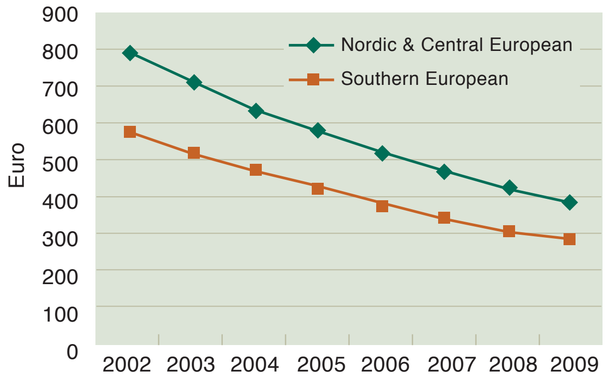


Figure 11 Tariff predictions

ited broadband infrastructure, the prognosis is significantly reduced.

To analyse whether the demand is different in urban and rural areas, the Internet traffic in rural and urban areas has been analysed in the project. The analysis shows that the generated traffic in rural areas is lower than in urban areas. The regression analysis shows a significant dependency between Internet usage and GDP in the different regions. The Internet usage increases with the GDP. Based on analysis of the Internet usage, an approach to predict broadband demand in rural areas is to reduce the country mean demand by about 20 %.

The forecasts are segmented in capacity classes and developed as mean forecasts for Europe based on numerous consultancy reports. We apply these results in our techno-economic evaluation. Scaling down the rural demand forecasts compared to urban demand forecasts for the different years, a factor between 0 and 1 was applied. For both a small Nordic country and a large Central European country this factor is 0.8 and for the Southern European country this factor is set to 0.5. A four parameter logistic model is applied. The results for the small Nordic country and the large European country are shown in Figures 10 and 11.

For Nordic and large Central European countries the subscriber penetration is growing from about 5 % in 2002 to almost 50 % in 2009. For a Southern European country, broadband penetration is growing from 3 % in 2002 to almost 30 % in 2009.

5.3 Southern European Country

The model used in the techno-economic evaluation of a Southern European country is illustrated in Figure 12.

In this model the area is modelled by nine nodes, interconnected by optical fibre as shown in the figure (bold). In the centre of each node there is a DSLAM. In each region, the distance between nodes (D) and household densities is defined. The number of households per node is fixed to 1000 while the nodes area varies, thereby controlling the L and D. In addition there is a local exchange, located at a distance equal to 36 km from the centre of the area (BAP-LAP cable length).

The areas under study are three different rural areas in the Southern European country. The fourth area, D, is not covered by the study but represent an area with low density and very little clustering structure. This will be studied in the future and is assumed to be the most unprofitable area in the country. Each of the zones studied is characterized by the parameters presented in Table 4.

The investments made in this scenario, as well as the generated revenues, are shown for the three areas in Figures 13 and 14.

The big slice of investments is made in the first year of the project. This is a consequence of the large civil works done related to deployment of the infrastructure. Area A requires most invest-

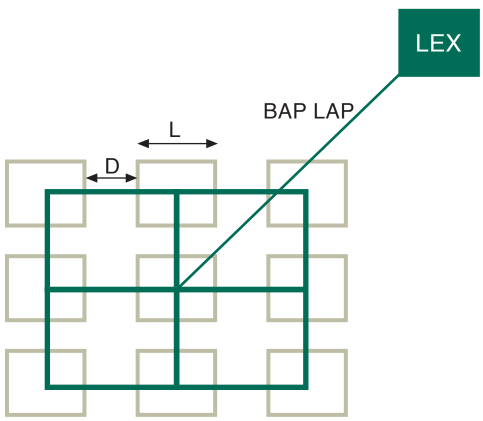


Figure 12 Model area

Table 4 Different area parameters

		Rural Areas			Comments
		A	B	C	
Parameters	Household Density per Node	3,750	1,240	1,050	In Hh/km^2
	Edge Distance (D)	10.5	4.4	3.0	In km
	Node's Area	0.27	0.81	0.95	Area = Number of households / Household Density (in km^2)
	Node side (L)	0.52	0.90	0.98	L = SQRT(Area) (in km)
	BAP_LAP Length	36	36	36	In km

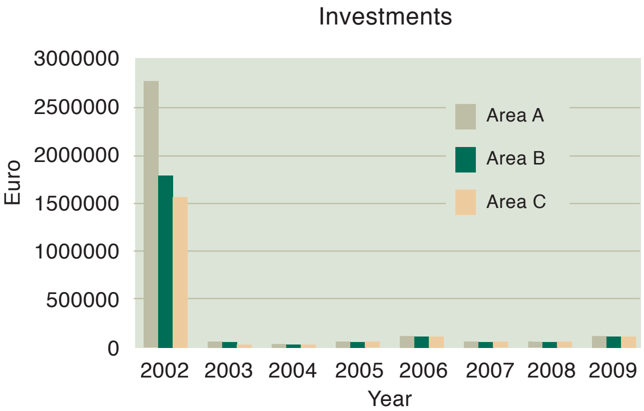


Figure 13 Investments for the different areas

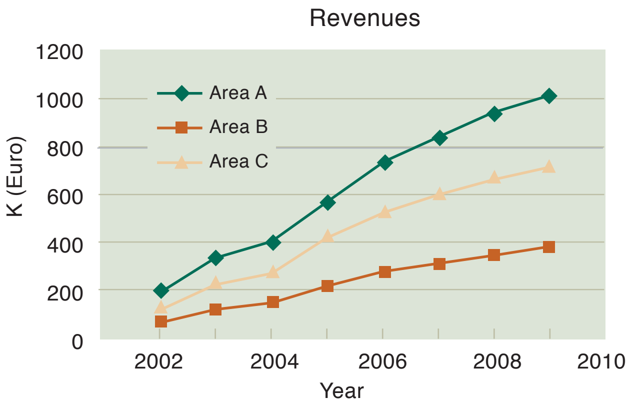


Figure 14 Revenues

ments. More use of civil works is required in the links between the central node and the secondary nodes.

Assuming the same penetration rate for every area studied, the revenues are closely related to the number of households per node. Area A has the highest number of households per node and is therefore most profitable. The key economic parameters are given in Table 5.

Area A is the one with lowest profitability, with an IRR (internal rate of return) of 12.2 %, which is hardly an acceptable profitability for a telecom operator while the areas B and C look profitable with the given assumptions.

The sensitivity analysis of the economic results to the BAP-LAP cable length shows that the NPV is always positive, though in Area A it is almost zero due to high BAP-LAP lengths. The NPV varies about 550 kEuro for a variation of 36 km of the BAP-LAP cable.

Annual tariff is the second most important parameter in this analysis, after service penetration. In Area A, the minimum tariff to obtain a positive NPV is about 520 Euro, decreasing to 380 Euro in Area B and 300 Euro in Area C.

The penetration rate is the most important parameter in the analysis of the financial viability of this project. Through sensitivity analysis of the penetration rate it is possible to understand the difference NPV is always positive.

5.4 Large Central European Country

The scenario includes the total number of customers within the network exchange area. The rural network exchange area (service area) normally consists of some central cluster of customers with high subscriber densities and outer areas with much lower values for the density. The mean value of a typical rural service area considered has been identified at 57 km^2. The

	Rural area		
Name	**Area A**	**Area B**	**Area C**
NPV	309,619	933,406	1,077,630
IRR	12.20 %	20.00 %	23.10 %
Payback period	7 years	6 years	5 years

Table 5 Key economic parameters

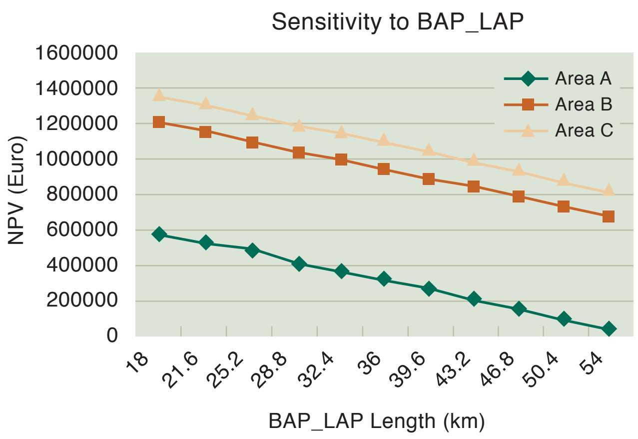


Figure 15 Sensitivity to BAP-LAP cable length

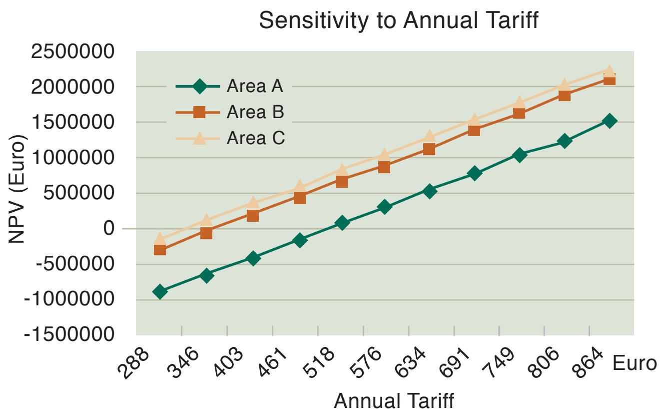


Figure 16 Sensitivity to annual tariff

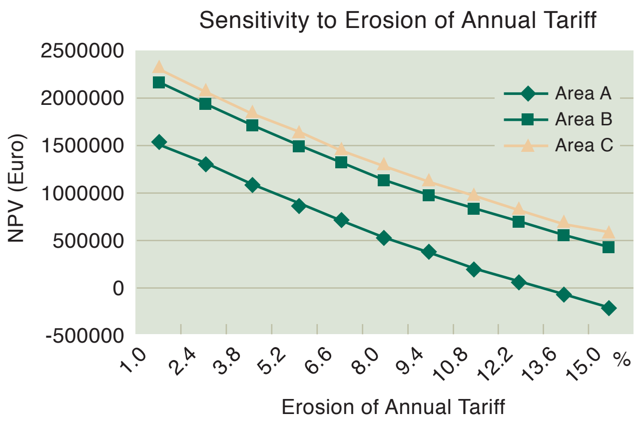


Figure 17 Sensitivity to erosion of annual tariff

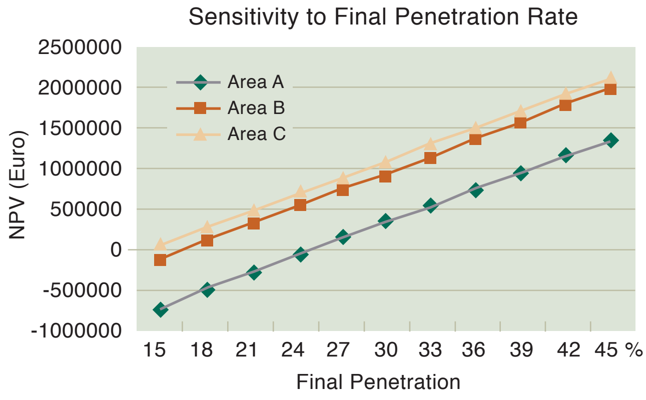
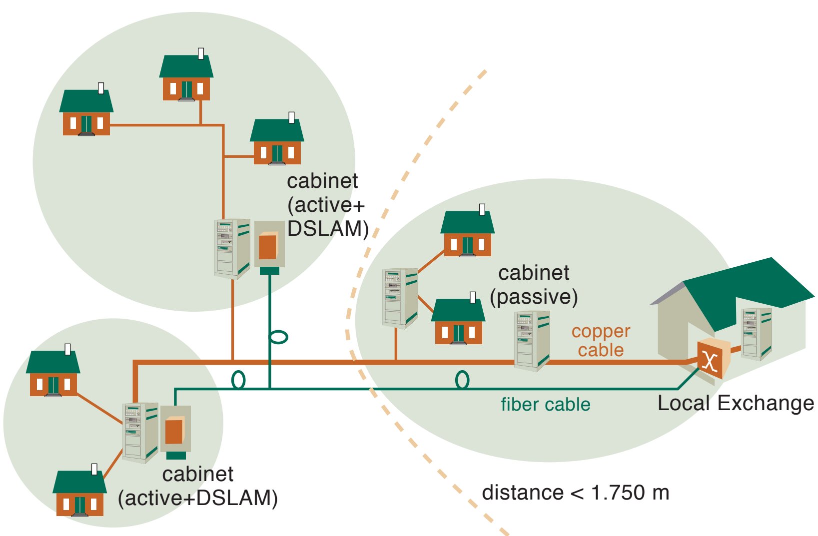


Figure 18 Sensitivity to final penetration rate

Figure 19 ADSL configuration (5 Mbit/s)



total number of customer units connected via POTS lines to one local node is assumed at 4,096. Half of the subscribers are in the central cluster. The assumed values lead to a subscriber density of roughly 70 per km^2. The total length of all main cables, which are connecting all cabinets, equals 40 km.

In order to offer a 5 Mbit/s service (e.g. one VoD-channel and an additional fast Internet connection) the subscribers near the local exchange (less than 1,750 meter) are connected via existing copper cables to the DSLAM within the Local Exchange. All cabinet locations that are located outside this area will get a new active outdoor cabinet solution.

Figure 20 shows the network model for one service area. It represents a typical infrastructure with four main cable directions. The additional cost required for the new cabinet is set at 4,100 Euro including power supply.

From Figure 21 we can see that investments in year 1 amounts to 1 million Euro. This is of course due to the high upfront costs associated with the deployment of fibres and investment in DSLAMs in the first year. Revenues are approximately 130,000 Euro in 2002 increasing to 1,000,0000 Euro in 2009.

Figure 22 depicts the sensitivity of the Cash Balance by variation of subscriber density. The difference in payback period is illustrated, and the strong influence on the profitability can be seen.

Another sensitivity analysis has been performed based on different tariff multipliers. If the tariffs are reduced 50 %, the NPV will be just roughly a fifth of the original value. The variation of the tariffs which are assumed gives an indication that the profitability of an ADSL rollout in rural areas for large European countries is given for 60 % of the assumed tariffs as well.

It is again important to bear in mind that the area studied is a mix of central exchange areas with very low cost and more peripheral areas with higher cost figures due to civil works and establishment of new cabinets.

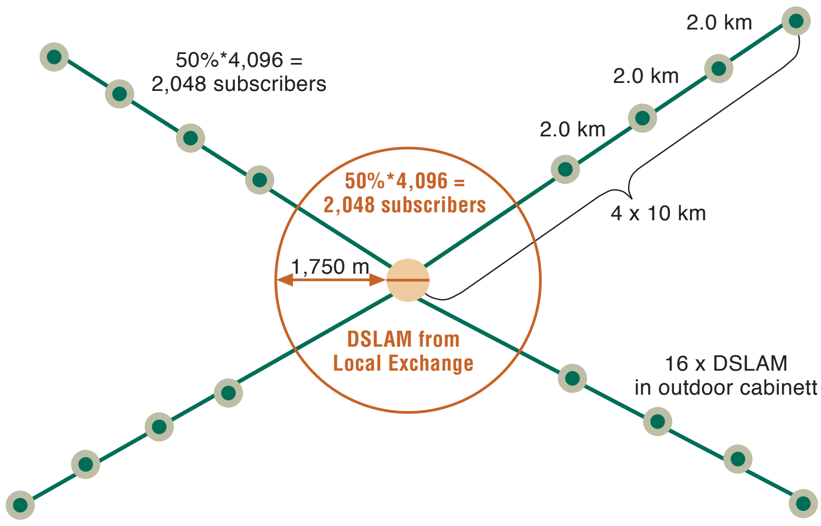


Figure 20 The network model for rural areas

5.5 Nordic Country

In the model used in the Nordic country, six nodes are connected by fibre and fed by a BAP-LAP fibre. The nodes are circles with a radius of 3 km. This means that the actual copper length of ADSL is longer. The default model density in the Nordic country was set to 10 households per km^2 and is chosen to reflect the non-dense area municipalities. This is equal to 280 households within the coverage of a node. The copper pair network for telephony is usually organised in a few remote subscriber units (RSUs). If the total amount of households is about 1500, maybe six or seven RSUs are used to connect to one exchange. In our case this means that the RSU "node" is the candidate for an ADSL node with

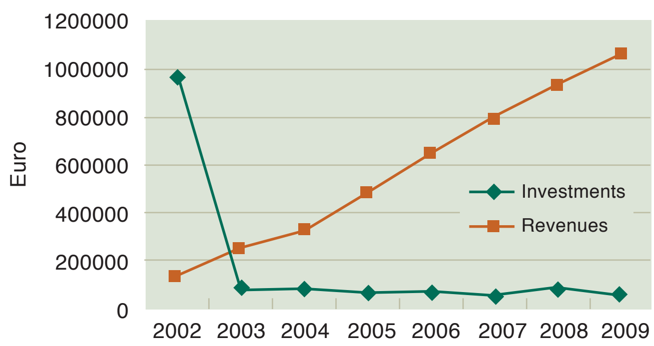


Figure 21 Investment and revenues

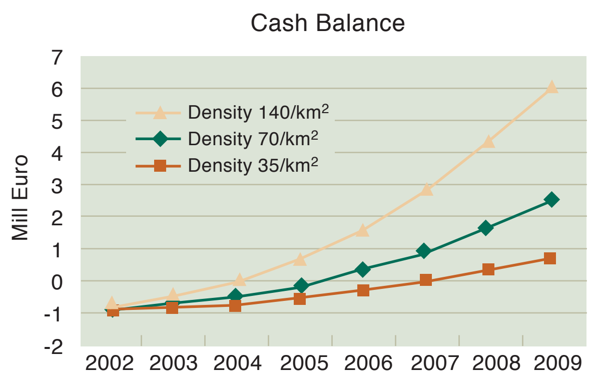


Figure 22 Sensitivity of Cash Balance by variation of subscriber density

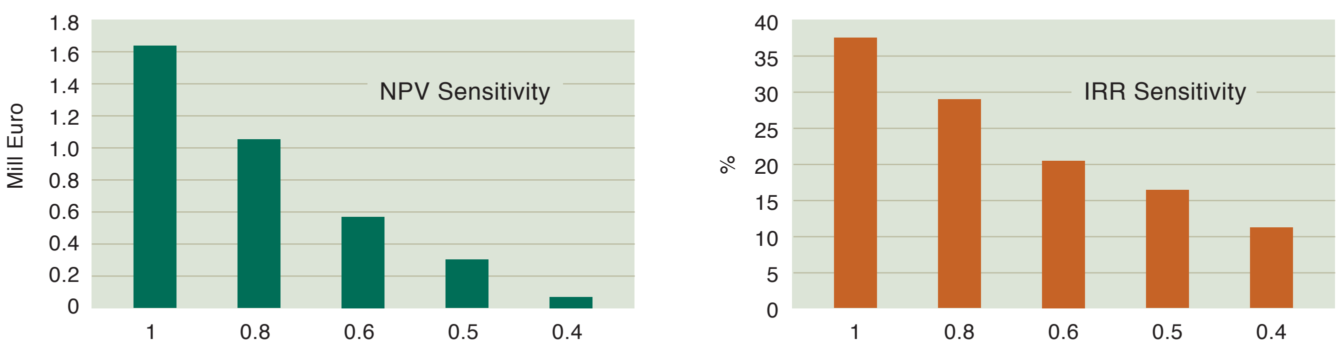


Figure 23 Sensitivity of NPV and IRR based on different Tariff Multiplier

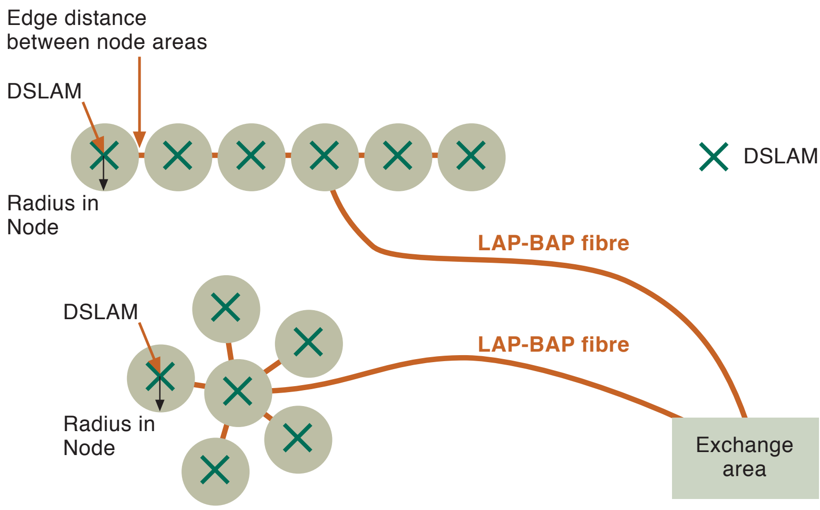


Figure 24 The network model

a DSLAM. We call it local access point (LAP). The nearest exchange area or fibre transport point is called broadband access point (BAP). Figure 24 demonstrates the network model.

The default edge distances are set at 500 metres in the present study and the feeder cable is set at 20 km.

The results from the techno economic modelling of ADSL services for a small Nordic country are shown in Figure 25.

From the figure we can see that investments in 2002 amount to 1 million Euro. This is due to the high upfront costs associated with the deployment of fibres and investments in DSLAMs. Revenues are approximately 50,000 Euro in 2002 increasing to 300,000 Euro in 2009. This means that even if tariffs are decreasing over the study period this is more than offset by the penetration of ADSL services. Installed First Cost (IFC) per household is 1,342 Euro. NPV is 25,172 Euro, and internal rate of return is 10.5 %. Given our model assumptions, the techno-economic modelling indicates that the provision of service provision of ADSL in non-competitive areas has a relatively long payback period and will not be considered profitable by most of the operators.

From Figure 26 we can see the impact of different household densities on installed first costs (IFC) and NPV. IFC per household (HH) are decreasing from about 2,500 Euro per household when household density is 5, to almost 500 Euro when household density is 30. The NPV is highly sensitive to household densities or number of houses in a node. From Figure 27 we can see the project is no longer economically viable when BAP-LAP lengths are exceeding 23 km.

Figure 28 shows how different start tariffs (influencing the general level) are affecting the

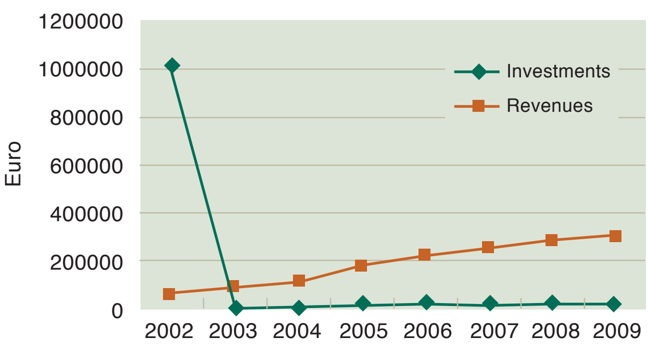


Figure 25 Investments and revenues

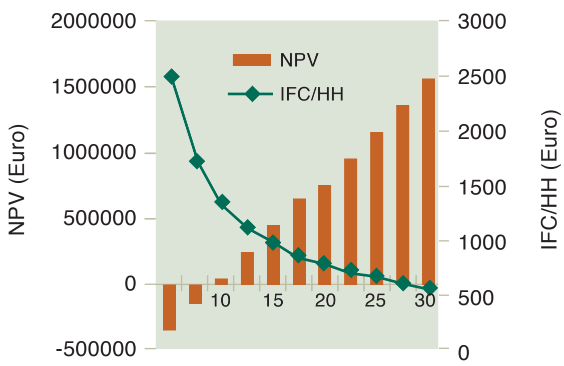


Figure 26 Sensitivity of household densities

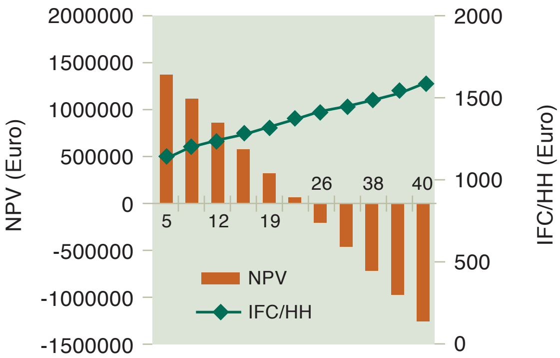


Figure 27 Sensitivity of BAP-LAP cable lengths

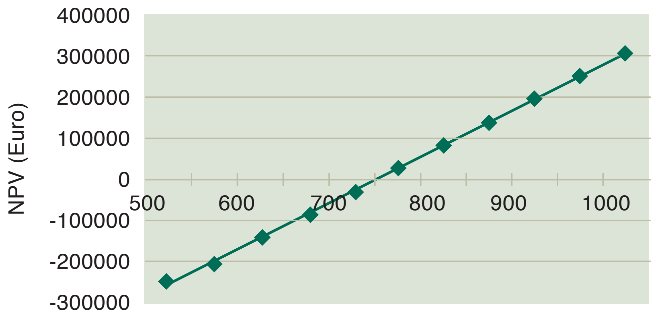


Figure 28 Sensitivity of tariff

NPV. We find that there is a critical start tariff at about 725 Euro that makes NPV equal to zero. Any lower tariffs will make NPV turn negative.

6 Governments' Role in Providing Broadband to Rural Areas

6.1 An Overview of Government Plans and Goals for Broadband

Provision of broadband networks to sparsely populated, rural and remote areas may not occur because investment in infrastructure may be unprofitable in those regions. In these regions subscribers tend to rely on a single telecommunications provider, which tends to be reluctant to invest in upgrading networks. From the demand side, subscribers in areas with low population densities may not generate sufficient demand and allow for profitable broadband deployment.

A number of OECD countries appear to believe in some policy initiatives. Especially financial incentives are imperative in order to narrow the geographical "digital divide" and deploy broadband services to rural communities. For example, the Italian government "now envisages the possibility of public intervention to create broadband infrastructure in rural areas and recognises the need for specific action in disadvantaged areas". The Japanese government suggested in its study group report that the deployment of fibre optic networks by public investment would be desirable for the unpopulated areas where private investment would not occur. The Swedish government also claims that sparsely populated areas "are main parts of Sweden where the market will not be able to fund the expansion without assistance".

Table 6 gives an overview of government plans and goals for broadband for different OECD countries.

6.2 An Attempt to Calculate Funding Required in a Generic Nordic Country

An attempt to calculate the necessary funding/subsidisation required from an operator for providing broadband services in non-competitive areas are done for a Nordic country. The non-competitive areas were divided into three sub-areas; *Area 1*, *Area 2* and *Area 3*. Each of these sub-areas differs with respect to average BAP-LAP cable lengths, household densities and edge distance lengths. From Table 7 we see that Area 3 is the less populated area and therefore the most expensive area in which to promote broadband.

Subsidisation is defined as the discounted sums of the additional tariff required by the telecom operator over the study period (2002 – 2009). Our results indicated that Area 1 might not need subsidisation at all. But as can be seen from Figure 29, substantial subsidisation per household is required in Area 2 and Area 3. Total subsidisations for covering Area 2 are only 160 millon Euro. Total subsidisation covering both Area 2 and Area 3 are 686 million Euro.

6.3 Provision of Broadband to Rural Areas in US

The National Exchange Carrier Association (NECA) recently released a survey showing it would cost nearly US$ 11 billion to upgrade U.S. rural telephone lines to broadband DSL (digital subscriber line) capability.

The 244 companies that participated in the survey serve sparsely populated regions of the U.S. from the bayous of Louisiana to the mountain ranges of Alaska. Typically, there are about five households per square mile in their coverage area. That figure compares with the typical 50 households per square mile in the coverage area of carriers that serve urban areas.

The U.S. Federal Communications Commission (FCC) defines broadband as the ability to support a data rate of at least 200K b/s (bits per second), both upstream and downstream. Alternative technologies exist for delivering broadband to remote areas; however, the study only produced estimates related to DSL.

The US$ 11 billion upgrade price tag would cover 3.3 million lines, which is equivalent to

Table 7 Classification rural areas

	Area 1	Area 2	Area 3
Households per km2	20	10	5
Fibre cable length in km	10	40	45
Edge distance in km	0.5	1	1.5

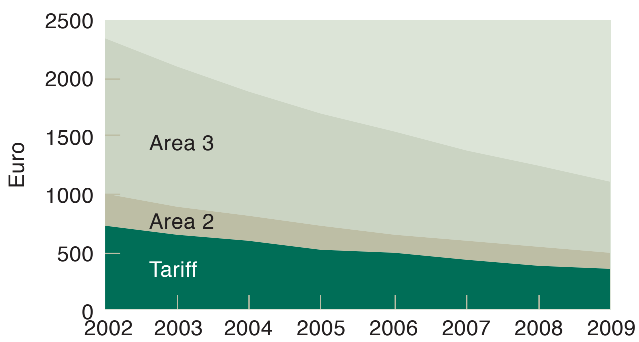


Figure 29 Subsidisation per household

Australia	• 3 % of Australian businesses will adopt broadband connections by 2003.[1)]
Canada	• Broadband services will be available to businesses and residents in every Canadian community by 2004. (Report of the National Broadband Task Force) • The Canadian government announced that it shifted its target of furthering broadband Internet coverage to 2005. The government has decided not to fund broadband investments at this time. (Part 6 of the Budget Plan 2001)
Denmark	• The telecommunications sector expects that by 2002, 95 % of all households (including businesses) in Denmark should have access to one or several technologies (high speed/broadband via ADSL, FWA or internet through cable TV modem). The goal is based on data from the telecommunications sector. The actual development in access will be analysed by the Danish National Telecom Agency in 2002.
Finland	• Finland will be developed into an information society, in which knowledge and expertise form part of the culture and are also the key factor in production. (The Government Programme, April 1999) • Broadband services should be available to all citizens and enterprises by 2005. (Goal set by the Ministry of Transport and Communications)
France	• All French citizens will enter an information society that embraces solidarity. (France in the Information Society)[2)]
Ireland	• Ireland will actively pursue the positioning of the country as a global leader in electronic commerce.[3)] (1998 report of the Advisory Committee on Telecommunications)
Italy	• Italy seeks to transform the country into a knowledge-based society and to ease its entrance into the Information Society over the next five years. (DPEF 2002-2006)
Japan	• By 2005, an environment that provides 24-hour connection to high-speed Internet access networks for at least 30 million households, and to ultra high-speed Internet access networks for 10 million households, will be created for all Japanese who need access to those networks at affordable rates. (e-Japan Strategy) • By 2005, Japan will attempt to deploy public LANs that connect schools, libraries, community centres and city halls across the country. (National Broadband Initiative)
Korea	• The Korean government expects subscribers to broadband services to increase to 13 million, 84 % of the total Korean households, by 2005. • By 2005, broadband subscriber access network will be deployed.
Netherlands	• It is essential to create the conditions under which intricate glass fibre infrastructure can be constructed in the Netherlands faster than, or at least as fast as in those countries with which we would wish to be compared. (Smart Digging)
Norway	• Norway should have favourable market offers that enable broadband in all parts of the country. • All primary schools, public libraries and local authority administrations should be offered broadband connections at competitive prices by the end of 2005, while all secondary schools should have this offer by 2003. • All hospitals should have favourable market offers that enable broadband connections by the end of 2002. (Action Plan on Broadband Communication: reassessed version)
Sweden	• Sweden will be the first country to become an information society for all, which means that everyone will have access to IT, have confidence in IT, be able to use it and benefit from the advantages it brings. (An Information Society for All – a publication about Swedish IT policy) • All households and businesses in Sweden should have access to an IT infrastructure with high transfer capacity (broadband) by 2005. (The Development of the IT Infrastructure – A publication about one of the priority areas of Swedish IT policy) • Over the next few years, households and businesses in all parts of Sweden should acquire access to IT infrastructure with a high transfer capacity. (The IT Bill of 2000) • The government will aim to connect 98 % of the nation's population within two years, dividing the cost between the state, districts and commercial operator. (The IT Bill of 2001) • Everyone will have a fixed Internet connection of at least 5 Mb/s real throughput capacity within Sweden by 2005. • By 2005, Sweden should have constructed a fine-meshed fibre optical network available to all. • The network shall be technically and competitively neutral and open to all operators, the aim being for everyone, through free competition, to gain access to high transmission capacity at low cost. (General Guide to Future Proof IT Infrastructure)[4)]
United Kingdom	• The UK will have the most extensive and competitive broadband market in the G7 by 2005. (UK Online: The Broadband Future: An action plan to facilitate roll-out of higher bandwidth and broadband services)
United States	• The government will increase investment in the fundamental information technology research in software, human-computer interaction and information management, scalable information infrastructure, and high-end computing. (Information Technology for the 21st Century)

Notes:

1) Newsbytes, October 26, 2000, http://www.newsbytes.com/news/00/157225.html.

2) Internet.gouv.fr, "France in the Information Society", http://www.internet.gouv.fr/francais/index.html.

3) The Irish Times, October 20, 1999, http://www.ireland.com/newspaper/ireland/1999/1020/hom14.htm.

4) See the Swedish ICT Commission, General Guide to a Future-proof IT Infrastructure: http://www.itkommissionen.se/extra/document/?id=347.

Table 6 Government plans and goals for broadband (Source OECD 2002) an average cost of about US$ 3,300 per line. That estimate is deceptive because the more remotely situated a customer is, the higher the price to upgrade the line. For example, in a town the upgrade cost per line is about US$ 500, but upgrading a telephone line that runs to a farm, mine or other rural enterprise can run well into the thousands of dollars.

The US$ 11 billion estimate covers only upgrades to equipment from a customer's home to the local exchange carrier's switch. It will actually cost an additional undetermined amount for DSL equipment, switches between a carrier and an ISP (Internet Service Provider) and backbone costs – all not factored into the survey.

The survey also concluded that the respondents are already planning a portion of the required upgrades. About 65 % of the lines owned by those polled by the survey will be capable of providing broadband service by 2002.

That finding shows that the companies serving rural areas are deploying services, but many companies do not have the money to extend broadband throughout its coverage area. Financial supports through grants, low interest loans or tax incentive programs are therefore required.

The U.S. Telecommunications Act of 1996 mandates the extension of broadband services to rural areas. To help in the policy making process, NECA plans to file the study with the FCC and share it with members of U.S. Congress, who have said they need more data on the status of rural broadband in order to draft legislation that would assist carriers serving rural areas.

7 Conclusions

Broadband is characterised by high-speed, "always on" connection and two-way capability. It is capable of supporting many applications. The activity sectors that most significantly will benefit from broadband services are believed to be: e-commerce, education, health care, entertainment and e-government.

The definition of rural and non-competitive areas is characterised by income level, cost of infrastructure related to settlement patterns or density in an area. No consistent definition of rural areas exists across Europe. In Northern Europe, the differences between rural and urban areas in the average income level and consumption of telecommunication services are relatively small. However, rural areas of Northern Europe have a very low density of population and, as a consequence very high costs of infrastructure supply. The reverse takes place in Southern Europe. Rural household densities are significantly higher and thus the disadvantages regarding the provision of infrastructure are smaller. However, there are huge social and economic differences between rural and urban areas, influencing the willingness to pay for telecommunication services. Therefore the studied business cases are not targeting exactly the same type of areas and generalisations must be taken with care.

The analysed household distributions reflect the fact that the Nordic countries have more sparsely populated rural areas compared to countries in Central and Southern Europe. The number of houses in the rural area clusters is significantly lower in the Nordic countries as compared to Central and Southern European regions.

The results show that broadband rollout of ADSL in Nordic countries has a rather long payback period. Substantial subsidisations from the Government/local Governments are necessary.

Rural areas in the Central European case represent a mix of a central exchange area with very low cost and more peripheral areas with higher cost figures due to civil works and establishment of new cabinets. The rollout of ADSL in such combined areas gives more profitable solutions with reasonable payback periods and net present values.

In the Southern European country, ADSL rollout in rural areas with settlement patterns made up of rather dense clusters range from a fairly good project value to non-profitable areas. However the economic results are very sensitive to several critical parameters like costs of civil works, distances between clusters, penetration of broadband services and the tariffs. It should also be emphasized that Area D is not analysed in the study but represents an area with low density and very little clustering structure. This is probably the most unprofitable area in this country group.

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2 Kalhagen, K O (ed.), Olsen, B T (ed.) et al. *First results on the Economic Viability of Broadband Services in Non-competitive areas*. Deliverable 6, TONIC (TechnO-ecoNomICs of IP optimised network and Services), IST-2000-25172, 30.09.2001.

3 Kalhagen, K O (ed.), Stordahl, K (ed.) et al. *Demand Models and Preliminary Forecasts for IP Survives*. Deliverable 2, TONIC, IST 25172, 21.06.2001.

4 Olsen, B T et al. *Competitive Access Solution*. ECCS200, Berlin, Germany, Sept 25–26, 2000.

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9 The Ministry of Industry, Employment and Communications. *The Development of the IT Infrastructure*. p. 5.

Interactive TV Services and Networks – An Overview

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Øyvind Kvennås (31) graduated as Master of Science in Electrical Engineering from the Norwegian University of Science and Technology (NTNU), formerly NTH) in 1995. Initially he was employed by Telenor Satellite Services AS, contributing to specification and establishment of the digital TV platform operated by Telenor. In the last few years he has been an active participant in the development of the Telenor MHP (Multimedia Home Platform) playout infrastructure as well as the NorDig specification work.

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In the past 10 years the broadcasting industry has gone through a tremendous change, first of all due to new digital encoding and transmission techniques, but also due to the possibility to offer value-added services along with the TV signals. The TV experience is about to change, from passively receiving video and audio signals into actively interacting with the broadcasters and back-end systems. Also, the emergence of new, non-broadcast networks being able to offer personalised TV content has led to a new way of thinking, bringing the broadcast and Internet technology closer together.

The Digital Video Broadcasting (DVB) project has been vital in the specification and marketing of digital transmission in Europe. Initially studying digital transmission techniques for broadcast networks only, DVB has moved into the interactive multimedia segment and is working to specify and establish a common interface for digital interactive applications (Multimedia Home Platform – MHP). In the latest years, DVB has also considered how to make DVB services available in non-broadcast networks, e.g. in switched broadband networks based on the Internet Protocol (IP). Using the IP protocol for TV transmission opens for new interactions between live video pictures and associated data and applications.

This article gives an overview of the past and present work by DVB and tries to identify the central role of the DVB project. Subsequently, the basics of the MHP specification are explained, as well as the impact the standard may have on the entire interactive application market. The future tasks of the DVB group are then considered, mainly with focus on the ongoing work for transportation of DVB services over IP-based networks. Finally, some future predictions are given.

1 Scope

The scope of this paper is to present an overview of the standardisation process for digital television in general and the evolution of interactive services in particular. The work of the DVB (Digital Video Broadcasting) project is highlighted, mainly focusing the current status of interactivity and the future tasks aiming towards a worldwide adoption of common standards for interactive television.

One of the major tasks within DVB at the time of writing, is the work towards bridging the broadband and the broadcast domains. As the standards for digital television over broadcast networks (i.e. satellite, cable and terrestrial) is adopted worldwide and regarded as very mature, the effort is now on offering DVB services over any kind of switched broadband networks. Closely related to this work is the further achievements within video compression technology. The evolution, the current achievements and the implications for broadband networks are highlighted.

2 The DVB (Digital Video Broadcasting) Project

The Digital Video Broadcasting project [1] is a joint European initiative that has led to a significant number of commercial requirements, technical specifications and guidelines for the development and deployment of digital television.

The DVB project has been quite productive since its start in 1993, producing a significant number of technical specifications and guidelines within various field.

2.1 The History of DVB

The DVB idea was born in 1991, when broadcasters and consumer equipment manufacturers met to discuss how to form a concerted pan-European platform to develop digital terrestrial television. At the end of that year, this first initiative led to the formation of the European Launching Group (ELG). Regulatory bodies were at this time invited to join the group. The first task for the ELG group was to create a Memorandum of Understanding (MoU), establishing rules for the future digital television market. The MoU was signed by all ELG participants in September 1993, and the ELG initiative became the DVB (Digital Video Broadcasting) group. The work towards a full digital television platform in Europe moved into top speed.

At the same time, the Working Group on Digital Television completed a report on prospects and possibilities for digital terrestrial television in Europe. This highly respected report introduced quite astonishing concepts like proposals to allow several different consumer markets to be served at the same time (e.g. portable TV, HDTV).

In parallel, it was clear that the once state-of-the art MAC[1)] technology in the satellite broadcasting market would have to give way to all-digital technology. It soon became clear that DVB technology would first be introduced in the satellite

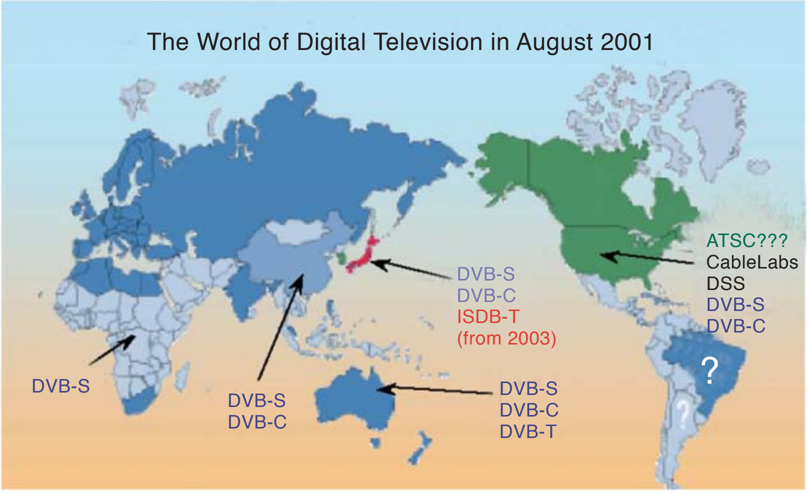


Figure 1 Commercial and test networks using DVB technology (updated per August 2001)

and cable broadcasting industry, while the terrestrial broadcasting industry moved slowly in the same direction. The DVB-S (satellite) transmission standard was the first one to be approved (1994). The standard, based on QPSK modulation, is now the de-facto world satellite transmission standard for digital TV applications. The DVB-C (cable) is closely related to the DVB-S specification, using QAM modulation. The last version of the main DVB-C specification (EN 300 429) was available from the ETSI website in April 1998. Finally, the DVB-T (terrestrial) specification EN 300 744 was released from the ETSI site in August 1997. The latest version (version 1.4.1) was available in January 2001.

2.2 World-Wide Adoption of DVB Standards

Europe was (not surprisingly) the first continent to adopt the DVB transmission standards. The first commercial DVB-S operations were seen early 1996, with an extensive evolution from 1998. The cable industry followed two to three years later, and since 2000 several commercial DVB-T networks are established.

Figure 1 shows the world-wide adoption of DVB standards per August 2001 [2]. It is worth noting that in the past years DVB standards have been adopted in the US (CableLabs) and South America (Brazil).

2.3 The Process of Making a Standard

The DVB consortium is divided into different sub-modules according to Figure 2. The first step in the standardisation process is to compile a set to commercial requirements, to be used as constraints (e.g. price level, user functions) on the specification. The Commercial Module (CM) is responsible for the commercial requirements.

Based on the commercial requirements from the Commercial Module, the Technical Module (TM) develops the specification itself. The technical specification shall be supported by the Commercial Module before it is finally approved by the DVB Steering Board.

Having been approved by the DVB Steering Board, the DVB specification is offered for standardisation to the relevant international standards body (ETSI or CENELEC), through the EBU/ETSI/CENELEC JTC (Joint Technical Committee), the ITU-R, ITU-T and DAVIC.

The Commercial Module (CM) and the Technical Module (TM) are split into different ad-hoc groups, each group working within a specific task. The actual specification work is performed in the ad-hoc groups. The present ad-hoc groups are shown in Figure 3.

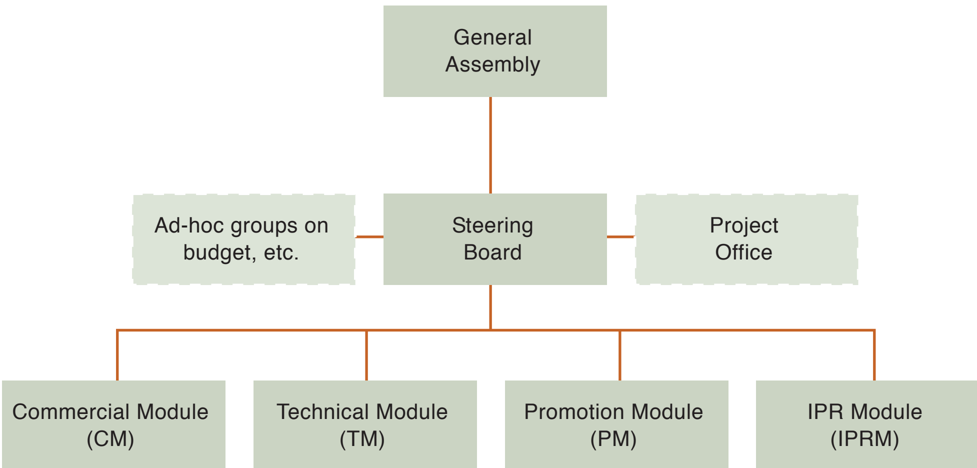


Figure 2 DVB organisation diagram

[1] *MAC (Multiple Analogue Components) was a European satellite broadcasting standard prior to the evolution of the digital standards. The MAC standard specified digital audio coding but analogue video coding.*

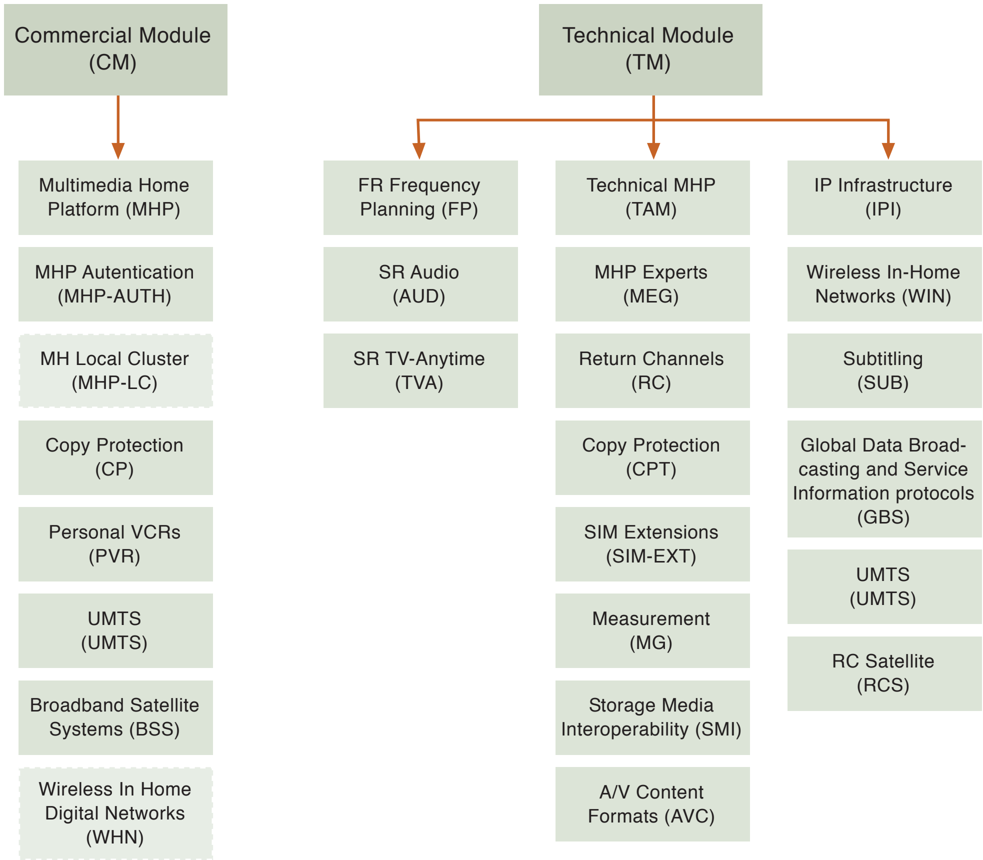


Figure 3 DVB ad-hoc groups (groups indicated with dotted lines are in "sleeping" mode, i.e. presently not active)

2.4 DVB and Interactivity

Finalising the main DVB transmission standards in 1997, the DVB project realised a need to standardise a common platform for application development, transmission and reception. Several legacy systems were available (e.g. OpenTV, Mediahighway, MHEG) and deployed in a large number of DVB-S and DVB-C networks from 1998 to 2000.

- *OpenTV* is the most widely deployed ITV solution, over 50 network operators in over 50 different countries have deployed OpenTV (cable operators in Denmark and Sweden, among others). OpenTV as a solution was originally created by an alliance between SUN MicroSystems and THOMSON multimedia. This alliance founded the company OpenTV that currently develop, maintain and market the OpenTV ITV solution. OpenTV has contributed to the MHP standard, and has recently launched an OpenTV MHP package, extending the OpenTV middleware to support DVB-MHP, and hence providing a migration path to MHP for existing OpenTV customers.

- *Mediahighway* is an ITV solution developed by Canal+ Technologies. Originally developed as a digital interactive Pay-TV system, the system has been extended to cover application development and data transmission. Mediahighway is for example used by the Nordic DTH operator Canal Digital, offering Mediahighway applications to large numbers of DTH customers in the Nordic area. Canal+ Technologies has, as is the case for OpenTV, contributed to the MHP standard, and the Mediahighway solution will be refined to support MHP.

- *MHEG* is actually a ISO/IEC/JTC1SC 29 working group (WG12), providing standards for the coded representation of multimedia information objects that are interchanged among applications and services using a variety of media. MHEG-5 is the fifth part of the MHEG standard suite. It was developed to support the distribution of interactive multimedia applications in a client/server architecture across platforms of different types and brands, specifically towards set-top boxes. MHEG-5 was adopted in the UK digital terrestrial network.

Although proprietary ITV solutions were widely deployed, a need arised to create a common framework that would allow any interactive TV application to execute on any digital TV set-top box. This common framework would be the Multimedia Home Platform.

2.4.1 Multimedia Home Platform (MHP)

In its simplest form, MHP [3] defines a generic interface between interactive digital applications and the terminals on which those applications execute. One of the major goals of the MHP

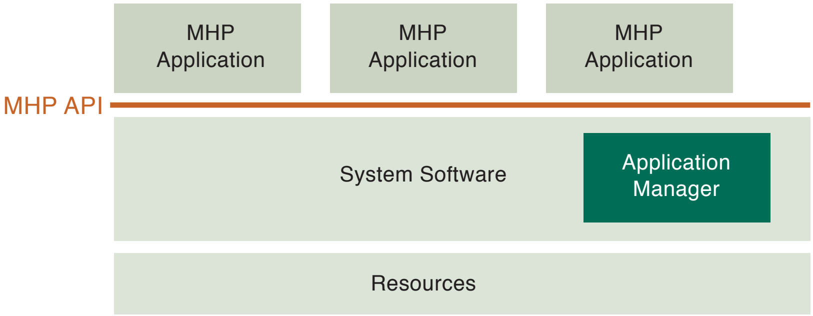


Figure 4 MHP set-top box architecture in terms of different layers

work is to migrate from different legacy API systems into this generic interface. The MHP API decouples the interactive applications from the hardware and software of different MHP terminal implementations. Hence MHP enables digital content providers to address all types of terminals, from low-end to high-end set-top boxes, integrated TV sets, multimedia PCs, and mobile phones (3G).

The MHP set-top box architecture is usually considered in terms of three layers, as is indicated in Figure 4.

Typical resources are MPEG processing (e.g. decoding), I/O functions, and graphics. The system software layer uses the resources to create a generic platform from the applications point of view. The system software contains an application manager (commonly known as "application navigator") whose task is to control the applications made available.

2.4.1.1 MHP Profiles

Three different profiles are defined for MHP, all identified in Table 1.

Hence MHP1.0 [3] contains the two first profiles (enhanced broadcast and interactive broadcast), while MHP1.1 [4] contains all three profiles. Including the Internet Access profile leads to several obvious benefits:

- Application download over return channel/ Internet or even altering between broadcast and return channels;
- DVB-HTML is fully defined, allowing both Java (Xlets) and HTML applications to be offered;
- Detailed plug-in support and execution – greatly benefitting the migration from legacy API systems;
- Narrow-banded networks can put MHP applications on WWW servers – enabling MHP applications to be downloaded and executed in non-broadcast networks;
- Enhanced caching of applications make it easier for terminals to access data quickly and improve response times;
- T/E Commerce capability, currency symbols, number formatting and date order with smart card capabilities;
- Full Internet functionality, DVB programs can be started from HTML pages, Bookmarking, WWW page access from within DVB-J applications.

2.4.1.2 The Cost of an MHP Terminal

The key issue for digital TV operators is the additional cost for set-top boxes in order to be MHP compatible. Some major STB manufacturers (Philips, Sony, Panasonic and Nokia) have evaluated the MHP standards and compared the required performance with requirements for other proprietary APIs [5]. The comparison is shown in Table 2.

The same manufacturers have also estimated the cost of interactivity, i.e. the increased cost for MHP vs. a basic digital TV zapper. Figure 5 shows the predicted cost increase.

Table 1 MHP profiles and standardisation status

Profile No.	Profile	Description	Status standardisation
1	Enhanced Broadcasting	This profile focuses basically pure broadcast applications that require limited interactivity. A small-bandwidth return channel is assumed (telephone/cable modem).	MHP 1.0 (TS101812 v1.2.1), June 2002, officially released from ETSI
2	Interactive TV	This profile uses a similar return channel as the Enhanced Broadcasting profile, but with greater activity along this return path. Thus, this profile requires more support in the software platform for interactive applications.	MHP 1.0 (TS101812 v1.2.1), June 2002, officially released from ETSI
3	Internet profile	The Internet profile targets a wide band interactive and return channel (e.g. cable modem and other high-bandwidth return channel technologies). This profile supports Internet type content downloaded directly from Internet.	MHP 1.1 (Draft TS102812 v1.1.1), November 2001, officially released from ETSI

The figure indicates the BOM (Bill Of Materials) cost uplift. To get the actual cost uplift in an unsubsidised retail market, the BOM cost uplift can be multiplied with a factor of three (rule of thumb).

Some general comments must be made with respect to the MHP profiles:

- The line for MHP Enhanced Broadcast profile does not include the cost of a modem.
- The line for MHP Interactive Broadcast profile includes the cost of a 56K modem.
- The line for MHP Internet Access profile includes the cost of a 56K modem.

3.4.1.3 MHP Test Suites

DVB realised that test suites were necessary to test and verify the conformance to the MHP standard for the solutions that are coming to market. Hence a small consortium was put together to develop a set of test procedures and to establish formal test suites. The MHP Test Suite (version 1.0.2a) was officially approved by the DVB Steering Board in July 2002, and has been forwarded to ETSI. The Test Suite will form the cornerstone of the MHP conformance process, and operators and vendors will be able to perform the tests and gain the right to use the MHP logo.

In parallel, an MHP Implementers Group has been established. The aim is to gather operators, application providers and other MHP vendors to perform interoperability tests and thus verify the interpretation of the MHP standards. Several interoperability workshops have been conducted.

2.4.1.4 MHP 2.0

MHP has started the process of making MHP available also for non-broadcast networks. A Globally Executable MHP (GEM) document is to be approved by the Technical Module (TM) in Q3'2002. This document shall basically define the means to incorporate MHP into non-broadcast networks, particularly targeting switched broadband networks (e.g. IP-based networks).

Furthermore MHP has been defined as the starting point for the Multimedia Car Platform (MCP). With the benefit of diversity antenna DVB-T (terrestrial) is also perfectly suited to mobile reception. The MCP project established that MHP is suitable for automotive environment, and the MCP software platform is based on the MHP 1.1 specification with extensions to access the navigation, the DAB system, the speech control, and the car data bus. Further information about the MCP project is found in [6].

STB solution	Processor	RAM	Flash/ROM
Basic TV zapper	30 MHz+	1 – 2 MB	1 – 2 MB
MHEG-5	50 MHz+	4 MB	2 MB
Open TV	50 MHz+	4 – 8 MB	4 MB
Mediahighway	50 MHz+	4 – 8 MB	4 MB
MHP Enhanced Broadcast profile	80 – 130 MHz+	8 – 16 MB	8 MB
MHP Interactive Broadcast profile	80 – 130 MHz+	8 – 16 MB	8 MB
MHP Internet Access profile	150 – 200 MHz+	16 – 32 MB	16 MB

Table 2 Performance requirements for MHP compatible set-top boxes

2.5 The "Next" DVB (DVB 2.0)

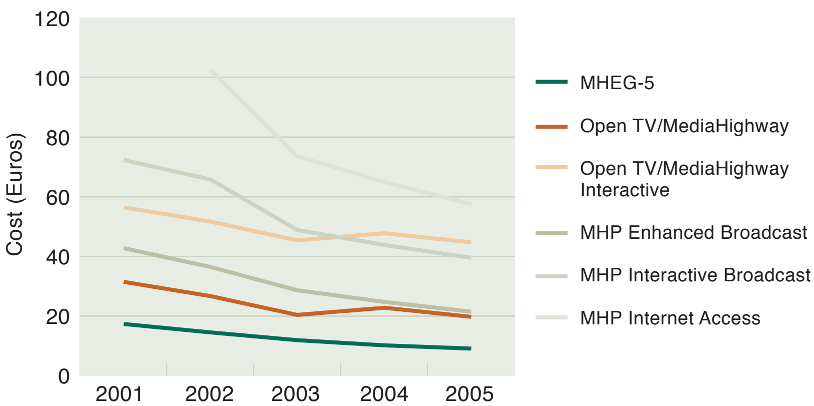
In October 2000, the DVB Steering Board defined a strategy for the "new" DVB, focusing three important tasks [2]:

- Further development in the area of MHP;
- Providing technologies that will enable delivery of DVB services to all kinds of networks (by re-using existing standards as far as possible);
- Continuous optimisation of broadcast network technologies and related terminal devices.

In particular the second task represents a new era of DVB work, trying to bridge the broadband and the broadcast markets into one common market. At the same time, it was clear that DVB realised that the wealth of Internet applications, the deployment of high-speed broadband networks, and the improvements in video compression technology over time would make TV transmission over switched broadband networks viable.

The tasks identified above are the foundation for the DVB 2.0. A reference model is given in Figure 6.

Figure 5 Additional STB cost compared to basic digital TV zapper



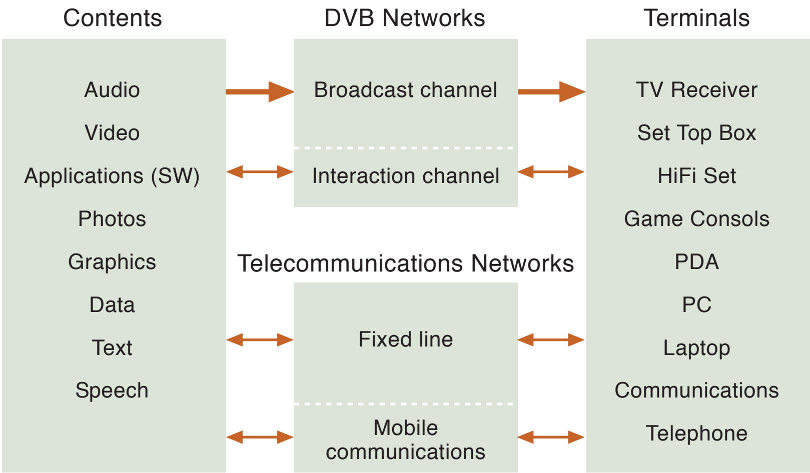


Figure 6 Reference model for DVB 2.0

Undoubtly the most interesting action in DVB 2.0 is the foundation of the IP Infrastructure (IPI) ad-hoc group. The work and current status of the IPI group is detailed in the next section.

2.5.1 DVB-IPI (IP Infrastructure)

The DVB-IPI ad-hoc group started in 2000 and per September 2002 the first specification is subject for approval by the DVB Streering Board. The IPI ad-hoc group shall develop specifications within the following fields [7]:

- **Architectural Framework for the Delivery of DVB Services over IP-based Networks (IPI2001-012):** These are commercial requirements produced by the DVB Commercial Module and were officially released as a Technical Report from ETSI in April 2002 (TR102033 v. 1.1.1 [7]).

- **Transport of DVB Services over IP-based Networks (IPI2001-016):** This specification describes how to transport DVB services over IP. It defines how the service is initiated, the protocol stack used for encapsulation DVB data, and the network requirement for correct and timely delivery of data. This specification is about to be officially approved by the DVB Steering Board, mainly editorial changes remain.

- **Service Discovery and Selection (IPI2001-059):** This specification describes the discovery of service providers, which DVB-IP services they provide and how to select those services. As such, the specification is analogous to the SI specification [8] in the broadcast domain. Note that PSI tables will also be used in IP-based networks (i.e. PAT, CAT and PMT), hence the MPEG processing chipsets do not have to be changed. The DVB SI tables are optional in IP-based networks, protocols like SDP and SAP are used instead.

- **Network Provisioning and IP Addressing (IPI2001-071):** This specification describes how the terminal devices shall obtain IP addresses, DNS and other basic IP services, as well as on-going management of the IP devices.

- **Ethernet Home Network Segment (IPI2001-072):** This specification defines a wired Home Network Segment based on Ethernet 100baseT, it defines how IP services will be carried over the network and makes recommendations for how IP QoS can be mapped to the Ethernet layer.

- **Security (IPI-073):** To be defined.

It is important to note that DVB-IPI has put a mandatory requirement to use the RTP protocol for timely delivery of MPEG-2 transport packets. Although a number of trials and pilot networks has ben establised for IP-based networks (e.g. xDSL), basically none of the existing ones use RTP. Hence the overall protocol stack should be as shown in Figure 7.

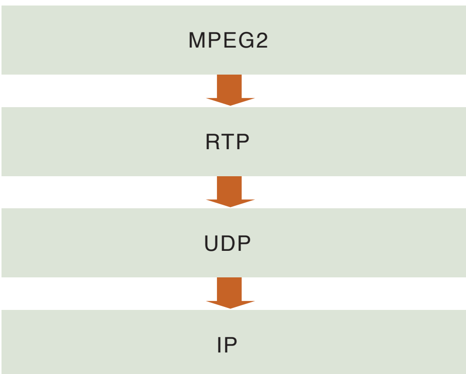


Figure 7 Protocol stack for delivery of DVB services over IP

3 The Future for Interactive Services and Networks

Interactive services and applications were predicted to play a major role in the broadcasting industry already from 2000 onwards. It was predicted that the transmission capacity (e.g. via satellite) available due to digitisation of the television services mainly would be filled with interactive applications and data transmissions. Simultaneously, the growth of the broadband infrastructure (fibre networks, high-capacity switched networks), also including the access network (e.g. xDSL), implied a large increase in the demand and usage of interactive multimedia services.

Two years have passed since 2000, and still the overall usage of interactive services and applications is quite modest. The predictions were obviously too optimistic, and television services are still the main attraction for broadband customers. The reason is probably two-fold. First of all, digital TV operators have mainly been focusing on deploying set-top boxes in the market, primarily for reception of digital television. Low price is a key issue, hence the processing power of the set-top boxes has not allowed to run sophisticated applications. Secondly, set-top boxes running MHP have not been available other than prototypes. Vendors are waiting for an order, while operators seem to be waiting for available set-top boxes.

Still, there are several indications that 2002 may be the year for market acceptance of the MHP standard. Proprietary API vendors have provided upgrades for MHP conformance, and several operators have committed to a migration plan into MHP. MHP has also been commercially deployed in terrestrial networks (Finland). During the last year, MHP has also been widely accepted outside Europe. The Australian terrestrial operator Network Ten offers MHP applications, there is a significant MHP interest in the Asian region, and finally MHP was adopted in the US. The US CableLabs organisation announced that MHP is to become the core of the OpenCable Application Platform (OCAP).

Until Q3'2002 there has not been a significant demand for digital television services over switched broadband networks. Several pilot networks are established, but very few operators have offered ITV services over switched broadband networks. The lack of definite standards is one reason. Hence, it may prove that the work of the DVB-IPI ad-hoc group is due in time for a widespread deployment of ITV services over such networks.

4 Conclusions

DVB has undoubtedly played an important role in the specification of and motivation for digital television worldwide. Originally focusing around transmission aspects of digital television, DVB has moved into the interactive sphere, bringing together the best of the broadcast industry and the telecommunications industry. Digital television is deployed worldwide, primarily over satellite (DVB-S) and cable (DVB-C) networks, but digital terrestrial (DVB-T) networks are starting to mature. The Multimedia Home Platform (MHP) specification has been the DVB answer to the proprietary legacy ITV systems, and although later than originally expected, it seems like the MHP standards have been widely adopted. The first commercial MHP compliant equipment and networks are present, and in the next 5 – 10 years a widespread migration into MHP is likely.

DVB is presently also focused around making DVB services available in non-broadcast networks. It has been proven viable to transmit TV-quality video (4 – 6 Mb/s) over switched broadband networks (e.g. xDSL), and continuous improvements in video compression techniques will make this even more feasible. There are still no definite standards for TV transmission in this market, however DVB-IPI is working progressively and the first specifications are expected to be approved in 2002. These types of networks also benefit from high bandwidth access to the Internet, allowing full interactivity. In addition, switched broadband networks (individual access) are the only network type that will allow pure video on demand. With the approval of the MHP 1.1 specification, MHP applications may also be accessed in switched broadband networks and can be merged together with pure Internet type of applications.

There is a significant amount of work being done within the fields of ITV transmission over switched broadband networks. A lot of the work and field trials are based on definite and well-proven standards (MPEG-2 for video compression, DVB-CA for conditional access, and various extensively used Internet standards). As the relevant standards are completed (e.g. VDSL specification), it opens for an accelerated move into commercial deployments. The first large-scale deployments of ITV services over switched broadband should be expected late 2004 / early 2005.

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Service Platforms for Next Generation Interactive Television Services

GUNN KRISTIN KLUNGSØYR

The introduction of digital television has paved the way for including multimedia elements to enhance the value of conventional television services. Through work in European collaborative projects, Telenor R&D has tried to show how sophisticated services, focusing on interactivity and personalisation, can be realised by using open standards. The projects – CustomTV, SAMBITS and SAVANT – have all designed and developed end-to-end systems along with sample applications or service scenarios to demonstrate the functionality achieved. The main technology used to realise these systems and services is the new standards from the MPEG and DVB consortia. The MPEG-4 standard is the key to interactivity. It is used to represent and encode audiovisual scenes and 3D graphical environments. The MPEG-7 standard is used for indexing and content annotation, and is the key element in making personalised services. Finally, DVB-MHP is used as middleware in the user terminals, thus providing a standardised interface to the interactive applications.

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1 Introduction

Since June 1998, Telenor has been working with TV-centric interactive multimedia services in European collaborative projects partly financed by the European Union. This article summarises the work performed this far, starting with the CustomTV project back in 1998, continuing with the SAMBITS project which started where CustomTV left off in 2000, and finally giving the intentions and status of the recent SAVANT project, which started spring 2002 and will run for two more years.

The project scope has expanded and the project consortia have changed over the years, but several partners, including Telenor, have been involved all the way. This has assured that experience gained in one project has been valid input for the next.

Sections 2 and 3 in this article summarise some key features and basic technology that form the basis for all three projects. Focus is given to the novel technology and new features that add value to the conventional television services. The following sections 4 to 6 describe the three projects separately, mainly focusing on the functionality that the corresponding systems provide, exemplified by sample applications.

2 Enhanced Digital Interactive Television Services

2.1 The Current Situation

Commercial digital televisions services have been around for some years now. In addition to conventional television programmes, some added value services are provided, like pay-per-view and near video-on-demand services, access to newspapers and games, as well as programme guides and simple means for navigating through channels. More sophisticated services are also offered during special events like the FIFA world cup, the Wimbledon tennis tournament and so on.

Digital television systems fundamentals are founded on the standardised MPEG and DVB technology, but the current interface to the added value services mostly relies on proprietary systems, like OpenTV and MediaHighway. This makes applications dependent on terminal hardware, thus prohibiting the applications to run on any arbitrary terminal.

Anyway, the introduction of digital television offers exciting possibilities for new services by adding multimedia enhancements to broadcasts. It is important though that the consumer regards digital television as more than just an increased number of programmes, namely as a new way of accessing services and information.

2.2 Key Components in Future Services

In order to make novel interesting services two important aspects have been identified:

- *Personalisation and customisation:* The possibility for viewers to customise the presentation of content according to their wishes will be essential. The screen display can for example be organised according to viewer preferences based on pre-recorded user profiles, and navigators can use these profiles to filter the information before presenting it to the user.

- *Interactivity:* The possibility for users to influence what he receives (remote interactivity) or what is presented to him (local interactivity) paves the way for many different types of applications, ranging from influencing the progress of a movie to downloading background information from servers. This moves television from a passive to an active experience.

This is most easily achieved if the following two features are available:

- *Interaction channel:* It is obvious that an interaction channel is important in systems for interactive television. Though improved functionality can also be achieved through smart usage of data carousels, and by using phone, SMS and e-mail for interaction, an integrated interaction channel is likely to increase the functionality substantially.

- *Local storage:* The possibility to download material for local storage in the user terminal introduces many possibilities for future services. Many sorts of material, e.g. video clips can be downloaded to the terminal during hours of low traffic, thus easing the strain on data carousels and transmission capacity. Response time when accessing this content will also be shorter.

Although this will ease implementation from a technical perspective, we must not forget that it raises many questions regarding ownership of content and hardware, rights management, etc.

2.3 Open Standards

In the European projects described in this article, it has been extremely important to show that good solutions and a rich set of functionality can be achieved within a framework based upon open standards. Open standards are believed to promote horizontal markets, which reduce the risk for incompatible solutions and hopefully lead to an increased acceptance of digital television.

Open standards allow set-top boxes from several vendors to work with services and distribution systems from several service providers. On the service provision side this makes it easier to create applications for a larger audience, and it renders creation of several versions of an application superfluous. Set-top box vendors avoid inclusion of several parallel application interpreters in their equipment, and finally it simplifies the usage for end-users and gives them access to a richer set of applications.

Currently most systems for enhanced digital television services are based on proprietary solutions. MHEG and DVB-MHP are two standardised alternatives. MHEG has been used for terrestrial systems for some years, but offers substantially less functionality than proprietary systems like OpenTV and MediaHighway. DVB-MHP, on the other hand, provides the required functionality, but is late finalising their specification and test material. Therefore manufacturers are delayed in getting equipment ready for the market.

2.4 Why DVB and MPEG

In the European projects where Telenor has contributed, there have been several reasons for choosing to base the systems on standards from DVB[1)] and MPEG[2)]:

- *Compatibility with conventional digital broadcasting:* This is important to shorten the way and time to market. It allows for insertion of enhancements and extra elements without interfering with the already existing services; the service providers do not have to replace the complete production chain; only end users who want to access the enhanced services need to aquire new equipment.

- *New standards from MPEG and DVB have a rich set of required features:* The MPEG-4 and MPEG-7 standards are paving the way for interactivity and customisation. MPEG-4 is a multimedia standard gluing all kinds of natural and synthetic material together. As well as being compression efficient, its object-based functionality is ideal for interactive applications. MPEG-7 is dedicated to content descriptions, facilitating efficient search and retrieval applications and service customisation. The MPEG-21 project, formally called *Multimedia framework*, is likely to play an important role in the currently running SAVANT project, as it is also addressing non-content aspects like terminal capabilities and network characteristics. The DVB Multimedia Home Platform goes beyond super-text TV and allows for quite sophisticated interactive applications.

- *Consistency:* Within MPEG and DVB efforts are made to make their standards work well together. As examples, MPEG has defined how to transport MPEG-4 elements in MPEG-2 systems, and DVB-MHP employs the transport mechanisms defined in existing DVB standards. This makes the final integration work easier.

3 Core Technology

Since our work with interactive digital television services has been centred around technology based on the DVB and MPEG standards, I will first introduce some key concepts from these

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1) *The DVB project started in 1993 as an initiative where European public and private sector organisations produced requirements, specifications and guidelines for the development of digital television.*

2) *The Moving Picture Experts Group is a working group in ISO, which started its work with the MPEG standards in 1988. Its formal name is ISO/IEC JTC1/SC29/WG11.*

standards, starting with MPEG-2 and the early DVB standards, continuing with the newer MPEG standards and finally a short introduction to DVB's Multimedia Home Platform.

3.1 MPEG-2 and DVB – Conventional Digital Television

Conventional digital television is mostly based on MPEG-2 [1] and several standards from DVB. There is a tight link between MPEG-2 and DVB because the DVB project chose to use both the core encoding techniques for audio and video as well as the multiplexing and systems part of the MPEG-2 standard as its cornerstones.

Many processing steps are required in order to prepare source material for transmission, and Figure 1 shows how these tasks are conducted by DVB and MPEG.

MPEG-2 allows for compression of audio and video source material. This is important in order to get a suffiently low bit rate to make economic use of available transmission bandwidth. Though more efficient algorithms have been developed in later years, they are not expected to replace MPEG-2 in digital television services yet.

In order to access single pictures or audio samples, the compressed streams must be packetised. These packets also form the basis for the MPEG-2 synchronisation mechanism, which allows accurate synchronisation between several compressed streams (e.g. lip-sync).

MPEG-2 also defines how to combine elementary streams of audio and video, as well as other data, into program streams or transport streams, which are suitable for storage or transmission. The transport stream was chosen by DVB to be used in digital television transmission systems. The MPEG-2 transport stream contains all data required by a receiver in order to recognise services, decode and present synchronously audio-visual material etc., including the system clock. Transport streams also carry basic signalling information, which is required to find out which service components belong together, how to switch between channels, etc. DVB defines more signalling information required or desired specifically in television broadcast systems, e.g. information about networks, services, programmes, service providers, etc.

The transport stream itself is network independent. DVB has made several specifications to adapt the transport stream to different broadcast delivery channels and networks. This includes error protection to make the signal error robust and signal shaping and modulation to adapt the base band signals to a variety of broadcast delivery channels. The first standards were made for satellite, cable and terrestrial broadcast.

In the advent of interactive TV and multimedia applications, the need for broadcasting other data than MPEG-2 encoded audio and video signals is getting increasingly important. DVB therefore has specified how general purpose data can be broadcast within the same framework as audio and video, namely in the transport stream. Several application areas are identified, and means for simple file download, delivery of IP data, and data- and object carousels (remote file systems) are specified [2].

3.2 MPEG-4 – Objects and Scenes

The main focus of MPEG-1 and MPEG-2 was compression, i.e. to minimize the use of bits or bandwidth to get the desired audio and video quality. This is still important in the MPEG-4 standard, but MPEG-4 also moved to a higher level of abstraction by introducing the concept of objects. In MPEG-4 everything is regarded as objects composing a scene. The standard provides the framework required to compose and interact with the scene and allows coding techniques particularly suited to represent each individual object to be used. MPEG-4 is a multimedia standard combining natural and synthetic material and allowing extensive interactivity [3] [4].

3.2.1 Coded Representation of Media Objects

MPEG-4 audiovisual scenes are composed of several media objects, such as:

- Still images (e.g. a fixed background);
- Video objects (e.g. a talking person – without the background);
- Audio objects (e.g. the voice associated with that person, background music).

A/V source material (uncompressed audio and video)	General purpose data	Signalling information
Compression (audio and video encoding) *Specified by MPEG in ISO/IEC 13818-2 and ISO/IEC 13818-3*	*Specified by DVB in EN 301 192*	*Specified by MPEG in ISO/IEC 13818-1, and by DVB in EN 300 468*
Packetisation (making accessible data units)	*Fundamentals specified by MPEG in ISO/IEC 13818-1, additions by MPEG and DVB e.g. in ISO/IEC 13818-6 and EN 301 192*	
TS-layer/Multiplexing (making transport streams)	*Specified by MPEG in ISO/IEC 13818-1*	
Link layer (protecting the transport streams)	*Specified by DVB, e.g. in EN 300 421, EN 300 744, and EN 300 429*	
Physical layer (transport to receiver side)	*Specified by DVB, e.g. in EN 300 421, EN 300 744, and EN 300 429*	

Figure 1 Processing steps from source material to transmissible stream

MPEG-4 standardises a number of such primitive media objects, capable of representing both natural and synthetic content types. MPEG-4 also defines coded representations of objects such as:

- Text and graphics;
- Talking synthetic heads and associated text used to synthesize the speech and animate the head; animated bodies to go with the faces;
- Synthetic sound.

Each media object can be represented independent of its surroundings or background, i.e. different types of objects can be encoded using different mechanisms even if they eventually are going to be combined into one single audiovisual scene.

3.2.2 Composition of Media Objects

Figure 2 shows how an audiovisual scene in MPEG-4 can be composed of individual objects. In order to combine different media objects into scenes, information on how to put them together must be transmitted along with the media object data itself. This composition information is contained in the Object Descriptor and Scene Description Information elementary streams. Starting from VRML (Virtual Reality Modeling Language), MPEG has developed a binary language for such scene descriptions. It is called BIFS (BInary Format for Scenes).

The different objects as shown in Figure 2 are encoded and stored or transmitted as single objects (live video and audio representing the talking woman, a 3D graphical representation of the room she is standing in, a 2D blackboard with graphical information, etc.). These primitive media objects can be further grouped to form compound media objects, thus allowing authors to construct complex scenes, and enabling consumers to manipulate meaningful sets of objects.

The streams describing the objects and the scene composition are sent to the player along with all the media objects. The actual composition of the scene takes place in the player prior to display. As each object is encoded as a single unit, it is fairly easy to replace objects and re-use the material in different scenarios without the need to encode the material over again. Only the scene composition information must be updated, and any new media streams must be added.

3.2.3 Interaction with Media Objects

In general, the user observes a scene that is composed according to the design of the scene author. Depending on the degree of freedom allowed by the author, however, the user has the possibility to interact with the scene. The content can be manipulated by the user locally at the client side or at the transmitting end through an interaction channel. Local manipulation, like changing the position of an object, making it visible or invisible, or changing the font size of text, is obtained through scene updates. The MPEG-4 player will process these commands in exactly the same way as if they were originated from the original content source and signalled in the Scene Description Information stream.

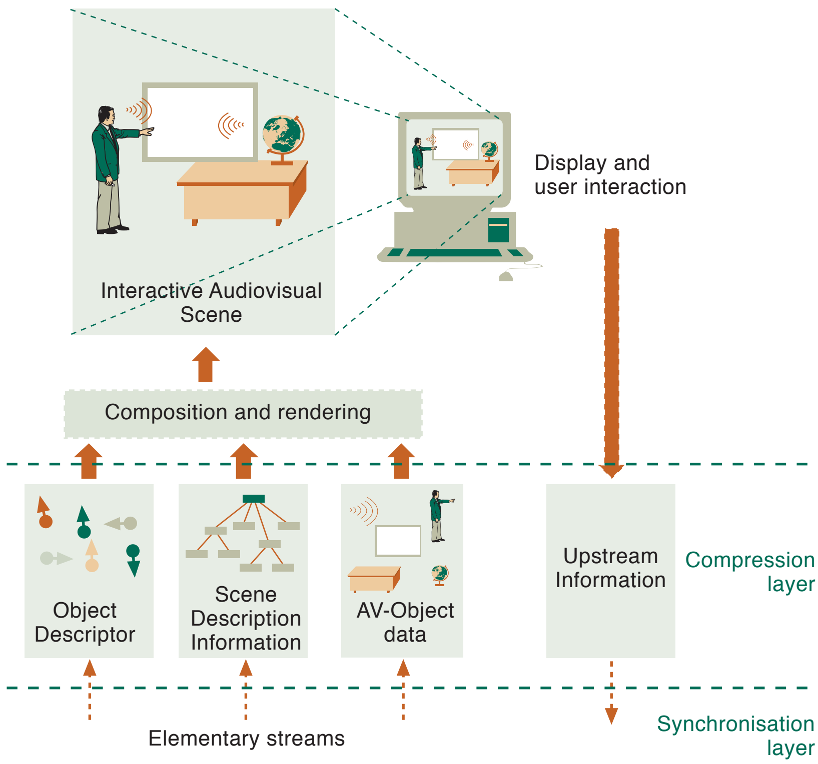
3.2.4 Streaming, Synchronisation and Transportation

MPEG-4 is designed to be transport-agnostic on purpose. MPEG has chosen to use other well-proven transport mechanisms, in order to introduce the standard to the market as quickly as possible.

MPEG-4 on MPEG-2: A work group within MPEG has studied how to convey MPEG-4 information in the existing MPEG-2 programme and transport streams. This work commenced in a specification, which is included in the 2000 edition of MPEG-2 part 1 (IS 13818-1:2000). It describes methods for:

- Transport of individual MPEG-4 audio or MPEG-4 visual elementary streams in MPEG-2 programme and transport streams;
- Transport of audiovisual MPEG-4 scenes with associated elementary streams in MPEG-2 programme and transport streams.

Figure 2 MPEG-4 scene composition



The MPEG-4 components can be tightly linked to the MPEG-2 programme clock reference, thus allowing synchronisation between the MPEG-4 components and other MPEG-2 elementary streams.

MPEG-4 over IP: The specifications for the transport of MPEG-4 content over IP networks are developed jointly with the IETF AVT working group. A framework and several RTP payload format specifications are developed.

The framework is an umbrella specification for the carriage and operation of MPEG-4 sessions over IP-based protocols, including RTP, RTSP, and HTTP. It also provides guidelines for designing payload format specifications for the detailed mapping of MPEG-4 content into several IP-based protocols. Several RTP payload formats are developed under this framework including a generic payload format that specifies a homogeneous carriage of various MPEG-4 streams. It defines a simple but efficient mapping between logical MPEG-4 packets (synchronisation layer) and RTP packets.

3.2.5 Key Features to Add Value to Digital Television

The functionality addressed and the rich set of tools provided by the MPEG-4 standard, introduce many features that can be applied in future interactive television scenarios. The list below shows some key features for creating added value in digital television applications:

- *Coding efficiency and low bit rates:* MPEG-4 can efficiently be used for transmission of information supporting the high quality MPEG-2 programmes, such as trailers or context sensitive add-ins.

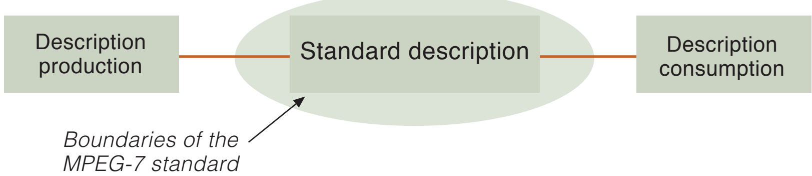
- *Object-based coding:* An object-based representation facilitates advanced interactivity and indexing with single objects.

- *Simple scene manipulation:* The MPEG-4 scene description mechanism (BIFS) supports quick and easy manipulation of scenes at the transmission or reception end.

- *Inherent local interactivity:* The BIFS mechanism already supports scene manipulation, e.g. by mouse clicks and movements. This allows generation of user interface elements such as buttons or labels. Also the behaviour of complete interactive scenes can be defined without any other mechanisms.

- *2D and 3D representation:* With high performance end terminals, a smooth transition to 3D scenes and 3D interactivity is facilitated.

Figure 3 The scope of MPEG-7



3.3 MPEG-7 – Describing Audiovisual Material

An enormous amount of audiovisual information is becoming available in digital form, e.g. in digital archives, in various databases, on the web and in broadcast data streams. In the next few years, users will have access to so much content provided by multiple sources that efficient and accurate access to it (by humans or machines) will be almost impossible. The vast challenge represented by this and the fact that the value of information often depends on how easy it can be found, retrieved, accessed, filtered and managed, are addressed by MPEG-7 [5] [6].

3.3.1 Descriptions

MPEG-7 deals with *descriptions* of audiovisual content. The title of the standard is *Multimedia Content Description Interface*, and it provides a rich set of tools to describe multimedia content.

As shown in Figure 3, it is only the actual descriptions that are standardised; neither how to generate descriptions (information extraction) nor how to use them (information retrieval). MPEG-7 will not be a replacement or competitor to the earlier MPEG standards since they deal with *representations* of the content itself. One might say that MPEG-1, -2, and -4 made content available, while MPEG-7 allows you to find the content you need.

MPEG-7 defines a rich set of descriptors that can be used to describe multimedia content. There are generic descriptors, e.g. for time, textual descriptions, controlled vocabularies etc., and descriptors directly related to the audio or video signals, like colour histograms, and spectral features of a speech signal. Some descriptors are simple, others more sophisticated or complex, e.g. when more than one medium are involved (e.g. audio and video). The description tools are grouped in five classes according to their functionality: content description, content management, content organisation, navigation and access, and user interaction.

MPEG-7 uses XML to model these structured data sets and descriptions. To overcome the lack of efficiency of text-based XML, MPEG-7 has also defined a binary format to facilitate the carriage and processing of MPEG-7 descriptions. This is useful in streaming and broadcasting environments, where transmission capacity is at a premium.

3.3.2 Using MPEG-7

It is often said that MPEG-7 will make large content archives (and the World Wide Web) as searchable for multimedia content as it is for text today. Agents for selection and filtering of broadcast material may also use the same information as is used for content retrieval. The emphasis of MPEG-7 was the provision of novel solutions for audiovisual content descriptions. The following examples are given to show how such audiovisual descriptions can be used:

- Play a few notes on a keyboard and retrieve a list of musical pieces similar to the requested tune;
- Draw a few lines on a screen and find a set of images containing similar graphics, logos, etc.;
- Use an excerpt of Pavarotti's voice to obtain a list of his records, video clips where he is singing and photographic material portraying him.

Even though addressing text-only documents was not among the goals of MPEG-7, the usefulness of textual descriptions are acknowledged, and different tools for textual annotation and controlled vocabularies are also included, taking into account existing standards and practices.

3.3.3 Key Features to Add Value to Digital Television

The MPEG-7 standard has a much broader scope than television and digital broadcasting. Therefore broadcast projects like CustomTV and SAMBITS only utilised a small part of the vast MPEG-7 functionality. It is still early days for interactive television, and we expect that further studies will open new ways of utilising MPEG-7 within this field.

This far, the following key features for creating added value in digital television applications by MPEG-7 have been identified:

- *Classification of and information about objects:* In combination with the object-based functionality of MPEG-4, this opens a way for adding information to individual objects within a scene.
- *Classification of and information about events:* In the temporal domain, fine granular indexing of programmes can be realised (e.g. tagging of a goal in a soccer game).
- *Advanced linking and filtering:* The above-mentioned features can efficiently be used to implement cross-links between multimedia elements, book-marking functions and filter mechanisms for objects and events. It can also be used to link different programme components together in order to achieve synchronised presentation of all elements.

The content and programme descriptions will be utilised both on the studio side (creating programmes) and at the end users' premises (presenting programmes). It is important to note that the use of descriptors on the two sides is quite different. On the studio side, many kinds of descriptors can help programme designers to search for programme elements in archives. MPEG-7 can also be used to link individual components together to make one consistent programme. The main tasks on the terminal side, on the other hand, will be filtering functions, making customised presentations based on user profiles, etc.

3.4 DVB-MHP – The Multimedia Home Platform

Since 1997, DVB has worked on defining a complete technical solution for a user terminal for interactive broadcasting (Multimedia Home Platform – MHP) [7]. MHP defines the interface between interactive digital applications and the terminals they execute on. This interface decouples the content provider's applications from the specific hardware and software details of different terminal implementations (see Figure 4).

3.4.1 Profiles

DVB-MHP has specified three "onion-layered" profiles, which reflect three different application areas (see Figure 5). They are:

- *Enhanced broadcasting:* This profile focuses basically on services with limited interactivity, e.g. broadcast services where additional applications are downloaded to the set-top box. Only a narrow-bandwidth return channel is required. The user interacts with the application mainly locally, thus influencing what is displayed on his screen, but not on what is sent to the set-top box.

Figure 4 Basic Multimedia Home Platform architecture

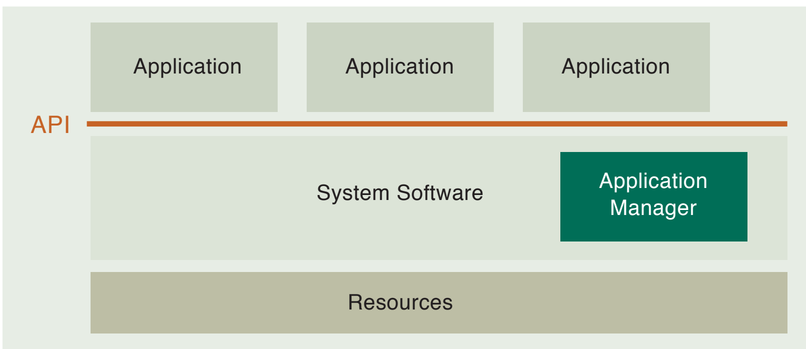
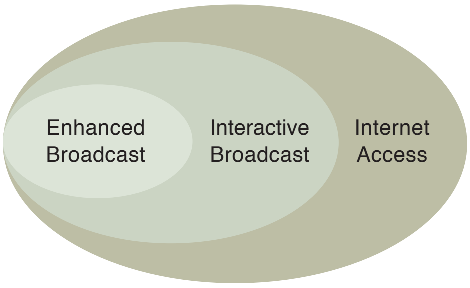


Figure 5 DVB-MHP profiles



- *Interactive broadcasting:* This profile allows for more interactivity (local and remote), but is still limited to what is feasible with a narrow-bandwidth interaction channel.

- *Internet access:* This profile aims for applications requiring a wide-bandwidth interaction channel. It allows for direct download of Internet type content from the Internet.

3.4.2 Transport

MHP is designed to work in the conventional DVB/MPEG-2 broadcast environment as described in section 3.1. It utilises the signalling mechanisms as well as transport mechanisms defined there.

One essential broadcast component is the object carousel. This transport mechanism allows a server to present a set of distinct objects (e.g. files) to a decoder by cyclically repeating the data. The objects in the carousel offer clients a way to access applications and content used by these applications, more or less as if an interactive connection with the server was present. When a decoder wants to access a particular object it has to wait for the next time it is broadcast. Response time is inversely proportional to the carousel size, and depending on the amount of data to be made available, considerable amount of bandwidth may be required for this part of the service. By practically organising the carousel though, the response time can be minimized.

MHP also defines an interaction channel. They specify a set of protocols to use on this channel, but not which physical channel to use. TCP and UDP with IP are the most important protocols used.

3.4.3 MHP Applications

The MHP application interface is Java based, thus opening for many programmers to create applications. The functionality provided by MHP allows many types of applications, some of which will be directly linked to broadcast television programmes, whilst others will be stand-alone. The following list shows a few examples of applications and services facilitated by MHP:

- *Electronic programme guides* (EPG) that can be based on both text and audiovisual material. An important function of an EPG will be to filter the available information to present only relevant information to each individual user.

- *Additional related information* to television programmes can be sent along with a programme. This background information can be presented on the screen if the user chooses to do so. It can be made available to the user prior, during, or after the main programme.

- *Multi-camera productions* can be made, in which users can choose between different cameras to watch video from.

- Different types of *games* can be made available to users for a certain period of time depending e.g. on subscriptions.

- *E-commerce* applications can be linked to TV-programmes and products shown therein.

4 The CustomTV Project – Enhanced Digital TV Pioneer

The CustomTV project was a European Union supported collaborative project funded under the ACTS programme. It was a fairly small project, beginning in June 1998 and lasting for 18 months. It had seven partners[3)] representing the telecom and broadcasting business sectors and industry, as well as universities and research institutes.

The aim of the project was to show how conventional digital television broadcasting could be made more attractive by adding multimedia elements and by adjusting the presentation of the services according to each user's preferences or profile. An important guideline was to use open standards were such existed, and to contribute to standardisation in the areas were standards were currently missing.

The project succeeded in creating a prototype system capable of showing fairly advanced interactive and personalised services by mostly utilising existing technology and without requiring a return channel or local storage facilities [8]. The project results were successfully shown at the International Broadcast Convention, IBC, in Amsterdam in September 1999.

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3) *Heinrich-Hertz-Institut für Nachrichtentechnik Berlin GmbH, Germany; Institut für Rundfunktechnik GmbH, Germany; Norwegian Broadcasting Corporation, Norway; Queen Mary and Westfield College, UK; Robert Bosch GmbH, Germany; Royal PTT Nederland – KPN, Netherlands; Telenor AS, Norway.*

4.1 The Demonstrator

The CustomTV system is based on DVB/MPEG-2 as described in section 3. The enhancements, like extra video clips, audio tracks, text and graphical elements are represented according to the MPEG-4 standard, and all elements are described and indexed using MPEG-7 like descriptions[4)]. The descriptors are describing either content or events (i.e. something that is happening), and form the basis for filtering and selection based on programme categories and personal profiles as well as messaging when specific things happen in a programme.

The user interface was implemented in Java, but was not compliant to DVB-MHP, since the standard was not available at the time of CustomTV.

Figure 6 shows the end-to-end CustomTV system. All service components were prepared beforehand (encoding, indexing, multiplexing), and streams ready for play-out were stored on a media server. The online demonstrator consisted of a real time receiver system, which was fed from the media server via a satellite link. The receiver system was not integrated in a single unit, but was realised by functional modules running on several PCs.

The Custom TV system did not make use of a return or interaction channel. All the added functionality was achieved through local interactivity and customisation of the user terminal. Extended use of local storage on the user terminal was also avoided. Despite this, CustomTV succeeded in making quite sophisticated services.

4.2 The Service Scenarios

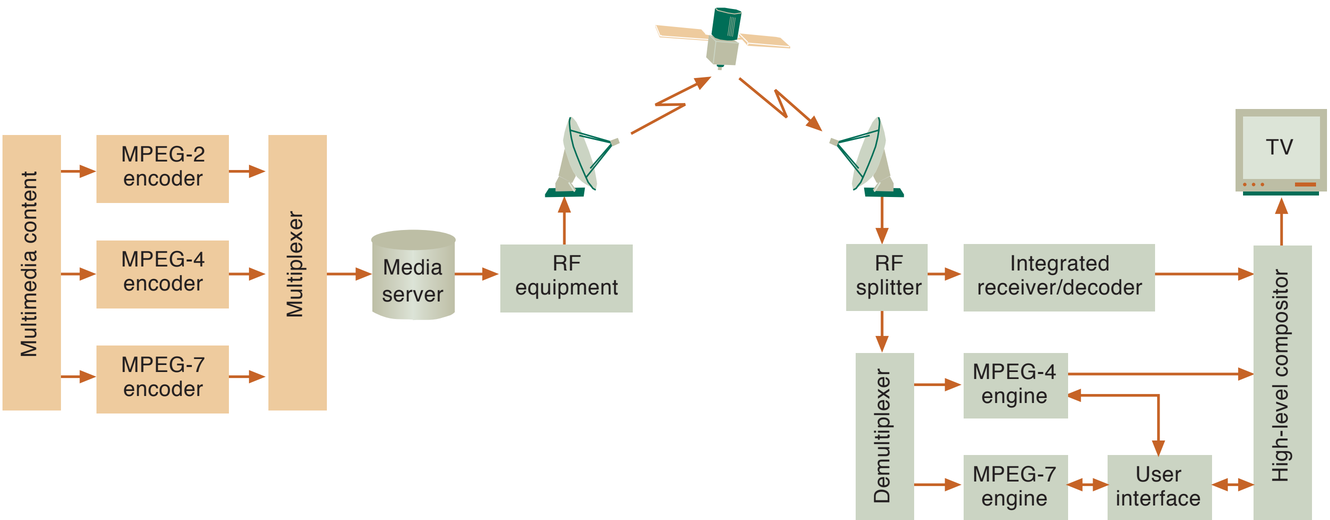
In order to demonstrate the functionality of the CustomTV system, three service scenarios showing different ways of utilising the new technology were designed.

4.2.1 Advanced Electronic Programme Guide

As more and more television channels and programmes become available, it will be increasingly important to offer applications that can help navigate through the abundance of input. The key concept in the CustomTV electronic programme guide (EPG) is that the channels will be automatically sorted according to stored user preferences or profiles. The channel list will be dynamically updated as programmes change, always placing the most interesting programmes at the top. The EPG also presents short audiovisual presentations of the currently running programmes (trailers) along with textual information.

A typical screen shot from this scenario is shown in Figure 7. When tuning into the CustomTV EPG, trailers of four running programmes are shown simultaneously. The selection is based on the list that was arranged according to the user preferences. The mosaic screen layout is an MPEG-4 scene with four audiovisual objects, namely the trailers. The trailers are encoded at low bit rate using the coding efficient MPEG-4 audio and video compression tools, and the viewer can interact with the objects in the scene using the ordinary BIFS tools. By focusing on a trailer he can enlarge it, ask for additional information about the programme, and switch to the programme itself.

Figure 6 The CustomTV system



4) The CustomTV project was running in parallel with the MPEG-7 standardisation process. The descriptions used were based on the project's early contributions to MPEG, and are not fully compliant with the final standard.

Figure 7 Screen shot from the Electronic Programme Guide scenario

By specifying interest in programme categories or sub-categories, each viewer can set up his own profile(s). These profiles can be easily adjusted or redefined at any time. MPEG-7 descriptions are used both in the profile set-up and in descriptions accompanying all programme elements, thus making the sorting of the programmes based on the user preferences easy.

MPEG-7 is also used to give alerts if something of particular interest happens or if current content on any other channel has a high interest rating in the user's profile. For example, a viewer can be notified if a hockey match starts on another channel, or when a goal is scored in that match.

In the CustomTV demonstration scenario we used only six television channels. When hundreds of channels are available, some adjustments must be made. Hundreds of trailers require a considerable amount of bandwidth, even if they are encoded at low bit rates. This makes online transmission hardly feasible. In combination with local storage, object carousels, smart combinations of trailers, still pictures and text, the functionality shown in this scenario will still be within reach.

4.2.2 Interactive Weather Forecast

CustomTV wanted to show how MPEG-4 could be utilised to create interactive TV programmes by using MPEG-4 scenes that are composed of many different, possibly arbitrarily shaped objects. The user can interact with each object in the scene, and the response will depend on which object he selects.

Figure 8 Screen shot from the Interactive Weather Forecast scenario

A typical screen shot from the CustomTV interactive weather forecast scenario is shown in Figure 8.

Initially the weather forecast for Europe is shown along with the presenter. Each country is an arbitrarily shaped MPEG-4 object, and can therefore be treated individually. By selecting one of the countries on the map, a video clip with a more detailed forecast for that region pops up. This video object can be resized and placed anywhere on the screen according to the user's choice. Which audio track to play is also the choice of the user. As this is implemented as one MPEG-4 scene composed of several object, all the object manipulation techniques inherent in MPEG-4 can be used. The forecasts for each country were encoded with high compression making the overall bit rate required for the complete application quite low. As always, quality, resolution and frame rate must be weighted against bandwidth requirements.

This CustomTV application was limited to a few European countries and there were also some limitations in the flexibility of moving and resizing objects. As more sophisticated MPEG-4 authoring tools and players become available these limitations can be overcome.

4.2.3 Interactive Data Services

Making additional data services available while watching any TV programme is yet another approach to enhancements of digital television services. The data services can be independent of the TV-programmes. CustomTV implemented two such services. One service provides flight information from an airport. You can get an overview of all flights or choose to track a certain flight to find out if it is on schedule or not. The other service is information about the stock market, market prices, graphical representation of its development, etc. Both services are implemented using the scene, text and graphics facilities of MPEG-4. This is a highly compressed form of representation making it very bandwidth efficient. For this service to be useful, the information must of course be updated as soon as new information is available. Such updates are signalled using MPEG-7.

A typical screen shot from this scenario is shown in Figure 9. The information on the screen can be iconised or moved around the screen, as the user wants.

4.3 Evaluation

A few usability tests were conducted based on the service scenarios described in the previous section. The general opinion was that the additional interactive features were valuable extensions to conventional television services. The users liked the perceived control by specifying preferences and interest, the event messaging and the presentation of programme information. The only major usability problem identified was the remote control, which was very hard to use.

The tests performed were all in a single-user environment, and therefore could not reveal anything related to the social aspects of television viewing. It is recognised though, that several interesting questions arise when using preferences-based models in multi-user scenarios.

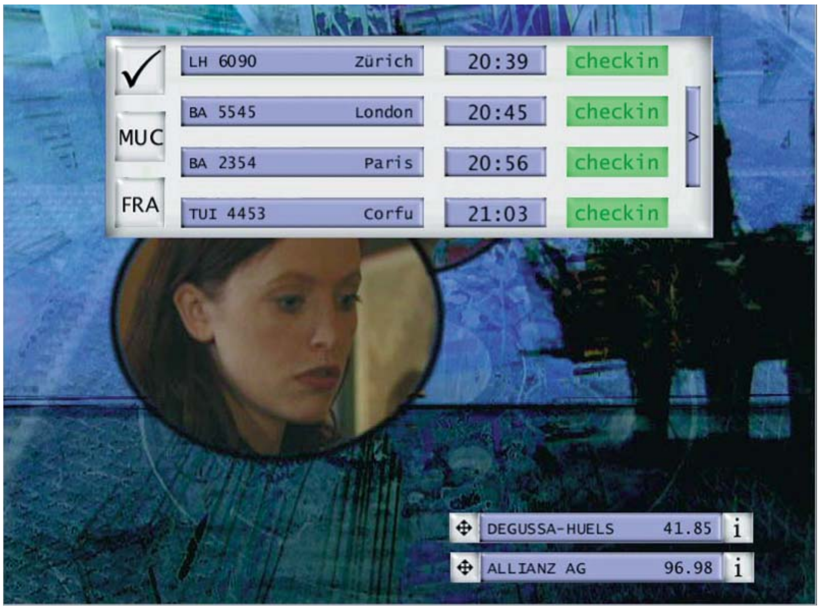


Figure 9 Screen shot from the Interactive Data Services scenario

5 The SAMBITS Project – Combining Internet and Television

The SAMBITS project, *System for Advanced Multimedia Broadcast and IT Services*, was part of the IST programme of the European Union. The consortium started their work in January 2000 and the project lasted for 24 months. Twelve European partners[5)], representing the telecom and broadcasting business sectors and industry, as well as universities and research institutes, formed the consortium. Most of the CustomTV partners joined this new consortium, assuring that the experiences from CustomTV were well taken care of. We can safely say that SAMBITS continued were CustomTV left off.

The aim of the project was to study how advanced additional services could enhance the value of current digital television transmissions by creating an integrated system where the conventional broadcasting technologies are combined with Internet in a way that exploits the best from both areas. Thus the project developed a multimedia studio system and an end user terminal, studied transport and delivery mechanisms, and designed example applications that provide more functionality than those applications which were already offered separately in digital television broadcasting or on the Internet.

5.1 Example Service Scenarios

SAMBITS had several service scenarios in mind when setting up the requirements for the SAMBITS system. As most of the requirements were common for all the scenarios studied, only two of them were pursued and used to demonstrate the system functionality. These two service scenarios are described in the following subsections.

5.1.1 The Ballad of Big Al

This scenario is based on a special made by BBC on their popular production "Walking with Dinosaurs". It is a popular science programme about the life of the dinosaur called Big Al. BBC had also produced lots of material on the science behind the story of Big Al, so many web pages and audiovisual clips were available to SAMBITS.

The narrative of this programme is essential, so having sign language interpretation is very important for the hard of hearing. Since the signer is implemented as an MPEG-4 object, each individual viewer can easily switch the sign language interpretation on or off whenever he wants. Viewers can watch the programme with no extra features (Figure 10) or with the signer included in the picture (Figure 11). The signer being an arbitrarily shaped object assures that it covers a minimum of the screen. By setting the user profile accordingly, sign language can be switched on by default whenever available.

Figure 11 also shows the user interface for the interactive services. The user interface is designed to signal when new additional information is available. The viewer can explore this information immediately or wait until later. The additional information can at any time be accessed via the programme overview showing all components of a service. Textual information about the running programme and its individual

5) Bayerischer Rundfunk, Germany; British Broadcasting Corporation, UK; Brunel University, UK; European Broadcasting Union, Belgium; GMD – Forschungszentrum Informationstechnik GmbH, Germany; Heinrich-Hertz-Institut für Nachrichtentechnik Berlin GmbH, Germany; Insititut für Rundfunktechnik GmbH, Germany; Koninklijke KPN NV, KPN Research, Netherlands; Philips France S.A.S, division Laboratoires d'Electronique Philips, France; Queen Mary and Westfield College, UK; Siemens Aktiengesellschaft, Germany; Telenor AS, Norway.

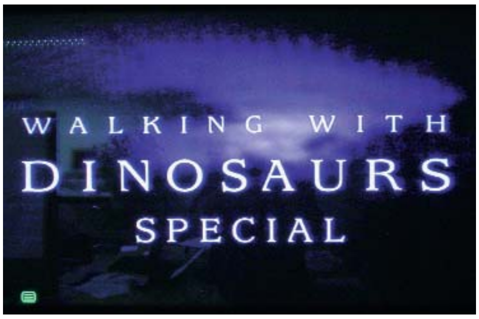


Figure 10 The main programme

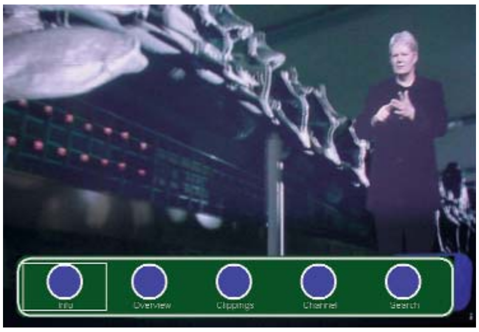


Figure 11 The main programme shown with signing

Figure 12 Information about the programme

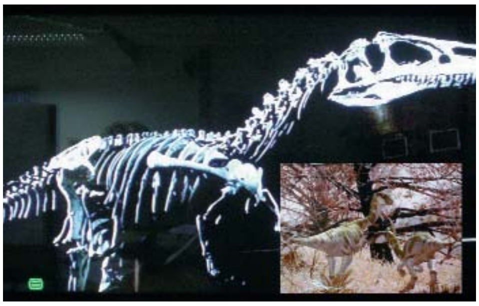


Figure 13 Background video clip

Figure 14 A web page related to the programme

scenes (Figure 12) can also be displayed at any time. MPEG-7 descriptions form the basis for the programme overview and information parts of the service.

Background information like video clips (Figure 13) and web pages (Figure 14) showing the science behind the story of Big Al were included in the service. Some information was linked to specific scenes in the main programme and was thus available only for a certain period of time. Other information was available during the entire programme as well as after the programme finished.

The audiovisual clips were encoded at low bit rate using the MPEG-4 standard. Sign language interpretation was included as a separate video object also for these clips. As the video clips were seen to be of general interest, they were broadcast to all users using the object carousel.

Some web pages were broadcast to all users using the object carousel, thus not being subject to congestion when many people tried to access the same page simultaneously. Other less popular pages were downloaded upon request to individual users.

5.1.2 The Eurovision Song Contest

This scenario is based on the EBU production of the Eurovision Song Contest in Copenhagen spring 2001. The EBU was also web casting this event, so plenty additional material was available to SAMBITS, e.g. live video from a backstage camera, audiovisual clips of former winners, the history of the Eurovision Song Contest, web pages about artists, countries, etc.

This scenario is built in much the same way as the previously described dinosaur scenario. The viewer can watch the main show (Figure 15) continuously, or he can choose to access background audiovisual clips and web pages along the way.

The live video from the backstage camera is streamed synchronously with the main programme and runs during the entire programme. Each individual viewer can choose when to switch it on and off. It is encoded according to the MPEG-4 standard at a low bit rate, and is displayed on top of the main programme as shown in Figure 16.

In this scenario we also included a three-dimensional graphic "Hall of Fame" created by using the MPEG-4 3D technology. Users can navigate through a 3D-gallery where pictures of previous winners of the European Song Contest decorate the walls. By selecting a specific picture, the corresponding winning entry will be played. The

3D-scene is displayed on top of the main programme as shown in Figure 17.

At any time during the programme, the viewer can search for further information using the built-in search engine. The search and retrieval is based on MPEG-7 descriptions. The result of the search (Figure 18) can be a mix of web pages and video clips which have either been previously recorded by the SAMBITS terminal or are available on the Internet.

5.2 The End-to-End System

The SAMBITS project covered a complete end-to-end-chain, starting with the content creation and preparation at the content producer's premises, continuing with multiplexing, network adaptation and service delivery, all the way to access and interaction with the service at the end-users' premises. The major building blocks of the system are shown in Figure 19, and the main subsystems are described further below.

5.2.1 Content Preparation

Added value content can be anything from simple text annotations to complex 3D-scenes that users can interact with. The SAMBITS service scenarios introduce the following types:

- Video material (e.g. sign language interpretation, live backstage camera);
- Audiovisual material (e.g. video clips with additional information about particular subjects);
- 3D-scenes (e.g. graphical models of objects);
- Meta-data (e.g. descriptive information about programmes and programme elements);
- Pictures and text.

One of SAMBITS' goals was to be compliant to open standards, and therefore the added value content was represented using DVB and MPEG specifications. The audiovisual material and the 3D-scenes were encoded using the MPEG-4 standard. It was used both to create files for download and to prepare material for real time streaming. The meta-data descriptions were conformant to the MPEG-7 standard.

SAMBITS developed a programme production system to take care of all processing required to prepare the service components. It is a set of tools for live content capturing, encoding of MPEG-2 and MPEG-4 audiovisual material, creation of interactive MPEG-4 graphical scenes, integration of media components, preparation of files for download, creation and adaptation of web material, indexing of audiovisual content, etc.

All the tools are running in a PC environment. Some of them were commercially available or obtained from other research projects, whereas others were developed within the SAMBITS project. In particular indexing tools were developed to make hierarchically structured MPEG-7 conformant descriptions of audiovisual material. Also tools for programme planning and visualisation were made, helping the producer to plan how to map content into the broadcast resources and to see how the integrated service appears on an end-user terminal.

Figure 15 The main programme

Figure 16 Streaming of additional live video

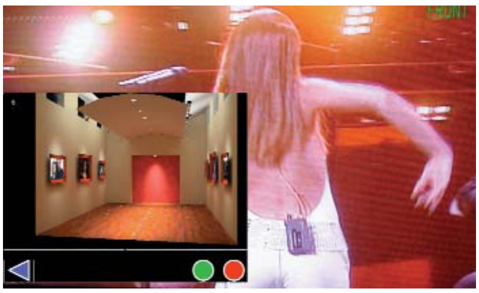


Figure 17 Additional 3D scenes

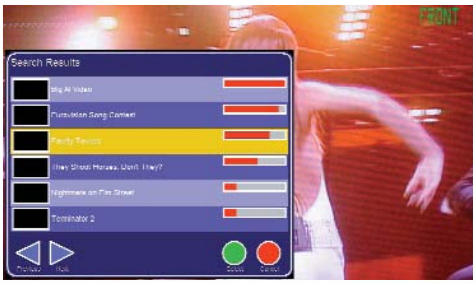


Figure 18 Search for further information

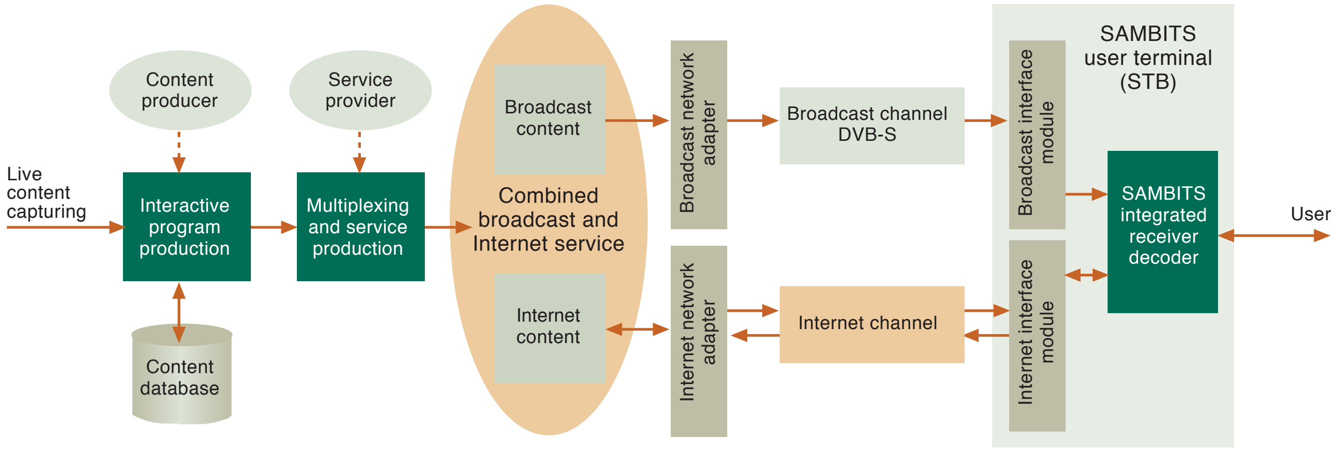


Figure 19 High-level overview of the SAMBITS system

5.2.2 Service Delivery

As shown in Figure 19 both a broadcast channel and an Internet channel are available for transport of service components to the users' premises. Internet can be used in many ways to enhance the broadcast service, but SAMBITS mainly used it for requests and retrieval of additional, personal information. The choice whether to use the Internet or the broadcast channel for the transfer is based on whether the content is of general interest or not. Web pages that are entry points (portals) to extra information about a programme are likely to be of interest to many users and will therefore be transmitted through the broadcast channel, while e.g. detailed information about the background of a programme can be regarded as being of personal interest, and will therefore be sent through the Internet to viewers requesting it.

As shown in Figure 20, SAMBITS studied three of the transport mechanisms defined in MPEG-2/DVB, all designed to serve different purposes.

- *Streaming content using MPEG-2 PES packets:* Content to be streamed with a strict time relation to the main programme, e.g. sign language interpretations, must be transmitted in a way that allows for accurate synchronisation. The MPEG-consortium has specified a method based on the PES structure of MPEG-2 for this. It implies that MPEG-4 video frames and audio blocks are time stamped with reference to the common clock in the MPEG-2 system. In the SAMBITS service scenarios only synchronous insertion of MPEG-4 video elements were required, but the specification also allows for synchronous insertion of audio components and more complex MPEG-4 scenes.

- *Transferring files using object carousels:* Object carousels are used to download files and directory structures to the user terminal. In SAMBITS the object carousel contains MPEG-7 meta-data and background information in the form of MPEG-4 audiovisual clips and HTML pages. The time relation to the main programme is not critical, but the files must be present in the carousel to cover the whole period when they are to be available to viewers. Carousel updates are signalled to the terminal, to tell when to start downloading a new carousel.

- *Sending content using multi-protocol encapsulation based on IP (MPE/IP):* MPE/IP was designed to create a transparent IP downlink over a broadcast channel. It is well suited to download Internet content to digital television receivers, but SAMBITS mainly used the object carousel for that. The IP channel was found useful though, for sending short messages (e.g. containing text and URLs) to the user terminal.

When sending service components to the user through different transmission channels using different transport mechanisms, it is important to keep in mind that the user shall experience all the components as one integrated service. The service delivery system must be capable of transmitting the added value content at the right time relative to the main TV programme.

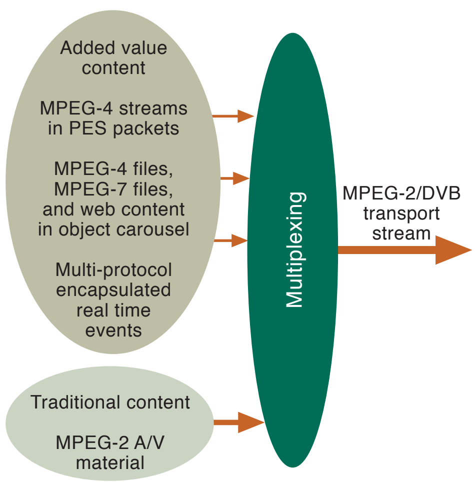


Figure 20 Added value content synchronised with conventional digital TV service

5.2.3 The SAMBITS User Terminal

The SAMBITS user terminal is basically a DVB-MHP set-top box consisting of a PC, a DVB receiver board and additional I/O functionalities, which are required for the Internet access, graphic display and audio and video playback. Figure 21 shows how it is built on a commercial Windows-based set-top box manufactured by Fujitsu-Siemens.

The main building blocks of the user terminal are:

- *MPEG-2 broadcast demultiplexer:* Extracts the MPEG-2, MPEG-4, MPEG-7 and HTML data from the MPEG-2 transport stream and sends it to its respective processing engines.
- *MPEG-2 player:* Displays and plays the main MPEG-2 audio and video components.
- *MPEG-4 engine:* Displays, plays and navigates all MPEG-4 audio, video and 3D graphics components. The player can receive content from file or from a streaming device.
- *MPEG-7 engine:* Locates specific content being broadcast and handles all MPEG-7 descriptions. All MPEG-7 related streams are processed immediately and the results are stored in an internal database. Also used for data search and retrieval.
- *Internet access interface:* The SAMBITS terminal was designed for use mainly within the broadcasters "walled garden", so for our demonstrations a simple HTML browser was adequate. As MHP is Java based, a Java based HTML browser was used.

MHP is used as middleware in the terminal. As SAMBITS adds significant functionality to MHP, it was substantially extended in two areas:

- *Storage manager:* Controls the access to the various content components and delivery channels. Many content components are interrelated.
- *User interface:* It is based on the MHP navigator, but also acts as the central control engine and interface to the MEPG-4 player and the MPEG-7 engine.

The terminal provides the user simultaneous access to high quality digital television programmes and to the broadcaster's web pages, interactive services, streaming content and databases of the Internet. The terminal utilizes both data stored on a broadcast server and on an Internet server. The terminal is designed to make it fully transparent to the user whether the data itself is transmitted via the broadcast channel or via the Internet, or even if it has been already stored locally in the terminal.

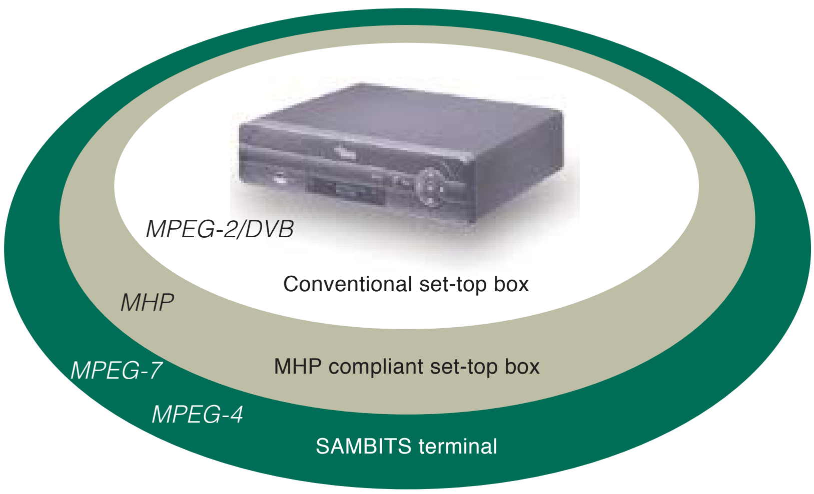
5.3 Demonstrations and Experiences

The SAMBITS system was first demonstrated at the International Broadcast Convention, IBC, in Amsterdam autumn 2001. The service scenarios described in section 5.1 were shown, and the overall response to our work were very encouraging. The visitors were impressed by the broad variety of functionality and the rich set of features shown. The fact that all add-ons were implemented on a regular set-top box instead of a PC surprisingly made a difference to many visitors.

It is stressed however, that all types of programmes are not equally suited for this kind of extension or enhancement. It is ideal for programmes that do not require the viewer's full attention all the time, like the Eurovision Song Contest. Such programmes can attract more viewers if additional video clips, information on artists etc. are available. For programmes you find very interesting and you want to know more about, it is crucial that you can watch the main programme without disturbance, and that you get the possibility to explore all the extra information later on. An even more sophisticated solution would of course be to allow time-shifted viewing. Then all service components, including the main programme, can be paused and played at each individual user's demand. Unfortunately it was not possible to implement this with the resources available to SAMBITS.

To summarise, the overall impressions of the SAMBITS demonstrations have been very positive, but with very clear remarks that there are many pitfalls if the extra information and its availability is not carefully thought through during the production.

Figure 21 The SAMBITS user terminal



6 The SAVANT Project – Scalable Services Across Networks

The SAVANT project, formally named *Synchronised and Scalable AV Services Across Networks*, is also funded through the 5th framework European Union research programme, IST. The project started in April 2002 and will last for 30 months. Seven of the consortium partners come from the former SAMBITS consortium and five new partners have joined in[6]. Again the partners are representing the telecom and broadcasting business sectors and industry, as well as universities and research institutes.

The scope of the SAVANT-project is wider than the scope of its predecessors, CustomTV and SAMBITS. A major goal is still to show how interactive multimedia elements and utilisation of detailed descriptions of service components can enhance conventional digital broadcasting services, but users will be allowed to access the services using several dissimilar types of terminals, and the service providers can deliver their services over multiple networks of different topology. Figure 22 summarises the main concept of the SAVANT system.

6.1 Multiple Terminal Types

During one day users may want access to information and services in different situations and surroundings. They are therefore likely to use different types of terminals with different capabilities. Having more than one end user terminal in view makes the service provider's task more complex.

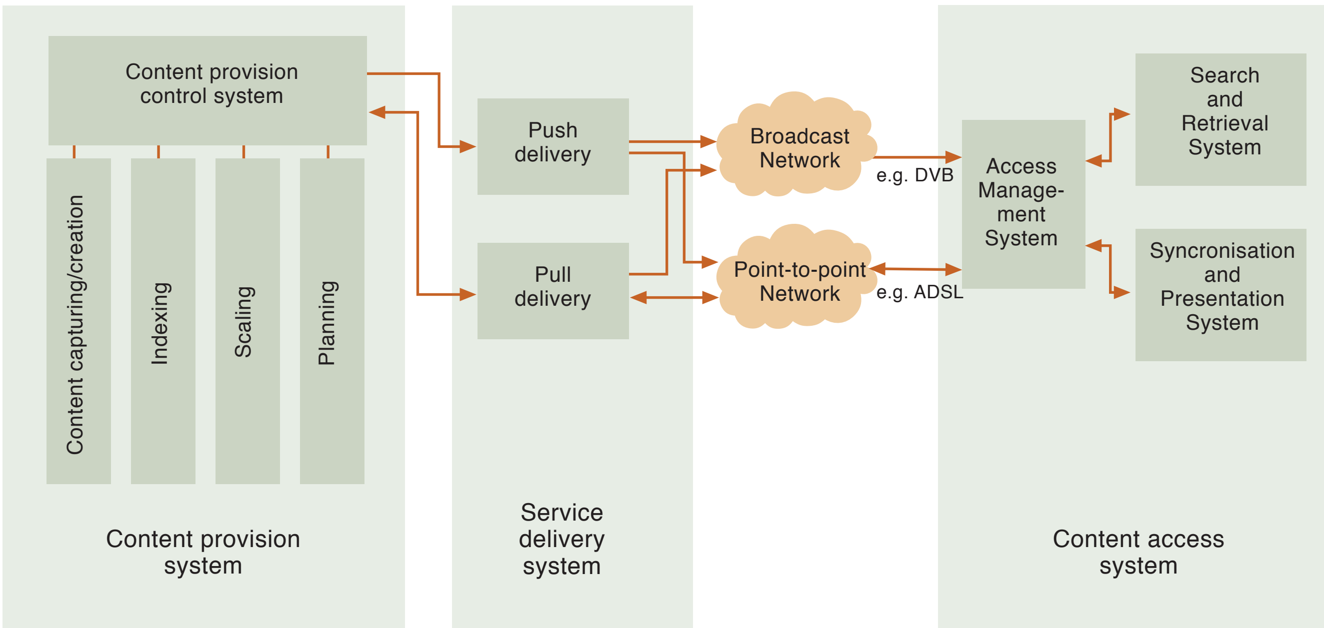
The creation of flexible and scalable services will be important in systems like SAVANT. To obtain this, SAVANT will consider using *scalable coding mechanisms*, i.e. mechanisms that allow terminals of different complexity and capabilities to decode appropriate portions of the same bit stream to generate intelligible audio signals or complete pictures of different quality. The introduction of *scalable services* is even more important, that is putting the focus on how a service is composed of different components (the main TV programme, additional explanatory video clips, sign language, text summaries, etc.). As many components as possible should be re-usable for several terminal types.

Though focusing on means to minimize the cost and efforts of making parallel versions of a service, it is important to bear in mind that the service quality experienced should not be significantly deteriorated compared to services being dedicated to a particular terminal type.

6.2 Multiple Delivery Channels

By utilising the multicast capabilities of a satellite broadcast channel and the point-to-point capabilities of the Internet, SAMBITS provided services that were better than those provided using one of the networks alone. SAVANT wants to push this concept further by allowing combinations from a richer set of networks, comprising point-to-point and broadcast networks, narrowband and broadband networks, mobile and fixed networks.

Figure 22 The SAVANT system concept



[6] *Brunel University, UK; Expway, France; Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., Germany; Insititut für Rundfunktechnik GmbH, Germany; Koninklijke KPN NV, KPN Research, Netherlands; Nederlands Omroepproduktie Bedrijf nv, Netherlands; Ostdeutscher Rundfunk Brandenburg, Germany; Queen Mary University of London, UK; Siemens Aktiengesellschaft, Germany; STT Ingenieria y Sistemas, S.L., Spain; Telenor Communication AS, Norway.*

Information and service components can reach the user through a number of networks and delivery channels. It will be an important task to make efficient choices of which service elements to transmit through each delivery channel. The increased flexibility for finding the best way to serve all end users can lead to better network capacity utilisation, but at the same time it is introducing major challenges regarding management and synchronisation of the programme elements. The balance between flexibility and complexity is important.

6.3 Standards

The project will be striving to use standards whenever possible and to contribute to standardisation where standards are still missing. As in CustomTV and SAMBITS, conventional DVB and MPEG-2 standards will be used along with MPEG-4, MPEG-7 and DVB-MHP. Other promising standards for SAVANT might be MPEG-21 and DVB 2.0. The MPEG-21 project has just started an activity on description of terminal capabilities and network characteristics. This goes very well with the SAVANT system ideas. The same applies to the DVB 2.0 reference model, as shown in Figure 6 in the previous article [9].

6.4 Status and Way Forward

Currently the SAVANT project is in its design phase. Service scenarios are being studied in order to find suitable example services that can be used to form the functional requirements for the system. Some first sketches are already prepared and the complete system design will be ready in spring 2003.

The design phase will be followed by an implementation phase where tools and components are being made and assembled, integrated and tested. This is a major task, since SAVANT is concerned with the complete end-to-end chain, i.e. all the way from content creation and service production by the service providers to the final consumption of the services by the end users.

Key concepts and components of the SAVANT system will first be shown at the Internationale Funkausstellung, IFA, in Berlin, August 2003, but the major demonstration of the complete system will be at the International Broadcast Convention, IBC, in Amsterdam, one year later.

Acknowledgement

The three projects described in this article, CustomTV, SAMBITS and SAVANT, are European collaborative projects partly funded through EU's ACTS and IST research programs. The results achieved are due to excellent collaboration and joint efforts made by all project partners and the support from the European Commission.

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Conditional Access to Broadcasting Content

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This paper explains the motivation and scenario for conditional access of broadcast content. The common architecture for conditional access systems and its main threats are outlined. Additional security elements required for interactive TV are presented as well as how on-line payment can be integrated into a digital-TV infrastructure.

1 The Motivation for Conditional Access

Conditional access is the process of selectively determining if a particular user shall be made able to make use of a video/audio product being distributed via a broadcast medium. The motivation for conditional access is twofold:

- Cost control: restrict access to the content to just a particular geographical area or to a specific group of users due to limitations in programme rights;
- Revenue source: force users that want access to the content to pay for it.

The main goal of the conditional access system is therefore normally to prevent commercial piracy. Commercial piracy occurs when the operator loses significant revenue due to a pirate distributing the means for un-authorized access to the content.

2 The Scenario

Broadcasting implies transmitting information from one sender to many recipients – point-to-multipoint. Although digital television is becoming interactive where the user decoder / set-top box (STB) may be communicating with a central server, the delivery of the content itself is still one-way communication.

The objective is therefore to protect a point-to-multipoint one-way information stream. This implies, unlike for instance GSM, that in broadcast systems there is, in principle, no way to detect if fraudsters are making use of the signal.

Further, the end users are not interested in secure communication, quite the contrary; they would like to get the content product for free if they could. This is different from, say, on-line bank transactions where secure communication is in the interest of the user.

Broadcast content is normally intended for a consumer audience. This implies that the reception equipment including any security devices must be of low cost.

The laws and law enforcement regarding signal theft used to be very weak. This situation has however slightly improved in some jurisdictions in recent years, and in some cases legal action has had some effect against pirates.

The large revenue potential associated with pay-TV attracts well funded, skilled and organized pirates. The enemy is therefore much more powerful than the odd university student or loosely organized hacker.

These factors constitute the scenario in which to implement secure communications.

3 The Broadcast Security Architecture

This section describes the broadcast security architecture used for MPEG-2 and DVB. Figure 1 shows the main system elements.

3.1 Transmission Elements

On the transmit side the audio and video source signal from a studio or a video server goes through:

- MPEG-2 compression to reduce the bitrate and encoding to prepare for transmission. These processes are performed by an encoder. The resulting bitstream is denoted a programme.
- Multiplexing – by a DVB Multiplexer – of several MPEG-2 encoded streams into one multi-programme transport stream. The scrambling of the programmes usually also takes place within the Mux.
- Modulation and frequency conversion according to medium – satellite, cable, terrestrial or broadband connection.

The DVB/MPEG-2 signal is then transmitted through the broadcast medium, and is received by the user's STB. The STB performs the reverse processing on the signal, i.e.:

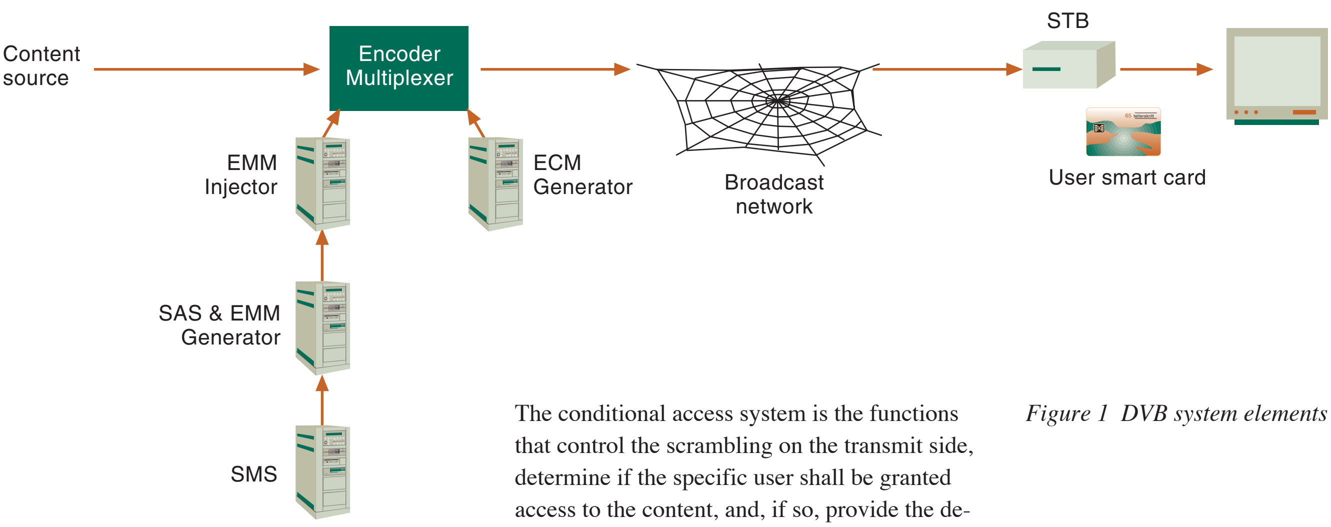


Figure 1 DVB system elements

- Frequency conversion (tuning) and de-modulation;
- De-multiplexing and de-scrambling;
- Decoding and de-compression;
- Conversion of the signal to the analogue PAL format suitable for the TV set.

3.2 The Security Elements

The way to secure a broadcast signal is to encrypt the signal on the transmit side before broadcasting it, and to control that only selected users are able to decrypt the signal on the receive side.

In order to enforce such decryption control on a broadcast signal, the operator needs to place a tamper resistant device with the user. This device determines if the particular user shall be granted access to the broadcast content.

Since the MAC transmission standard followed by the MPEG-2 and DVB standards, the security functions have been separated into the so-called scrambling system and the conditional access system.

The scrambling system is the functions that encrypt, decrypt and synchronise the encryption of the (digital) content itself, i.e. encryption of the payload. The keys used by the scrambling system are usually valid only for a small piece of the content, normally of 10 seconds duration. As keys are changed so frequently and the content is released in the clear to the user, secrecy of the keys is normally not an important issue. Rather, it must not be possible based on previous keys to predict subsequent keys. The key sequence is controlled by the transmit side, and the de-scrambling function is consequently allowed to reside in a non-secure environment – normally the STB.

The conditional access system is the functions that control the scrambling on the transmit side, determine if the specific user shall be granted access to the content, and, if so, provide the de-scrambling function in the STB with the keys necessary to decrypt the content. The conditional access system is on the receive side usually implemented in a smart card. The smart card provides for a tamper resistant environment.

3.3 Scrambling and De-scrambling of a Programme

Cf. Figure 2, the scrambling process on the transmit side is controlled by cryptographic keys denoted Control Words (CW). The DVB-standardised scrambling algorithm is symmetric, and the CW used on the transmit side must therefore be conveyed to the STB. The CWs are normally changed every 10 seconds, and the new CWs are carried in a particular type of conditional access system messages denoted Entitlement Control Messages (ECM). The steps are:

- The Mux generates a CW, and requests the ECM Generator to embed it into an ECM.

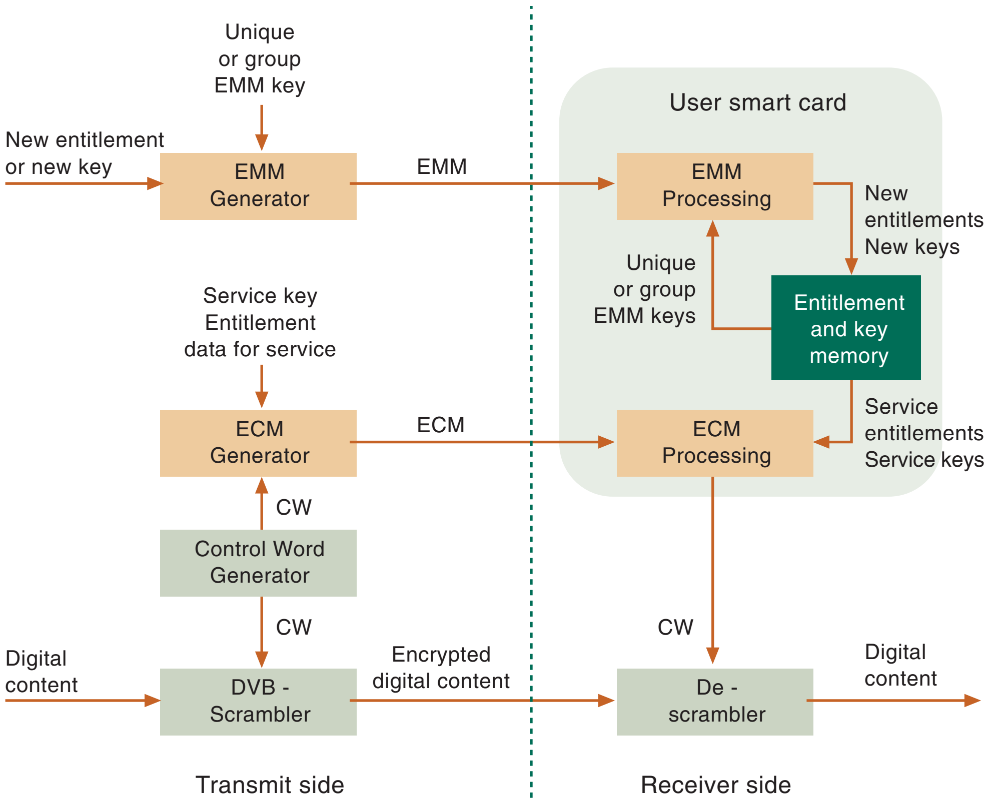
- The ECM Generator prepares the ECM content which is the CW(s) and service references – e.g. a channel identifier – and the entitlement(s) required for accessing the service. The ECMs are then encrypted using a conditional access system specific crypto algorithm and keys that are normally denoted Service Keys (SK). The encrypted ECMs are returned to the Mux for inclusion into the DVB transport stream.

- On the receiver side the STB acquires the ECMs and forwards them to the user smart card.

- The user smart card first decrypts the ECM, then compares the service reference and entitlement information in the ECM with corresponding information in its memory. If there is match, the user smart card releases the CWs for the STB.

- The STB uses the CWs for the de-scrambling of the source signal.

Figure 2 The security architecture



3.4 Authorisation for Programme Packages

Authorisations for user smart cards, i.e. the information establishing and/or updating the memory of the user smart card with service references, entitlements, start/end dates and times for access, cryptographic keys, etc., are carried in so-called Entitlement Management Messages (EMM). The EMMs are encrypted and addressed to a particular user smart card or a group of user smart cards.

Authorisations are generated and transported through the following steps:

- All users and user smart cards are registered in the Subscriber Management System (SMS). The SMS decides based on criteria like customer product selection and payment status if – and for which services – the user smart card of a particular user shall be authorised. The SMS requests the Subscriber Authorisation System (SAS) to generate EMMs.

- The SAS and EMM Generator generates and encrypts EMMs corresponding to the requests from the SMS. The EMMs are sent to the relevant EMM Injector. The EMM Injector inputs the EMMs repeatedly into the Mux.

- The user smart card presents during initialisation its addresses to the STB. The STB uses this address information for filtering/acquisition of EMMs relevant for the user smart card from the transport stream.

- The EMMs are sent to the user smart card. The user smart card decrypts the EMM, then updates its memory with the information in the EMM, e.g. the new subscription dates.

3.5 The Threats

The scrambling control and authorisation processes and their implementation into STBs and user smart cards described above are the same for most commercial conditional access systems available.

The conditional access systems therefore also share the main threats for commercial piracy:

- Breaching the scrambling, ECM or EMM crypto algorithms. An efficient attack on the scrambling algorithm may imply replacing the STBs in order to restore security. An efficient attack on the ECM or EMM algorithms may imply replacing the smart cards to restore security. Algorithm attacks are normally not a problem in practice.

- Logical attacks on the user smart card. This includes exploiting programming errors, wrong use of crypto algorithms or other logical faults in the implementation of the smart card software in order to obtain secret information.

- Attacks on the transmit side equipment. This includes intrusion into components holding secret information like the SAS/EMM Generator and the ECM Generator. As transmit side keys are either (re-)generated in specific smart cards or do not provide sufficient information to build a pirate device, this type of attacks are normally not successful.

- Physical attacks on the user smart cards. This includes invasive attacks, i.e. the physical manipulation – etching of layers, probing, etc. – of the smart card chip, and non-invasive attacks, i.e. the measuring of physical parameters like power consumption and the correlation of such measurements to extract secret information.

- Illoyal employees.

Although not at all trivial, physical attacks have been the most common reason for conditional access systems being compromised. This is not surprising as the tools once used to design and manufacture the chips have the precision necessary for also attacking them. It is therefore just a matter of time before tools of sufficient precision become available to the pirates.

Despite normally applying state-of-the-art chips and algorithms, securing broadcast content is therefore cursed with the need for relatively frequent upgrade of security devices in order to shut out pirates.

4 Interactive TV

Digital-TV STBs are normally equipped with a PSTN or cable network modem enabling for the connection of the STBs to back-end servers providing for an electronic return path from the user to the broadcast operator. Also, STBs are normally able to upload software applications and large amounts of data from the broadcast stream.

These features in combination with increasing storage and processing capabilities in the STB, open for a whole new set of TV-centric services known as Interactive TV. Examples of iTV services are:

- Ordering of television movies or events offered in pay-per-view mode (see below).

- Interactive advertisement and shopping: a product is presented in a TV-advertisement or the user can click on an icon to enter into a shopping mall describing products and services. The product presentation(s) are acquired from the broadcast stream and presented by the STB. When the user has decided to buy the product, the order for the product is sent electronically via the return path.

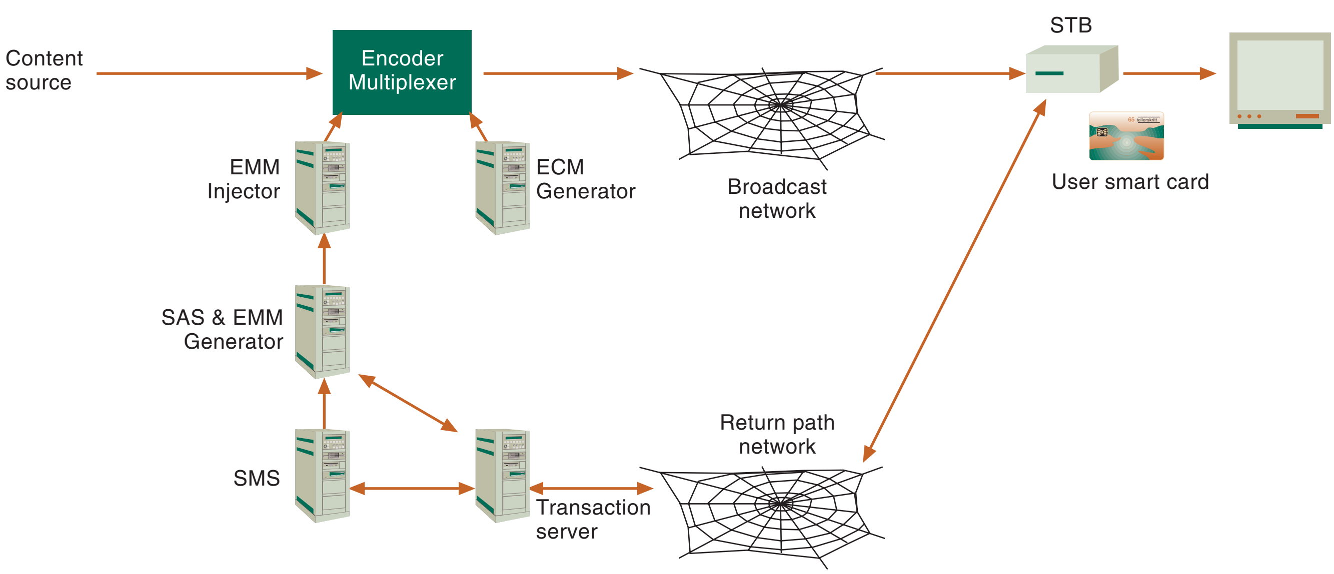
- Money games / betting: a game or sport event is shown on TV. The user is presented with the game combinations and odds, and is offered to place bets. The combinations, bets and receipts are communicated via the return path.

4.1 Interactive Pay-per-view

Pay-per-view (PPV) or the purchase of a particular movie, a sports event or another programme event can be arranged in several ways including the user dialling a call centre. For several reasons, however, it is desirable if the user instead ordered PPV via the STB and the return path.

The Conax conditional access system offers support for PPV purchase via the return path, and the steps of a Conax PPV operation are (see Figure 3):

Figure 3 DVB system with PPV ordering via return path



- Information about the available PPV products such as title and short description about the movie, recommended parental rating, price, etc. is included in the transport stream. Also, a subset of PPV data is included in the ECM.

- When the user tunes into the movie or event, the STB and the user smart card will interpret their respective PPV data.

- The user is then usually given a preview of the programme, is presented with the price and other details and is asked to buy.

- The user confirms to buy the programme by entering a PIN code into the user smart card via the STB. The PIN code is verified in the user smart card, and the user smart card generates a PPV purchase request message. This message normally contains the product reference and the user smart card serial number, and it is authenticated by a digital signature specific for the user smart card.

- The STB connects to the back end server and relays the PPV purchase request message to the Conax Transaction server (CxTS). CxTS verifies the digital signature, checks if the product reference and serial numbers are valid, and if the user shall be allowed to purchase the PPV product (can be restrictions due to bad payer, parents having blocked for purchases, ..).

- If all checks are satisfied, a corresponding EMM authorisation is generated and returned to the user smart card either via the broadcast network or via the return path. Upon receipt of the EMM, the user smart card grants access to the PPV product. The SMS is notified about the purchase, and can invoice the user accordingly.

The PPV products can also be pre-booked using the same mechanism.

4.2 Security Mechanisms for other Interactive TV Applications

In order to provide for security mechanisms for interactive TV in large at least the following security functions are required:

- Authentication of software or data included in the broadcast stream. This to e.g. ensure that an STB applet origins from the operator and is free of virus.

- Encryption of software or data included in the broadcast stream. This to e.g. ensure confidentiality of personal messages/mail.

- Authentication of software or data being communicated in the return path. This to e.g. ensure that a purchase order request comes from a particular user through verifying the digital signature of the request.

- Encryption of software or data being communicated in the return path. This to e.g. ensure confidentiality of the user's credit card number.

The MPEG-2/DVB framework provides support for encryption of software or data formatted into MPEG-2 transport packets and included in the broadcast stream.

The other functions need to be provided as extensions supported by the conditional access system, or by one or more additional security systems – or functions.

The Conax conditional access systems provide support for all these functions.

5 Electronic Payment

Invoice has been the main payment method for pay-TV services. Invoice, however, is not a suitable method when the amount to be paid is small compared to the cost of issuing the invoice or when payment needs to be in place before the service is delivered – one example is money games.

It can therefore be desirable to complement or replace invoice payment with credit card payment, payment based on direct debit of bank account and payment based on electronic purse.

Credit card payment and direct debit can both be performed on-line electronically. Due to the cost structure of these methods, they are best suited for amounts above a few hundred NOK.

Electronic purse is a payment method with cost structure adapted to small amounts, e.g. the purchase of a movie offered at NOK 39 or a NOK 50 bet. Several electronic purse options exist – smart card based such as Mondex and Proton, or database based such as SmartCash offered in Telenor and DnB's Smartpay concept.

In the scenario of pay-TV, PPV and iTV services, credit card / direct debit and electronic purse complement each other as credit card / direct debit is used to shop more expensive items and to load the electronic purse, while the electronic purse is used to pay for movies, pizzas and bets.

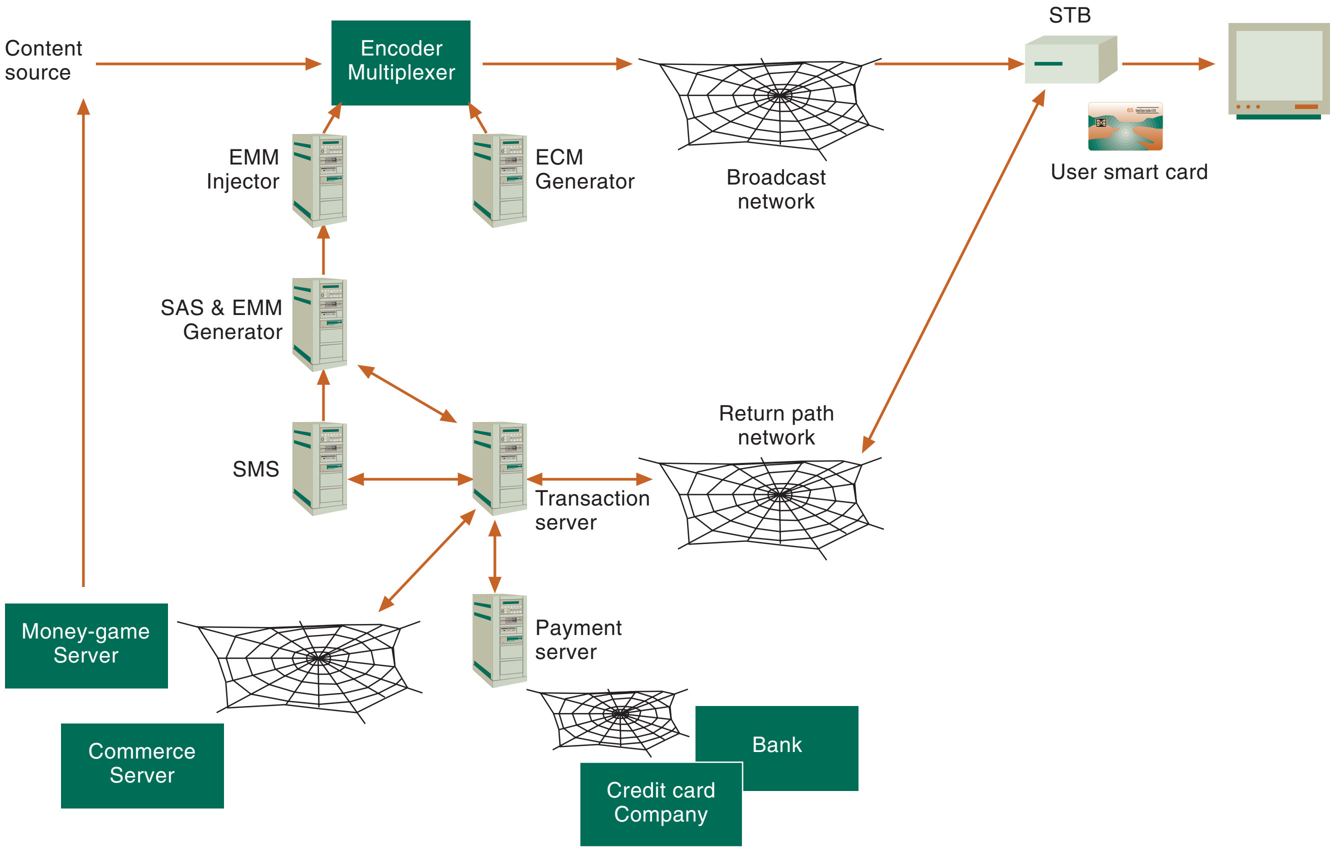


Figure 4 iTV infrastructure including payment server and application servers

In order to integrate electronic payment into the TV infrastructure one must add payment support in product descriptions (i.e. list available payment options per product) and in STB software.

For high level security and cost synergy, the user smart card should be used for authentication of the user (using the digital signature capability), and for encryption of sensitive data such as the credit card number and CVV2 codes.

On the server side there must be a server managing the routing of the payment transactions to the appropriate financial institutions/function for authorisation. Transaction authentication (verification of digital signature) is performed either by this payment server or by the financial institution.

As an add-on to its conditional access systems, Conax offers the Conax payment server (CxPS). CxPS supports direct debit from bank account, credit card payment (Visa, MasterCard, American Express and Diners Club) and server based electronic purse.

The CxPS is one of the main components of Telenor and DnBs scheme Smartpay for mobile commerce payments, and it is ready also for use in conjunction with digital TV and IP streaming.

Multimedia Customer Premise Equipment – Upgradable for Interactive Services

DAVID LESLIE AND GWEN HARRIS

This paper outlines requirements for broadband home terminals for multimedia services over IP networks, including a view of customer requirements, interoperability and the need for a range of reliable equipment and with a short discussion of standards and likely developments. Pace Micro Technology Plc. has played a leading role in developing and marketing the required multimedia terminals and the paper draws extensively from this experience in setting guidelines for expected developments.

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Summary

The world is changing and bringing with it better ways to deliver entertainment to the home. Today households spend large amounts of time viewing TV presented to them by broadcasters who essentially choose which programmes the majority will watch. This is changing and households are requiring more diversity and more ability to personalise their own entertainment to individual lifestyles.

The new digital customer equipment makes it possible for operators to group content suppliers offerings and offer a range of services through the network, in a way much more attractive to consumers than traditional broadcasting. A range of different equipment is becoming available and there is sufficient practical experience in using it for operators to have confidence in the launch of these TV-centric entertainment services.

Higher end equipment will provide for a range of different revenue generating services. With an 'in-home' network this could be based on a home hub with service delivery to a number of points within the home. Services include information and communication, as well as entertainment. However there is a range of factors which an operator must take into account when choosing equipment. These include flexibility and upgradability of equipment, as well as cost, services enabled, performance, life in service and installation possibilities.

It is difficult for traditional standards bodies to keep up with the speed of progress but the success of the DVB organisation shows what is possible in this field. Standards based interoperability is an important issue even where rigid adherence to clear international standards may not always be realistic.

The rate of take up depends on a range of factors including network parameters and the ability of the network operator to form the right content partnerships. In part these content partnerships will depend on the customer premise equipment being able to deliver valuable entertainment material to the end user in the most attractive way.

Role of Network Operator

Digital multimedia terminals have to date been in the domain of broadcast organisations whether for terrestrial, satellite or cable distribution. However traditional telephony network operators are now able to enter this business and can offer a number of important advantages over traditional broadcasters.

The new Internet Protocol (IP) networks are able to deliver multimedia services alongside standard telephony and data traffic. These networks provide for greatly improved interactivity and a more complete ability to deliver a variety of services than the traditional broadcast systems.

In the longer term, customer equipment will change to reflect the new access possibilities. Certainly in line with other areas which have been affected by the Internet, we can expect a rise in the role of content owners so that consumer choice and personalisation of services becomes much more important than in a traditional broadcast paradigm. At the same time, technology is advancing fast, so any future-proof consumer hardware must be designed to be flexible, and with the ability for upgrade over the network. Of course it must also be capable of delivering compelling new customer services.

Customer Services

The 21st century household requires a diversity of remotely delivered services and these can be delivered through a traditional telecommunications network, whether fixed line or wireless. For example:

- TV Channels;
- Video-on-Demand;
- Interactive Advertising;
- Internet access and content supply;
- E-mail, voice mail, picture and video mail;
- Telephony, video telephony, Karaoke, educational services, multiplayer network games, etc.

The service bundle can be made more or less attractive depending on the presentation to the customer, the interactivity made possible for the

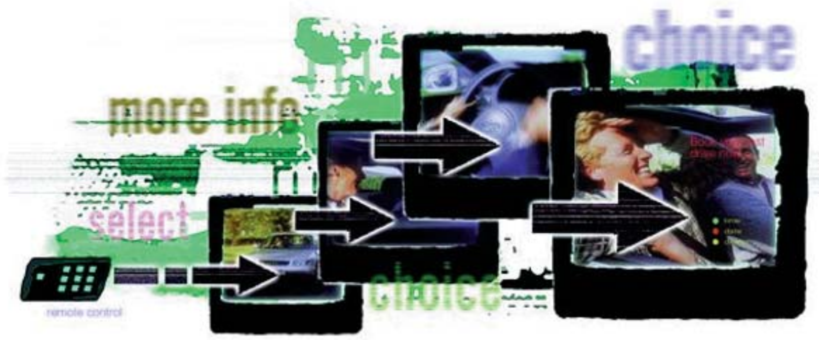


Figure 1 Customers require greater choice and personalisation of multimedia services

user, the personalisation of services and so forth. Perhaps the single most important feature is to make sure the service is upgradable over the network. Any service which is set up without this built in facility for regular upgrade and improvement over time risks being overtaken by services which are dynamic in this way.

Customer Premise Equipment

Today for a network operator, we would think of customer premise equipment as being a standard telephone (often more than one) together with a PC (in certain households) and perhaps a modem (512K; ISDN; xDSL). Increasingly operators are linking to the set-top box (Home Gateway) and television set. Longer-term households will demand an 'in-home' network with the ability to route data and entertainment around the home.

The new TV-centric services must be easy to use; foolproof; excellent video quality, and allow instant choice of appropriate entertainment. Around the world there is already a variety of operators with experience in running these new services, in managing the network, and maintaining the optimum services through upgrade over the network of the customer premise equipment software and capability.

Home Gateways – Whole Life Cost

The broadband home gateway plays a crucial part in the delivery of entertainment and video services whether over xDSL or delivery by some other means. For a host of reasons the equipment decision is one that it is vital to get right.

The home gateway can represent a substantial portion of the capital investment needed to launch services. Prices are coming down but the sheer volume needed for a volume service means the decision is important.

From the operator's point of view the customer perception is also important. Since the home gateway is the device that sits in the customer's home, if the device fails to work effectively it is the thing that the customer will point to and complain about.

Without careful planning, the home gateway may be relatively expensive to install and change. From a service providers' point of view the whole life cost of ownership of the home gateway is the key metric. This includes the actual cost to buy the product from vendors such as Pace, but also the cost to install, manage, and upgrade.

If an engineer is needed for installation then the costs to deploy services quickly mount up. Traditionally, changing the product, whether by replacing it or upgrading the physical hardware has meant cost will be incurred for the new equipment plus the cost to send an installer to carry out the change. Upgrade over the network and 'self install' are therefore obviously priorities for the operator in choosing equipment.

The challenge for the home gateway provider is both to lower the whole life cost of ownership together with the challenge of increasing the revenue generating potential of the product.

Home Gateways – Revenue Generating Potential

From a revenue generation perspective there are a number of approaches to designing the product. Essentially the more services a product supports the more revenue generating potential it has. Importantly, the more simultaneous revenue generating services that it can support the better. If the operator can provide a cost effective way of allowing one household member to play a game, whilst a different person is paying for a video on demand movie then the average revenue per user (ARPU) will grow.

The challenge for the service provider is to understand what services the consumer is willing to pay for, and this varies from market to market. The set-top box vendor can help this by educating the service provider about the cost implications of adding this functionality to the home gateway.

Today's IP home gateways from Pace tackle all of these challenges. The IP series of products includes a number of variants from the most cost effective product supporting video on demand, browsing, and broadcast TV, through to the most advanced that include hard disk drive for PVR (personal video recorder), VoIP (voice over Internet protocol), low bit rate video support, and the ability to drive two independent TVs from the same home gateway. Because all the variants are based upon the same architecture an operator can mix and match products within the same network or in the same home. The integrated modem version can be coupled with home networking technologies to provide for service distribution around the home.

In practice each market is different and so there is not a 'one product fits all' device that can be built today. Some providers may feel that offering a video-on-demand and broadcast TV service over DSL is the optimum mix for their customers. For other operators, given their local conditions (networks, regulatory environment, consumer price expectation for services, acceptance of Internet and digital TV), this simple set of services is not enough to make the business case profitable in the right timeframe. For these operators, services such as timeshift TV and personal video recorder functionality, gaming, two-way video services such as video telephony, enhanced messaging and additional telephone lines (delivered using voice over IP) provide the incremental revenue needed to make it all worthwhile.

The complication in the market is that some customers want few services and some want many. For the service provider, managing multiple home gateways on the same network, each delivering different services is a challenge if each gateway is based upon a different architecture (processors, operating system, application layer, security solution, etc.)

The challenge can be summarised as trying to provide a home gateway that has enough functionality to handle the services that the customer is willing to pay for, without having to pay extra for features that only a few will fully exploit and even then, only a year or more after installation.

If hardware could be downloaded then this problem would disappear!

Home Gateways and the Network

Modern fibre based network designs from the major network equipment vendors are capable of delivering multistream video service direct to the end user in the home. However the service operator is still hampered by the inherent capabilities of the existing network and particularly the capacity of the 'last mile'. Especially in rural areas, the long length of the local loop means that using MPEG-2 encoding (as currently used to deliver adequate picture quality for good TV viewing), the bandwidth needed to deliver video services is just not available. It is perfectly possible that simply not enough customers can be reached with enough bandwidth to make the entire service business case attractive enough.

Advanced coding schemes such as MPEG-4 and other low bit rate codecs can dramatically change this. High-speed processors are needed in the customer device to regenerate a good quality picture from a low bandwidth signal. In Pace products this processor is chosen to be a general purpose media processor and able to be programmed to deliver video coded in a variety of different ways. However some vendors provide specific hardware or firmware which cannot be used flexibly in this way. Operators choosing these types of equipment may well find they are stuck with an out of date coding format and cannot upgrade to evolving industry standards.

There is a range of other issues relating to the network. For example, an operator may believe it possible to deliver service to a percentage only of his customer base. He must then work out how to manage commercially a situation where only some of his customers can get service and plan a roll out based on certain geographical areas. In practise this is little different to the cable or satellite competitors who are also limited in this way. Satellite service penetration for example, is generally poor in city centre areas and cable networks are usually limited geographically.

Network equipment may not have been bought initially with video delivery included in the specifications and there is a range of issues including IGMP (Internet Group Multicast Protocol) where existing equipment will need to be tested for video compatibility before commercial plans can proceed.

Home Gateways – Integration

Features and Equipment to be integrated could include a variety of equipment;

- Hard Disc Drive;
- ADSL modem;
- Other type of modem (VDSL, xDSL);
- Digital Cable or Satellite tuner, Analogue tuner;
- Voice over IP module;
- Wireless or wired home networking interfaces.

The list can go on, but each item added will complicate the equipment, the software needed to operate the system and of course push up equipment costs and the difficulty of proving interoperability. The more features that can be added without sending an engineer to change the product the better. Allowing software features and applications to be added remotely or allowing hardware upgrades to be added by the consumer (for example with a PC Card sent through the mail) expands the capability and lifespan of the product.

By integrating more and more of the home equipment into the home gateway, the 'total' cost of equipment in the home can be reduced quite dramatically. For example by integrating the xDSL modem and adding home networking functionality, the total costs are significantly reduced when compared to the cost of a modem and a home gateway bought separately. Of course this could create home wiring problems when the xDSL line does not enter the home near the TV or when connections to both the TV and PC are needed. Thankfully home networking technologies that make use of the telephone wiring or powerlines are reaching the capabilities and price points needed. Wireless data technologies will remove the wiring issue altogether, although price points still have some way to go before mass adoption is likely.

Home Gateways – Solution

Given all of these challenges a picture of an ideal IP set-top box begins to materialise. It should include:

- A range of products that target each operator's business model optimally and allow the operator with a large customer base to target different segments at different price points or rentals;
- Product variants based on the same architecture to allow operators to add multiple variants within the same network or even the same home base on individual consumer needs;
- Support for 'basic' services such as video on demand but also advanced services such as gaming, timeshift TV and PVR, video telephony, enhanced messaging and home networking;
- Support for multiple simultaneous revenue generating services;
- Support for low bit rate video;
- Upgradable software features and services, which can be downloaded by the operator over time as consumer needs are understood more;
- Can be installed by the consumer;
- A high speed processor that will perform well for years;
- Support for home networking to allow services to be delivered easily around the home;
- Low cost!

Self-install capability removes the need to send an installation engineer, and the design allows software features, applications and services to be upgraded remotely. Future hardware based functionality can be added using the PC card upgrade slot, and indeed the card could be sold through retail outlets or sent through the mail for the consumer to install themselves.

The chart in Figure 3 illustrates part of the customer value perceived for one of the functional items to be added – the hard disc drive. However there is much more value possible from an integrated hard disc drive than is measured from valuation of the PVR (personal video recorder) functionality alone since addition of such a storage device then allows for more personalisation, targeted advertising, advanced network games and other services with a lesser call on prime network time for managing the large data flows involved. This is a feature where increased investment in the customer premise equipment will save investment in the network.

Home Network

With a big increase in the availability of services to the home the pressure on the central TV in the home is increasing. Any multi-person household can be expected to demand that the services are available at more than one location. In practise most homes already have more than one TV screen so it is logical to demand a home gateway that allows for two or more stream processing and delivery. In Europe the requirement is perhaps less than in the US and Pace are planning equipment which can deliver two entertainment

Figure 2 Pace IP500 Next generation Home Gateway with option of integrated hard disc drive and ADSL modem

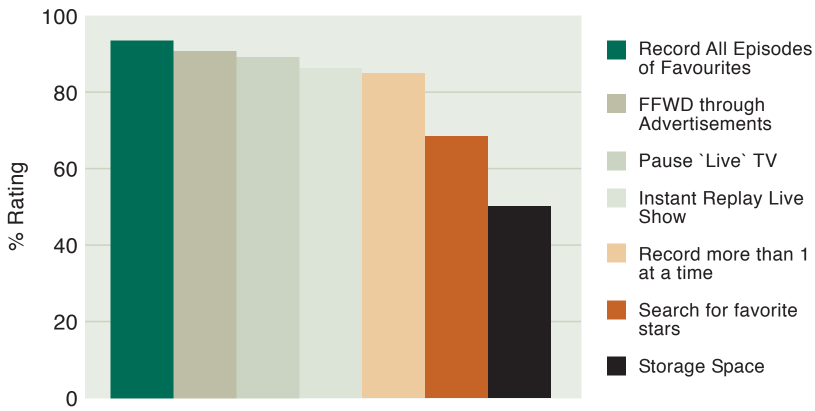


Figure 3 Customers rate highly the value added by integrated hard disc drive even where the operator is not yet adding new services possible. Source: NextResearch Inc.

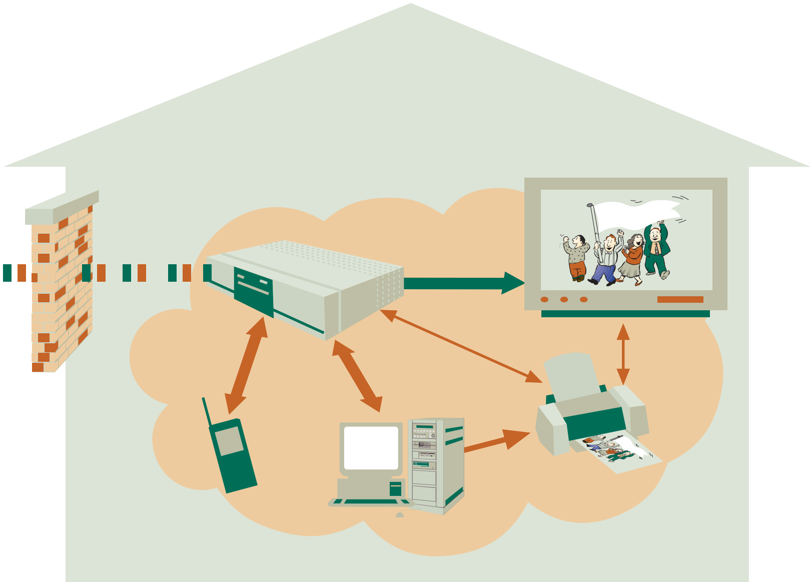


Figure 4 In-home network allows for distribution of services to different appliances and service points in the home and allows connection to a single point for IP signals from the network

streams to two separate screens in the home. Two or more gateways can of course be connected so that households can enjoy two, three, four or more screens enabled with the new services provided they are willing to pay and providing the network has bandwidth available.

The 'in-home' network could be wired or wireless and there is a number of different standards in this area. As the number of high bandwidth mobile devices evolve so a wireless 'in-home' network will become more attractive. The advantages of such an in-home network can be summarised as;

- Services available at multiple points in the home;
- Shared entry point for all IP data required;
- Shared facilities (eg. memory, processing power and other facilities) providing for the multiple service points.

The most cost-effective network will be different between different countries even within Europe because of different characteristics and internal home wiring practise. This is an area where standards can really help in developing the right framework for operators and equipment vendors to follow.

Standards

Standards are evolving faster in today's high technology environments. This evolution aims to meet the household need for lifestyle enhancement through better services, more personalisation, and more security as outlined above.

The main strands of the evolution can be summarised as

- *Video standards*
  MPEG-1 has developed into a well-established MPEG-2 standard, and the jump to lower bit rate standards such as MPEG-4 is now possible. Various players including Microsoft believe they can profit from the move, which will take place over the next few years.

- *Audio standards*
  MP3 is currently a highly effective standard for moving audio around. However audiophiles searching for still higher quality are keen on Digital Dolby TM AC3 (now the de facto digital broadcast standard in the US, and AAC which is important in a number of far eastern markets including Japan). We can expect further evolution here, not least to ensure security for careful content owners.

- *Data*
  Internet protocols will move from version 4 to version 6 (the Ipv6 standard) at some point and work is going on to be sure the maximum benefit is taken from this move and to plan for the huge increase in IP address requirements which can be expected over the next years.

- *Security*
  In Scandinavia the standard for content security is clearly Conax. However on a global scale the current penetration of this vendor is still fairly light. Many of the DVB security vendors are looking at development of IP based systems capable of providing security for any type of IP packet not restricted to MPEG streams for video and so able to provide security (and sometimes privacy) of other types of information and content.

- *MHP*
  A considerable effort has been made to get support behind the MHP standard for middleware so as to ensure a much greater interoperability of different applications. Backing is particularly strong in Northern Europe. There are some warning signs that the standard is in danger of trying to lead requirements rather than following the developments which are required by customer and system needs but at least in the short term we at Pace are ensuring that our products are MHP compatible.

- *Networking Standards*
  Wired networks can utilise either existing cables (power line, telephone lines or coax cable) using a variety of standards or can use new wiring for USB, ethernet, firewire (IEEE1394) or ethernet connection. Each has alternatives in some circumstances, but HPNA2 and ethernet are currently gaining ground in many parts of the world. For wire-

less networks, cost is generally seen as a barrier to widespread adoption, but it must be a more effective solution long term. There are various standards including HomeRF, HyperLAN2, Bluetooth and IEE802.11.These may not always be competitive and in the very near future there will be households using Bluetooth for handheld peripherals while 802.11 will be the chosen standard for data flows between fixed appliances in different rooms.

- *Proprietary and de facto standards*
  Microsoft is clearly a major player in the multimedia domain and has a history of defining its own standards rather than following industry standards evolutions. For this reason a service operator cannot ignore the large quantity of multimedia content available for standards such as Windows Media Technologies™.

  There are other examples (Sun for example) and de facto standards such as ATVEF and network protocols such as the Internet Group Multicast Protocol (IGMP) which must be adhered to.

Generally, it is important that customer premise equipment is standards based but not standards driven. Evolution of equipment is rapid to meet the overriding imperative of delivering the right customer services. Standards therefore must not be too rigidly enforced but used flexibly and to ensure a good degree of interoperability, upgrade over the network can often be used to improve existing equipment, in line with changes in standards.

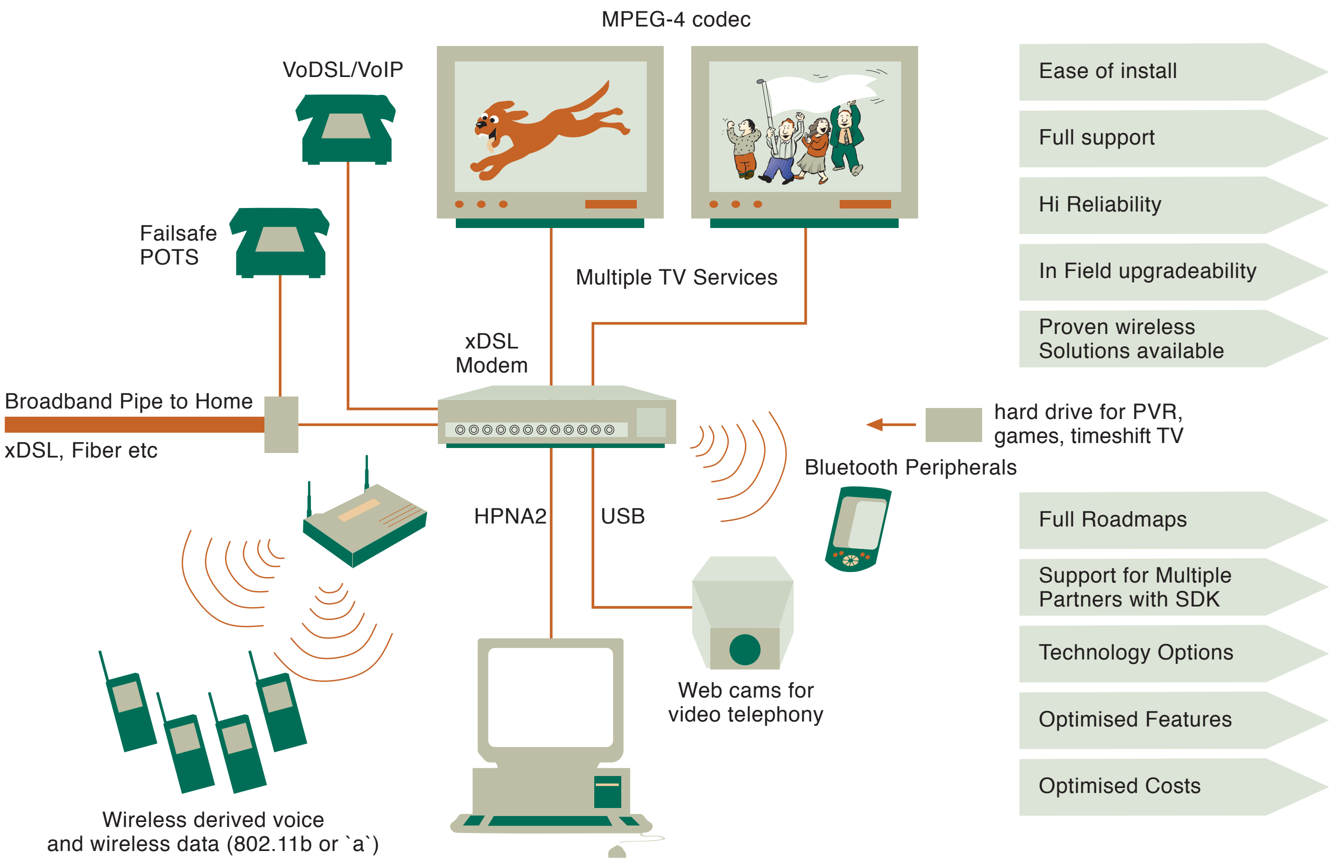
Summary and Conclusions

It is difficult to summarise the topics covered above. However perhaps the important key words are flexible, upgradable and interoperable. These words touch on most aspects of the decision any operator must make on the home gateway. This must be based on;

- Variety of different services, actual, planned and foreseen;
- Range of equipment on offer from simple TV decoders to complex equipment able to deliver multiple revenue generating services;
- Interoperability with network and head-end equipment needed to deliver an end-to-end service;
- Upgradability to provide memory and processing power for low bit rate video and other services anticipated over the service lifetime.

Figure 6 illustrates the range of services available from a highly featured equipment of the next generation.

Figure 6 The range of services a high-end digital home gateway can deliver with a single IP channel for delivery of services



Not all operators will want the most highly featured product. Pace has available for order a range of three different variants;

- An MPEG2 product, highly specified in terms of performance;
- A product which includes low bit rate video capability;
- A fully specified unit with two stream throughput and the capability of included hard disc drive.

The operator will have to choose between these sorts of specifications based on the services required, on cost and the obvious desire to ensure these products are upgradable over the network to ensure optimum service profitability.

Home gateway development companies such as Pace Micro Technology are working already for even more impressive performance and at affordable prices for the services customers will want over the next decade and more.

Experiences from Broadband Rollout and Future Steps in KT

HONGSEOK KIM

Hongsoek Kim (27) received his B.S.E.E. and M.S.E.E. degrees from the Seoul National University in 1998 and 2000, respectively. Since 2000 he has been working in Korea Telecom (KT) as a member of technical staff. His research interests are broadband access network systems such as ADSL, VDSL, BPON and currently up to EPON. Since FS-VDSL started, he is mainly involved in FS-VDSL for the next broadband access network in KT.

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This paper provides the overview, experiences and future steps on broadband access networks in Korea Telecom (KT). The overall number of high speed Internet users in Korea, by July 2002, is over 9.2 million including 5.1 million ADSL subscribers, while KT has 3.8 million ADSL subscribers. The number has grown rapidly during the last three years. This is the fastest and largest broadband access rollout. It is now, however, almost matured, and KT is actively seeking alternative solutions for next broadband access. In this paper, we first review various kinds of access network topologies in KT; central office based ADSL, FTTC ADSL and Home LAN. Then, we provide up-to-date details of experiences in ADSL deployment such as traffic pattern, protocols, link performance, interoperability and crosstalk in real field. Finally, based on the experiences and current status, we briefly show future steps on broadband access networks including VDSL, PON, Metro Ethernet and MSPP.

1 Introduction

1.1 Statistics of Broadband Access in Korea

The Internet is so popular in Korea. According to the Korea Network Information Center (KRNIC), which is the Internet domain administrator in Korea, the number of Internet users is over 25 million by June 2002 as shown in Figure 1. It means about 58 % of Koreans use the Internet; that is one of the highest ratios in the world. The growth rate, however, has now slowed down somewhat.

Table 1 shows the broadband statistics in Korea. The number of high speed Internet users, mainly consisting of ASDL, CATV and Home LAN users, is over 9.2 million. There are 5.1 million ADSL subscribers, while KT has 3.8 million. The strongest point of ADSL is that it reuses the existing copper wires for Plain Old Telephone Service (POTS), so there is no need for new installation of access network infrastructure unlike CATV system. This makes ADSL the most popular service amongst various access technologies.

The CATV is the second popular with 3.3 million users followed by 0.6 million Home LAN users. Home LAN is a kind of customer premises communication and intended for users in apartment complexes. Leased line, mainly

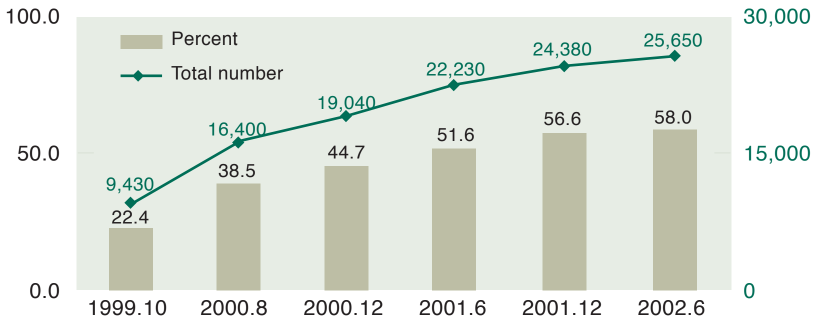


Figure 1 The growth of Internet users in Korea (unit: thousand)

	KT	HTI	ThruNet	Other ISPs	Total
ADSL	**3,782,437**	**1,151,448**	3,511	207,900	**5,145,296**
CATV	0	1,237,343	1,298,676	734,705	**3,270,724**
Home LAN	537,951	16,740	0	60,947	615,638
Etc.	137,764	55,697	2,086	20,064	215,611
Total	**4,458,152**	2,461,228	1,304,273	1,023,616	**9,247,269**

Table 1 Broadband access users

Table 2 Applications in the Internet

	Web surfing	Online game	Email	Education	Shopping Reserv-ation	Chatting	eCom-merce	Etc.
2001.6	61.7 %	15.2 %	13.5 %	3.4 %	1.6 %	1.8 %	1.4 %	2.4 %
2002.6	49.1 %	25.7 %	13.5 %	2.7 %	2.3 %	1.8 %	1.4 %	3.5 %

Table 3 Protocols used in the Internet

Protocol	HTTP	P2P	WMP_TCP	Telnet	Real_UDP	Etc.
Percent	72.2	4.1	3.9	2.65	0.69	2.3

fiber, connects the Internet to the apartment complex, and users in apartments are interconnected locally by various copper technologies such as TLAN, Ethernet, SHDSL or VDSL.

Table 2 shows users' preferences in the Internet. It indicates that web surfing to get some information is the highest preference of Internet users. The second preference is a network game. In Korea, the Internet online games are so popular, and it is easy to find network gamers in PC rooms that are a kind of Internet café offering network games and high-speed access for as little as one or two dollars per hour. Even though many users can access the Internet in their own homes now, they still like to play network games in PC rooms. Shopping, reservation and eCommerce do not yet occupy much of the portion, but they are expected to grow steadily in the near future.

Internet usage according to age indicates that 90 % of children and teenagers and 86 % of people in their twenties are accessing the web; further, almost 100 % of students from elementary school to university are using the Internet. These days, the ratio of men in their thirties using the Internet is steadily rising. As regards PC environment, PC penetrates 78.6 % of the total number of homes in Korea, and 86.9 % of PC equipped homes can access the Internet. It means that about 70 % (0.786 × 0.869) of a total of 13.4 million homes are penetrated by high speed Internet. Thus, we think the broadband access market is now somewhat saturated, and the growth rate is not so high these days.

1.2 Primary Factors of the Fastest and Largest Broadband Rollout in Korea

There are several factors for this rapid growth. First, the government strongly encourages Information Technology (IT) industries. Accordingly, many IT enterprises such as Internet Service Providers (ISPs) and network equipment vendors as well as IT venture companies are still actively emerging. Thus, government policies and voluntarily induced individuals construct abundant IT infrastructures.

Second, the regulator, the Ministry of Information and Communications (MIC) introduced hard competition in IT industry. Thus, ISPs have little choice but to cut down the broadband access tariffs and provide good services for their survival. The induced low ADSL tariff in Korea, e.g. 25 to 33 dollars per month, indirectly encouraged the broadband tariffs of other countries to be down.

The third reason is the Koreans' strong preference for high technologies. The fact that 68 % of the Koreans have mobile phones is a good example. They also need the Internet for various purposes: educational usage, cyber stock trading, Internet banking and so on. For example, students in elementary schools are asked to send in their homeworks using the Internet, so parents with a high educational fever cannot help subscribing to the broadband access.

The fourth reason comes from the social aspect, more specifically Korean nationality and culture. To satisfy high demands in network game and the Internet, many PC rooms have sprouted like mushrooms all over the country during the last four years. Students from elementary schools to universities as well as adults are their regular customers. The Koreans have a tendency of behaving in a group, and PC rooms are crucial as meeting places for network gamers and Internet users. Thus, at the time when broadband access was not widely used, PC rooms made certain cyber cultures amongst young people. Accordingly, while using the Internet in PC rooms, they began to need Internet access in their own homes as well, and this greatly helped access networks to be deployed. Moreover, they sometimes feel like purchasing something on impulse if the majority of their friends already have it. They might feel some sense of isolation if they do not have broadband access lines in their own homes.

The final reason is the high population density induced from the distinctive housing styles. We can categorize the housing styles in three main types: One is apartment complexes, another is housing complexes including multiple dwelling units (MDU) or multiple floor-row houses, and the third is normal houses. For simplicity, housing complexes and normal houses will be collectively called residential houses. Here is an example of population density measured in the field. We define the population density as the number of residents per 100 × 100 m^2. The measured densities in example areas are 215 for an apartment complex, 306 for a housing complex, and 125 for normal houses. Thus, even areas with normal houses have a population density which is notably high compared to that of apartment complexes or housing complexes. As regards the portion of housing styles, normal houses occupy 50 %, apartment complexes occupy 37 % and housing complexes occupy 6 %. All of these housing patterns enable cost-effective deployment.

2 Basic Topologies of Broadband access in KT

2.1 Local Loops Condition and Basic Broadband Access to Date

Table 4 shows the cumulative distribution of users and local loops respectively. 52 % of users are within 2 km from the central office, and the average distance from the central office to the users is 2,440 m. 57.7 % of local loops are within 2 km, and the average distance is 1,912 m. 80 % of users as well as local loops are within 3 km.

2.2 ADSL

2.2.1 Central Office Based ADSL (CO ADSL)

Figure 2 shows two kinds of ADSL access networks in KT. The first one is central office based ADSL, hereafter called CO ADSL. In this scheme DSLAM is located in the central office, and users are directly connected to DSLAM via ADSL. 90 % of installed ADSL in KT are CO ADSL, and it is mainly targeted for users in residential houses. KT has a strong point with CO ADSL because only KT has local loops to subscribers in residential houses, and even though local loop unbundling (LLU) is underway in accordance with the MIC recommendation, other ISPs are hardly renting KT local loops yet. In fact, HTI is providing only FTTC ADSL to users in apartment complexes. HTI or ThruNet serve users in residential houses with CATV.

2.2.2 FTTC ADSL

The second type of ADSL is based on fiber loop carrier. FTTC ADSL mainly serves users in apartment complexes as shown in Figure 2, but sometimes it also serves users in residential houses beyond 3 km from the CO. The ONU is placed in the apartment, so it can serve regardless of copper loop length between CO and apartment complex. In KT this scheme is sometimes called Remote DSLAM. 10 % of installed ADSL in KT are based on FTTC ADSL.

2.3 Home LAN

Besides ADSL, another major broadband access is Home LAN. Home LAN mainly consists of two types; one is Building and Apartment (B&A), and the other is NTOPIA. Two methods are based on Ethernet in layer 2 and commonly targeted for users in apartment complexes.

2.3.1 B&A

At an early stage of broadband access in Korea, other ISPs were offensively providing broadband access into apartment complexes. In order to defend the broadband market in apartments, KT was providing B&A. However, it is not recommended these days due to low bandwidth and some management problems. B&A consists of leased line and LAN. Leased line is connected between KORNET and the apartment complex.

Distribution	~ 1 km	~ 2 km	~ 3 km	~ 4 km	~ 5 km	~ 6 km	Average distance
Users	15.7 %	52.0 %	79.7 %	85.4 %	98.3 %	99.4 %	2,440 m
Local loops	27.1 %	57.7 %	80.7 %	93.2 %	98.7 %	99.8 %	1,912 m

Table 4 Cumulative distribution of users and local loops

	ADSL		Home LAN		ETC	Total
	CO ADSL	FTTC ADSL	B&A	NTOPIA		
Percent	76 %	8 %	12 %	3 %	1 %	100 %
	84 %		15 %			

Table 5 Basic broadband access networks

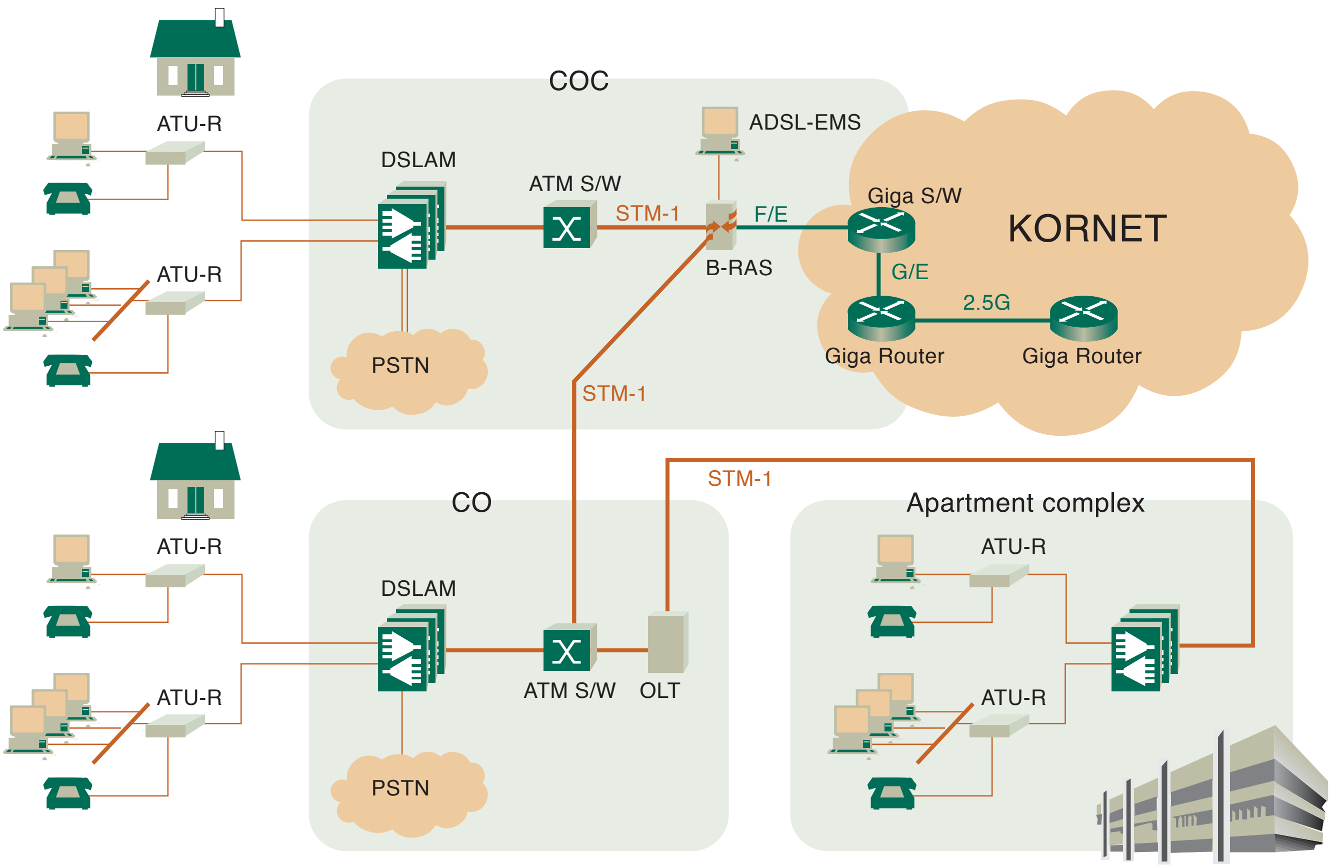


Figure 2 The topology of ADSL access network in KT

A small router is placed in the apartment complex and Ethernet interconnects each user with a router. PHY of B&A was based on TLAN, which stands for Time-division duplex LAN and was developed by some Korean venture company. B&A can provide high speed in the local network within apartments, but usually the capacity of the leased line is low. Thus, bandwidth per user to the backbone is not high compared to other broadband access.

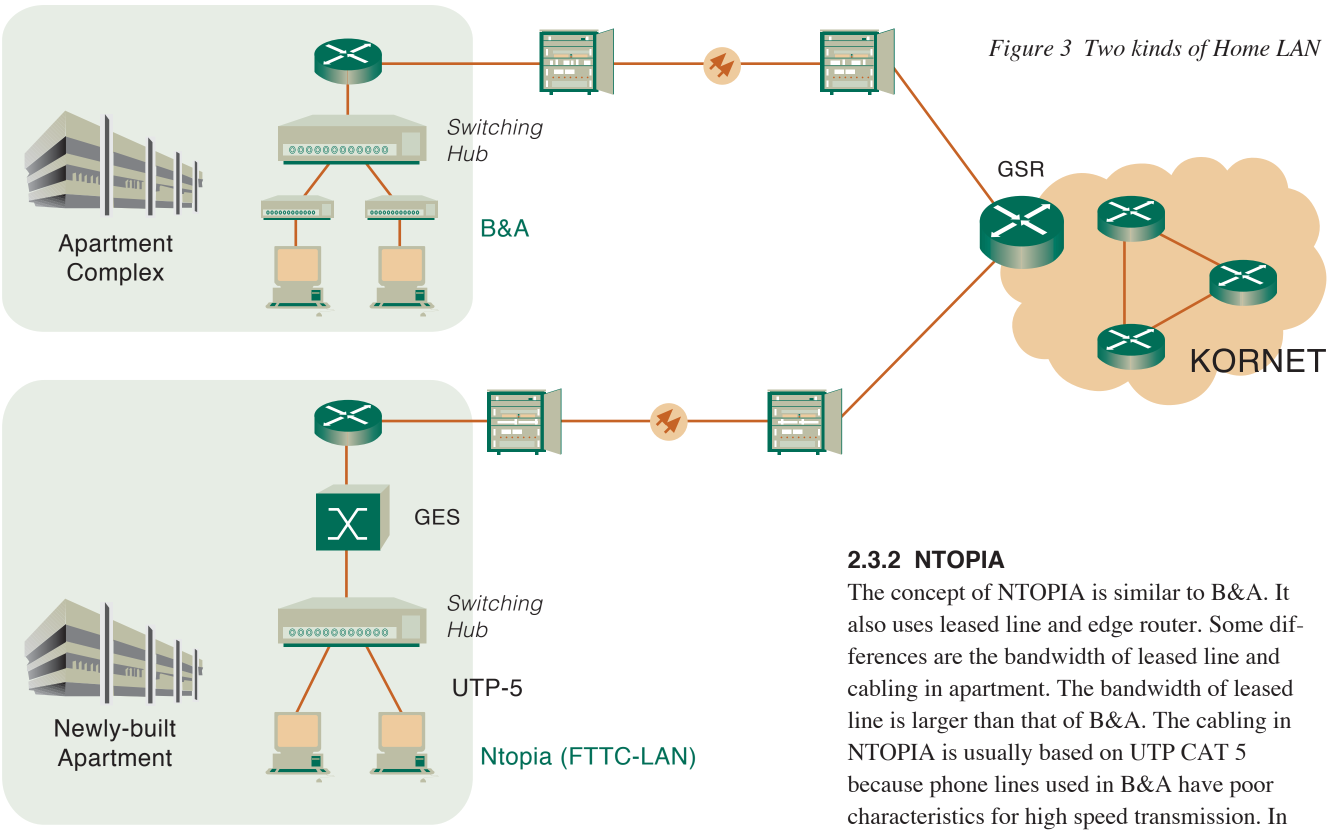


Figure 3 Two kinds of Home LAN

2.3.2 NTOPIA

The concept of NTOPIA is similar to B&A. It also uses leased line and edge router. Some differences are the bandwidth of leased line and cabling in apartment. The bandwidth of leased line is larger than that of B&A. The cabling in NTOPIA is usually based on UTP CAT 5 because phone lines used in B&A have poor characteristics for high speed transmission. In new buildings and apartments, it is common to be equipped with more than UTP CAT5. The apartment equipped with UTP CAT 5 and qualified for broadband access is usually called Cyber Apartment. The regulator, MIC, evaluates the conformance of broadband access when new apartments are built. Then, MIC categorizes the level of the apartment in accordance with broadband accessibility and cabling condition. So, NTOPIA is the specially prepared broadband access for this kind of Cyber Apartment. This kind of NTOPIA is called NTOPIA-E, which stands for NTOPIA Ethernet. According to the condition of local loop in apartment complexes, the PHY of NTOPIA can be various types, such as 10Base-T, 100Base-T, SHDSL or VDSL. In case of no UTP, PHY is based on SHDSL or VDSL instead of 10Base-T or 100Base-T. They are called NTOPIA-S or NTOPIA-V respectively. KT is actively deploying NTOPIA-E and NTOPIA-S though they do not occupy many portions yet, as shown in Table 5. KT has also started to deploy NTOPIA-V even though ITU-T VDSL standardization is not finished.

2.4 IEEE 802.11b (NETSPOT)

The growth of wired broadband access has now slowed down, and KT expects wireless LAN to be the next leader in broadband access. Using IEEE 802.11b, KT started the wireless LAN service called NETSPOT already in April and is actively installing Access Points around the country. NETSPOT and ADSL can be combined for wireless as well as wired broadband access; wireless access in the home and wired access out of the home.

2.5 Regional Broadband Network

Figure 4 shows the topology of Regional Broadband Network. It connects DSLAMS and Broadband Remote Access Server (B-RAS) to KORNET, which is the backbone Internet in KT. In Central Office Concentrator (COC), B-RAS and ADSL Element Management System (EMS) are installed. The operator uses ADSL EMS for management and maintenance of DSLAM as well as provision and management of ADSL services. One B-RAS, a gateway to the Internet, terminates about 150,000 to 200,000 ATM PVCs from several DSLAMs. There are about 40 COCs around the country. One COC accommodates 10 to 15 central offices (COs).

There are about four hundred COs around the country, and one CO usually accommodates 10,000 to 15,000 subscribers. In CO, the operator only uses Command Line Interface (CLI) to manage DSLAM, but most functions are read only, and few functions are writable.

2.6 Contents Delivery Network (CDN)

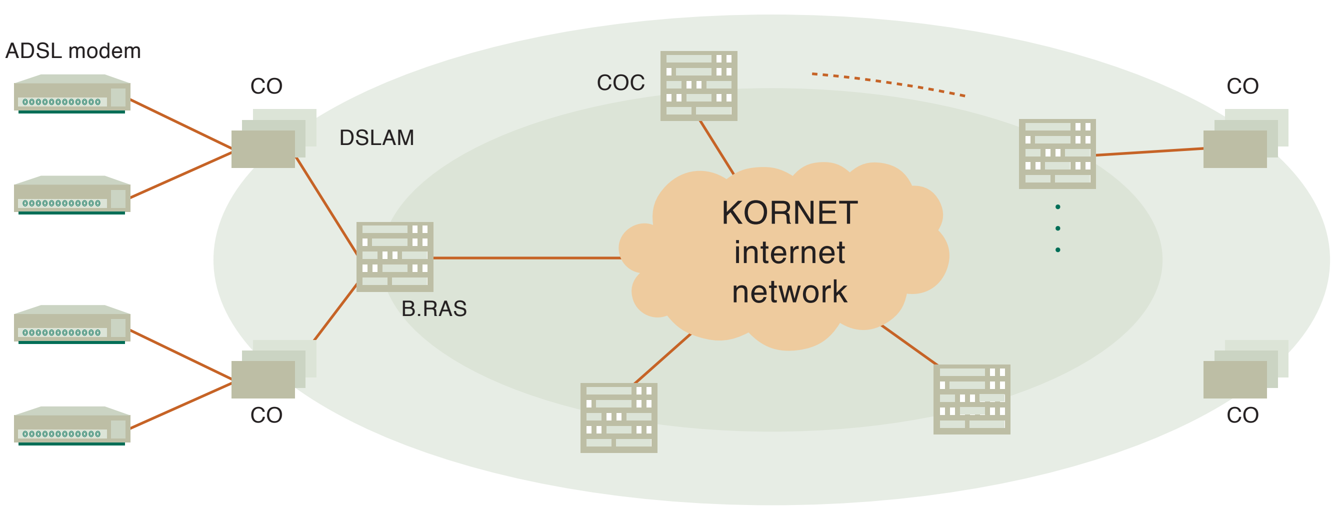
The real time traffic protocol such as UDP does not occupy many portions, but real time multimedia traffic is expected to grow rapidly. KT is constructing CDN to effectively support this traffic. Figure 5 shows the topology of CDN. There is one main node in Seoul and ten regional nodes in other major cities. Regional nodes are cache servers for popular contents, and dually connected to the main node via satellite and leased line/ATM. The number of regional nodes has started to grow. Its aim is to support 1 Mb/s stream based video around the whole country. Currently, many video service providers are using CDN, and KT is starting an IP-based VoD commercial service based on CDN.

2.7 Branding and Tariffs

Table 6 shows the branding and tariffs. All kinds of broadband access have the unified name called MEGAPASS. The tariffs are discounted in accordance with long term contracts as shown in the table.

MEGAPASS PREMIUM is an ADSL service with up to 8 Mbit/s / 640 kbit/s. MEGAPASS LITE is an ADSL service with up to 2 Mbit/s /

Figure 4 Regional Broadband Network



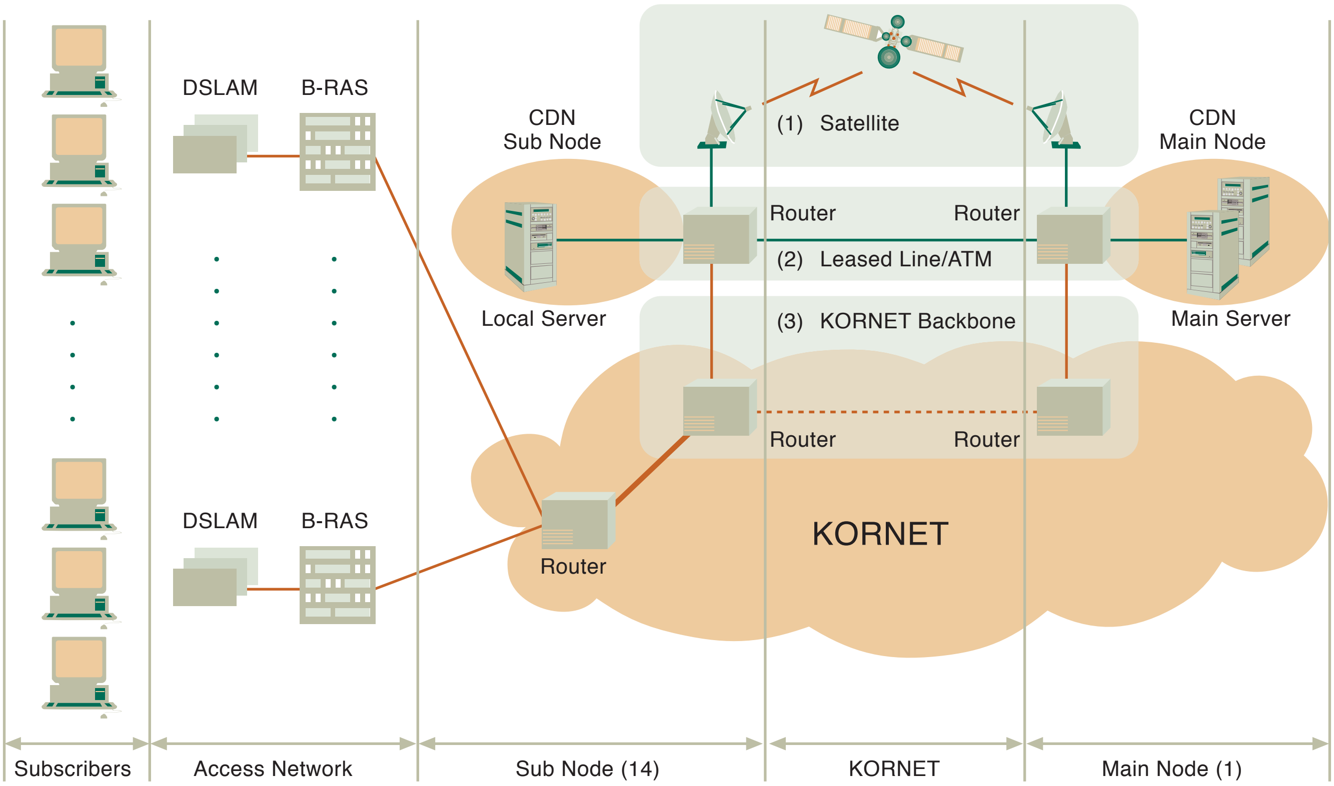


Figure 5 Contents Delivery Network

256 kbit/s. Since ADSL G.992.1 can support these two kinds of services, KT did not adopt ADSL G.992.2. The most popular protocol in KT ADSL is PPPoE with external modem.

From the end user's viewpoint, MEGAPASS NTOPIA is not so different from the two services above. PHY of NTOPIA can be various kinds, such as 10BASE-T, SHDSL or VDSL, and the speeds also vary as denoted vaguely in Table 6. The tariff of NTOPIA shown in Table 6 is for one user, and additional users have to pay US$ 12. Thus, NTOPIA can accommodate up to 4 users.

MEGAPASS MyIP and MEGAPASS MultiIP are also using ADSL G.992.1, but they have a different IP address scheme. PREMIUM, LITE or NTOPIA are based on dynamic IP addresses, but MyIP and MultiIP have fixed IP addresses. So, they enable users to operate their own servers. While PREMIUM, LITE or NTOPIA are mainly for residential users, MyIP or MultiIP are suitable for SOHO users. We should note, however, that the boom of the Internet is mainly driven by residential users, especially LITE users. 80 % of ADSL users are using LITE. It means that 2 Mbit/s is enough for the Internet access. On the contrary, MyIP or MultiIP users are quite small compared to LITE users.

Table 6 Branding and tariffs

	Application	Modulation	Speed	< 1 yr	1 yr (5 %)	2 yrs (10 %)	3 yrs (15 %)
MEGAPASS PREMIUM	1 user (PPPoE/PPP)	ADSL (VDSL)	D: 8 Mbit/s U: 640 kbit/s	40,000 (33 US$)	38,000	36,000	34,000
MEGAPASS LITE	1 user (PPPoE/PPP)	ADSL	D: 2 Mbit/s U: 256 kbit/s	30,000 (25 US$)	28,500	27,000	25,500
MEGAPASS NTOPIA	1 user + 3 (PPPoE)	Ethernet SHDSL VDSL	D: 2 ~ 13 Mbit/s U: 2 ~ 13 Mbit/s	36,000 (30 US$)	34,200	32,400	30,600
MEGAPASS MyIP	1 IP-3 user (Layer 2)	ADSL	D: 1.5 Mbit/s U: 384 kbit/s	80,000 (67 US$)	76,000	72,000	68,000
MEGAPASS MultiIP	5 IP-13 users (Layer 3)	ADSL	D: 2 Mbit/s U: 512 kbit/s	180,000 (150 US$)	171,000	162,000	153,000
Monthly modem rental fee				3,000 (2.5 US$)	3,000	3,000	3,000 *free > 3 yrs

One thing we have to keep in mind is that the denoted speeds are theoretical upper limits, and they can be different from the denoted speed in accordance with several conditions such as loop length, loop condition and noise. Nevertheless, the marketing and advertising based on the maximum speed help the growth of broadband access. Recently, however, the regulator, MIC, is planning to force ISPs to guarantee the minimum speed according to the Service Level Agreement (SLA). It is expected to be valid from October, and MIC and ISPs are now discussing the detailed principles and procedures.

3 Experiences from the Field

3.1 Statistics of ADSL Traffic

Figure 6 shows an example of active PPP connections in a day. In this graph, the maximum is about 35 %, and the peak time is about 3 p.m. It shows the maximum portion of concurrent PPP users to be just 35 %.

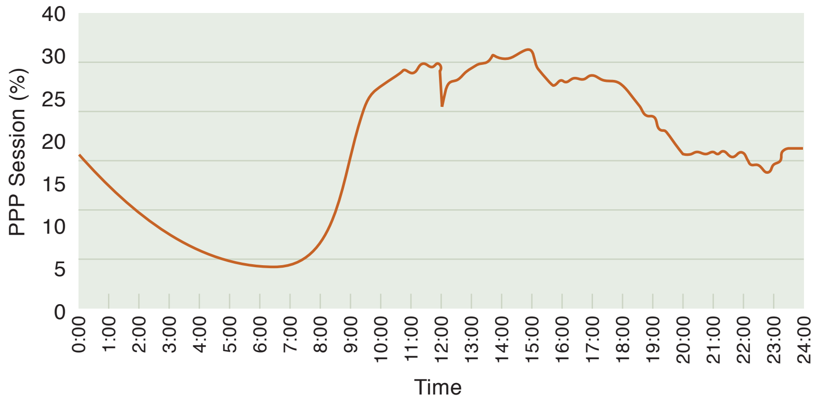


Figure 6 Ratio of active PPP connections

Figure 7 shows daily average traffic measured in B-RAS that accommodates four DSLAMs. Note that the downstream traffic is five times that of upstream in this graph. The peak time is from 10 p.m. to 2 a.m. Since peak time traffic is important for network design, we analyze the characteristics of ADSL traffic using only peak time traffic. The measured peak downstream rate per user was 11.1 kbit/s, and the measured peak upstream rate per users was 2.9 kbit/s. Assuming the maximum ratio of concurrent users is 35 %, the peak downstream rate per active user is estimated as 31.7 kbit/s. In general, one DSLAM equipped with STM-1 has around 1300 subscribers, so the peak rate from one DSLAM would be 14.4 Mbit/s. However, these statistics are provided only as an illustrative example and can be different according to the time and the location of measurement.

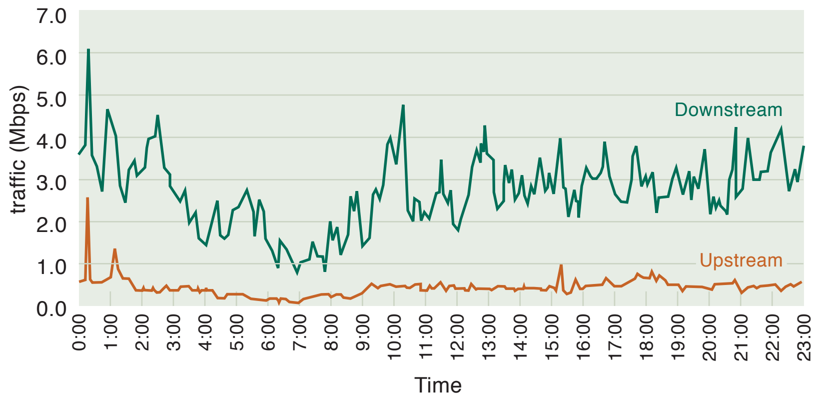


Figure 7 Daily average traffic

3.3 ADSL Loop Management (ATLAS)

KT has POTS management systems named TIMS and TOMS. Telephone-service Integration Management System (TIMS) matches the phone number with the exact physical line number. Telephone Outside-plant Management System (TOMS) stores the line number and its corresponding line configurations such as installed location with map, wire gauge, length, insulated material, and other electrical characteristics. Based on TIMS and TOMS, KT developed ADSL Transmission Line Analysis System (ATLAS) [2]. Figure 8 shows the integration of ATLAS, TIMS and TOMS. When a new end user asks for ADSL service, ATLAS can be used for pre-qualification by estimating the ADSL link speed based on the information from TIMS and TOMS. It can be also used for after-sale service and subscriber management.

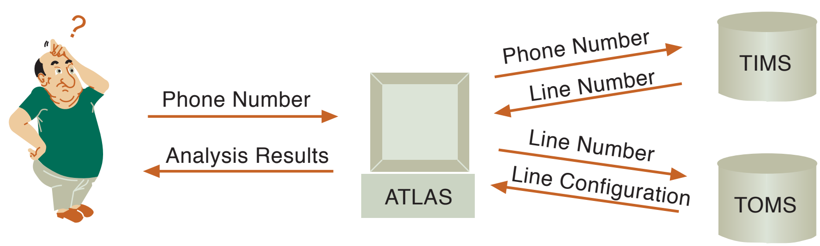


Figure 8 The integration of ATLAS, TIMS and TOMS

3.4 ADSL Link Performance

Figure 9 and Table 7 show the measured ADSL link performance in KT. The speed of MEGAPASS LITE, 2 Mbit/s, is achievable for 93 % of users within 2 km, for example. In case ADSL speed cannot be guaranteed because of long loop, FTTC ADSL is deployed.

3.5 Crosstalk in the Field

When FTTC ADSL and CO ADSL coexist in the same binder, the loop length of FTTC ADSL is much shorter than that of CO ADSL. Thus, a

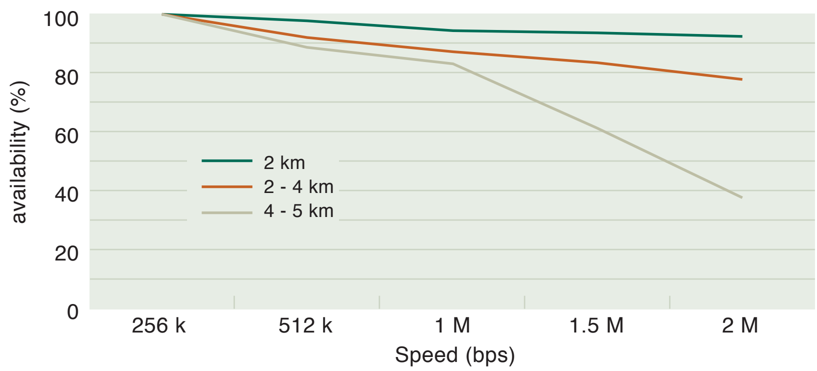


Figure 9 ADSL link performance graph

Distance	~ 256 kbit/s	~ 512 kbit/s	~ 1 Mbit/s	~ 1.5 Mbit/s	~ 2 Mbit/s
~ 2 km	99.5 %	97.5 %	94.5 %	94 %	93 %
2 ~ 4 km	99.5 %	92.5 %	88 %	84 %	78.5 %
4 ~ 5 km	99.5 %	89 %	84 %	62 %	39 %

Table 7 ADSL link performance chart

strong FTTC ADSL signal can cause self-FEXT to the attenuated CO ADSL signal, and it results in performance degradation of CO ADSL. According to the laboratory test, KT found that self-FEXT is not serious in the UTP cable but very serious in the CPEV cable.

To overcome this problem, we can consider three solutions. The first one is to update the current CPEV cables with UTP cables. For example, the performance degradation of UTP cable is merely 29 % at 4 km while it is 72 % for CPEV. More detailed data can be found in [3]. But updating old in-house cables with new ones is very expensive, and this solution is hardly realistic. The second solution is to reduce transmission power of FTTC ADSL. If FTTC ADSL signal power is equal to the attenuated CO ADSL signal power, there is no considerable self-FEXT between them. However, this solution may not be practicable because the service provider of FTTC ADSL can be different from that of CO ADSL. The last solution is to move the DSLAM out from the central office to a concentrated residential area. If so, CO ADSL turns to be FTTC ADSL, and there will be no considerable self-FEXT. In addition, the reduced loop length will improve ADSL service quality.

3.6 ADSL Interoperability (IOP)

ADSL IOP is necessary to guarantee the DMT chipsets from different vendors are fully compliant to G.992.1 DMT code. Proprietary implementations by different vendors were threatening ADSL IOP. However, interoperable ADSL is crucial for an open CPE market. If all ATU-C and ATU-R are interoperable, the end user can buy his ADSL modem by himself in the market. Thus, KT has studied technical issues for ADSL interoperability. In the beginning of ADSL deployment, there were 8 DSLAM vendors, 21 CPE vendors, 4 ATU-C chipset vendors and 6 ATU-R chipset vendors. Some problems were brought to light by the test results; some transceiver functions such as overhead framing mode or interleaved delay were not interoperable between some systems. This kind of problem could be solved by firmware upgrade or restricting non-suitable functions. In contrast, ADSL link performance interoperability was a big problem. Chipset vendors had to make huge and contiguous efforts to make chipset or firmware code be any-to-any interoperable. For a detailed description of ADSL IOP in KT, [4] is recommended.

4 Future Steps

4.1 VDSL

In 2000, KT provided two types of VDSL trial services. The first one was a kind of Home LAN previously explained in section 2.3. The second one was traditional ATM mode VDSL and can be regarded as an extension of ADSL PREMIUM. Two trial services were carried out for 50 subscribers respectively. Even though ITU-T has not finalized G.vdsl series yet, KT has started to deploy NTOPIA-V (IP VDSL) into apartment complexes for commercial services. IP VDSL means VDSL with packet transfer mode defined in G.993.1 Annex H, PTM-TC. IP VDSL is purely for Internet access only and far from the Full Service originated from FSAN/FS-VDSL. The volume of current IP VDSL is not so huge at this stage.

4.2 PON

FSAN recommends Passive Optical Network (PON) to be the most cost-effective FTTC solution and has developed a G.983 series BPON specification. KT is planning to provide a BPON trial service in the winter of 2002. This trial service is basically based on the FSAN/FS-VSDL recommendation. In parallel, KT is also developing the KT GPON specification based on EFM EPON and FSAN GPON for service starting next year, if possible. PON will be deployed mainly for residential users but it is also suitable for a small number of business customers. To accommodate PON systems, KT is actively developing Optical Distribution Network (ODN) infrastructure such as broadband (BB) shelter, BB cabinet, BB box and their powering scheme [5].

4.3 Metro Ethernet and MSPP

KT has an active plan to deploy Metro Ethernet and Multi Service Provisional Platform (MSPP) for business customers. KT considers Metro

Ethernet to be suitable for business customers in small ISP/ASP or PC rooms, and MSPP is suitable for large and huge business customers in large ISP/ASP.

5 Summary

In this paper, we survey the overview, experiences and future steps of broadband access networks in KT. Broadband access has been successful in Korea and indicated a rapid growth during the last three years, but now it is thought to be saturated. We analyse basic factors of the rapid and large deployment of broadband access in Korea. To satisfy various customers' needs, KT has many types of broadband access such as central office based ADSL, FTTC ADSL, Home LAN and wireless LAN. Regional broadband network, Contents Delivery Network, branding and tariffs are also introduced for better understanding of broadband environment in KT. Then, some ADSL experiences from the field are shown; aggregated traffic pattern, loop management, link performance, crosstalk and interoperability. Finally, we give you an idea about on-going and future steps on KT broadband access networks including VDSL, PON, Metro Ethernet and MSPP.

6 Acronyms

ADSL	Asymmetric Digital Subscriber Line
ATLAS	ADSL Transmission Line Analysis System
ATM	Asynchronous Transfer Mode
ATU-C	ADSL Transmission Unit – Central
ATU-R	ADSL Transmission Unit – Remote
B&A	Building And Apartment
BPON	Broadband Passive Optical Network
B-RAS	Broadband Remote Access Server
CAT	Category
CATV	Cable TV modem
CDN	Content Delivery Network
CLI	Command Line Interface
CO	Central Office
COC	Central Office Concentrator
CPE	Customer Premises Equipment
DMT	Discrete Multi Tone
DSLAM	Digital Subscriber Line Acces Multiplexer
EFM	Ethernet in the First Mile
EMS	Element Management System
EPON	Ethernet Passive Optical Network
FEXT	Far End Cross Talk
FTTC	Fiber To The Curb
F/E	Fast Ethernet
FSAN	Full Service Access Network
FS-VDSL	Full Service VDSL
GES	Giga Ethernet Switch
GPON	Gigabit per second Passive Optical Network
GSR	Giga Switch Router
KORNET	KORea Telecom NETwork
IOP	Interoperability
MDU	Multiple Dwelling Unit
MIC	Ministry of Information and Communications
MSPP	Multi Service Provisional Platform
NEXT	Near End Cross Talk
NTOPIA-E	NTOPIA based on Ethernet
NTOPIA-S	NTOPIA based on SHDSL
NTOPIA-V	NTOPIA based on VDSL
OLT	Optical Line Termination
ONU	Optical Network Unit
PHY	Physical layer
POTS	Plain Old Telephone Service
PPP	Point-to-Point Protocol
PPPoE	PPP over Ethernet
P2P	Peer to Peer
PTM-TC	Packet Transfer Mode Transmission Convergence
SHDSL	Single-pair High-speed Digital Subscriber Line
SLA	Service Level Agreement
STM	Synchronous Transfer Mode
TIMS	Telephone-service Integration Management System
TLAN	Time-division duplex LAN
TOMS	Telephone Outside-plant Management System
UTP	Unshielded Twisted Pair
VDSL	Very high speed Digital Subscriber Line
WMP	Window Media Player

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Delivering the Future of TV in Hull

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In 1999, after several years of technical trials, Kingston Communications (Hull, England) became the world's first telecommunications company to deliver a commercial full service broadband interactive television (iTV) offering to its subscribers using ADSL over existing telephony infrastructure.

The KIT (Kingston Interactive Television) service has since attracted over 20,000 users and continues to evolve as a showcase of both the technology and the exciting market opportunity.

As the BBC Director General Greg Dyke said as he launched the public broadcaster's presence on the KIT platform in October 2001 *"The future of television is happening in Hull"*.

This paper presents an overview of the service and an exploration of some of the unique features provided in its deployment.

KiT The KIT Service Offering

The KIT service utilises ADSL (asymmetric digital subscriber loop) technology to deliver the following:

- A simple-to use TV portal / electronic programme guide (EPG) with themed categories of content. The vast majority of content is accessed using a simple TV remote-control handset;
- 70 channels of Digital Broadcast TV and Radio, arranged into a number of basic, premium and standalone subscription packages;
- True Video On Demand (VOD) – over 2,000 items of movies and compelling TV content available via pay-per-view and subscription channels with content from Hollywood Studios, BBC and leading commercial programme makers;
- 'Virtual' broadcast channels played out from KITs extensive video server facility;
- Broadcast digital radio feeds;
- The 'KIT Channel' – local interactive content on demand including news, weather, sports, entertainment and education as well as a comprehensive directory of local shops and services;
- Unmetered Broadband Internet Access to both the TV and PC (in the case of the PC, this is delivered simultaneously with the TV-based services);
- TV- and PC-based email;
- Enhanced and nonlinear programming (such as BBCi's acclaimed 'Walking with Beasts' and 'Blue Planet');
- Games on Demand;
- Secure TV shopping, banking and betting services;
- A single monthly bill for all interactive and TV services.

ADSL technology allows Kingston Communications to exploit new revenue streams and maximise the added value which can be delivered via the investments in its existing copper network, thus competing with offerings more commonly associated with cable and satellite service providers. It enables Kingston as an operator to break away from the increasingly commoditised consumer voice and data communications markets.

Kingston provides a 'home gateway' for the consumer – acting as the telephone provider, digital TV provider, Video On Demand Service and broadband ISP. Using a single technology infrastructure for delivery of all broadband and video applications means cost-effective delivery and a less complicated access and provisioning network.

The fully deployed network in Hull now has the potential reach of 105,000 households living within a 2.5 km line-length of Kingston's 14 DSL-enabled telephone exchanges in and around the city of Hull. The service delivers a guaranteed bandwidth in excess of 5 Mbit/s.

Subscribers, Advertisers and Content Providers

From the subscriber's standpoint there is no need for satellite dishes, additional telephone lines or cable – the entire service is delivered using the existing telephone line, which remains unaffected by the service.

Subscription to the entry level service currently costs £ 6.80 (approx. 10 Euro) per month. In practice however, most KIT subscribers purchase additional Pay TV, Internet, Email and video-on-demand services which will typically amount to a spend in excess of £ 20 (approx. 30 Euro) per month.

The Set Top Box (Pace DSL4000) and DSL modem are provided free-of-charge to the subscriber with a minimum 12-month contract. The service is professionally installed by a KIT representative who will give the new subscriber an introduction to the unique services on offer. Presently around 85 % of the service subscribers take an extended Pay-TV offering and over half of the service subscribers have paid to rent a Video-On-Demand movie since the service was launched. One in three subscribers make use of the unmetered TV Internet and email offering.

More recently, subscribers have been presented with content which combines broadcast, VOD and broadband Internet delivery to provide enhanced TV delivery. For instance during the FIFA World Cup KIT viewers were able to move between multiple views of a live match (delivered via satellite into the Kingston network), catch up on the latest tournament news (via a web feed from BBC Sport) and view exclusive interviews, full-screen, on-demand (delivered via the KIT VOD servers). Such services have proven popular with subscribers with up to one third of viewers proactively choosing to explore the interactive features of such events.

From an advertiser's perspective also, KIT presents a number of opportunities for addressable advertising and brand-building. A recent campaign, conceived in partnership with a leading agency, allowed users to 'jump' out of the broadcast program into an interactive advertisement in which the viewer could control the narrative, ultimately being presented with a personalised offer.

For the advertising community services such as KIT provide potential for media integration and accountability, providing marketers with a direct/interactive medium that works in concert with other media. In addition, consumers trust and accept television more than other direct/interactive media so it can provide marketers with a unique environment in which to trial new delivery concepts.

International brands, including Nestlé, have recently used KIT as a strategic brand-building tool with rich offerings combining content, sponsorship and commerce in a wholly innovative way. Early research from such trials has been very encouraging with increased brand awareness and positive consumer feedback.

Using an open architecture, based upon established standards-based Internet protocols allows third party content providers and aggregators to assemble content offerings on the platform using existing resources and skill sets. Local, regional and global commercial and public service broadcasters, programming content libraries and e-commerce providers have already established branded presence within the KIT portal, drawing upon the wealth of skills and content on the World Wide Web.

The recently revised KIT interface allows providers and advertisers to 'push' rich content, including video, to the user, overcoming many of the navigational problems associated with complex, tree-structured portal interfaces.

Technical and Network Architecture

The KIT broadband TV service utilises a high capacity ATM core network which feeds IP-aware digital subscriber line access multiplexers (DSLAMs) located in the local telephone exchange.

Using Tandberg encoders, broadcast video is encoded using MPEG in real time at a combined audio/video data rate of approximately 4.3 Mbit/s. By replicating each of the 60 multicast channels (fed from a satellite/DTT head-end) at each DSLAM, the immense bandwidth requirement for delivering service with 100 % concurrency (no 'busy' signals and fast channel changes) is achieved in the most cost-effective manner. Each DSLAM has the capacity to serve 936 subscribers.

Figure 1 The KIT Portal Interface showing directional advertising placement

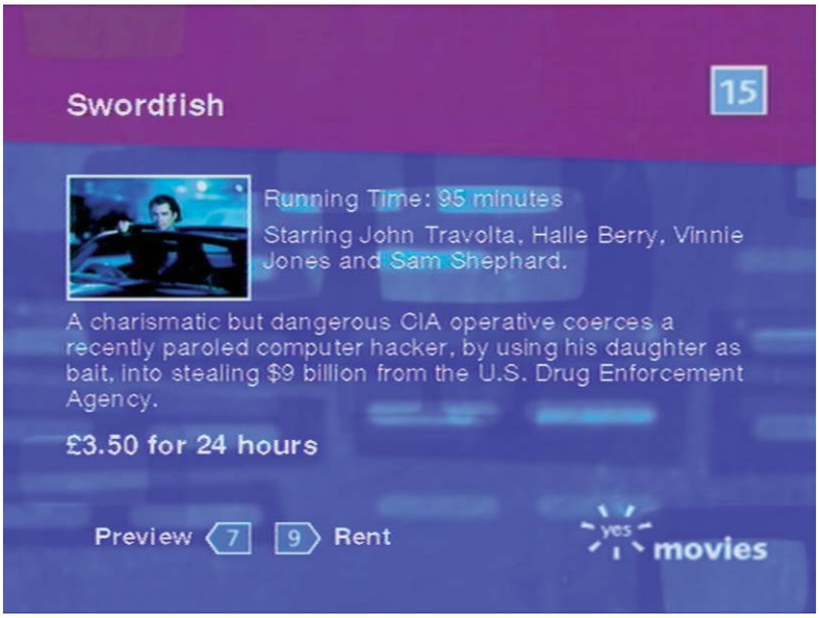

Figure 2 Video-On-Demand Selection Screen

The video-on-demand infrastructure, whilst essentially similar, delivers a theoretical maximum 20 % concurrency at each DSLAM, due to the need to provide a virtual circuit back to the video servers (nCube). In practice, this concurrency 'ceiling' has never been reached. The content is again encoded using MPEG, although in this case multiple pass offline techniques can be used to reduce the combined data rate to around 2 Mbit/s. This gives image quality comparable with a good broadcast signal and superior to a VHS source.

Video On Demand Content can be controlled by the subscriber with Pause, Rewind, Fast-Forward and Step-Frame features.

The Video On Demand servers, one of the world's largest commercial deployments, have capacity to deliver around 2,500 simultaneous video streams. Recent developments have also allowed the creation of arbitrary 'virtual' channels, composed of assets fed from the VOD servers, to be provided.

Locally-oriented VOD content has proven to be popular, in particular Children's, News and Sports content, particularly that with a local angle have been consistently at the top of the usage tables. Subscribers have the chance also to submit their own content via a 'local video diary' portal on the service. The popularity of movies-on-demand has risen since the launch of the service, with subscribers on average viewing over two pay-movies each month.

The commercial Video On Demand Service, which is provided in partnership with Yes Television, provides PIN-controlled and time-limited access to individual items of content. For movies each 'rental' can attract a charge which relates to a period of availability (typically 24 hrs) to the subscriber. Other types of video programming are made available via 'programme libraries' which attract a fixed monthly subscription fee for unlimited access.

Customer management, conditional access and the broadcast programme guide are provisioned using middleware supplied by iMagicTV, a Canadian-based software developer. This is integrated with a billing engine developed in-house by Kingston Communications. Each Set Top box is individually addressable, making remote management and software upgrades efficient.

The KIT portal interface is developed using HTML and JavaScript which runs in a browser on the Set Top Box. Third party content offerings are similarly produced according to a set of interface guidelines, using HTML and JavaScript.

An Open Platform

Over the past three years a number of third parties have worked to develop bespoke presence on the KIT platform. The open standards archi-

Figure 3 Third Party Application Examples

tecture used by the service allows the partner to develop and maintain a tailored presence authored and hosted using standard web technologies. This has cost and skills utilisation benefits when compared to the proprietary systems used in other iTV deployments.

For third parties, the only requirement is that the MPEG streamed video is stored on the KIT video servers; this ensures quality of service delivery. Thus in the two screen shots shown on the previous page the video in the window is served from the local network (NB. this can run at full-screen as well) whilst the surrounding text and images are held on standard web servers, containing calls to the broadband content.

Summary

Throughout its first 60 years, television was a broadcast, passive, monolog, and linear entertainment viewing experience for millions of people in unidentifiable fragmented viewing groups. However the future of TV is now evolving into an on-demand, participating, non-linear, infotainment, targeted advertising, and broadband, two-way communications platform.

Services such as KIT are evolving new delivery concepts which bring together the power of TV with the open standards architecture of the Web and PCs to deliver a mix of local, regional and national, entertainment, information and education. As users become familiar with the interactive and on-demand features of such services there is strong evidence to suggest that their media consumption habits change enormously – giving rise to entirely new media, programming and advertising concepts.

Bell Canada Delivers Data, Video and Voice to Multi-Dwelling Residences on Copper

CLAYTON MANGIONE

Clayton Mangione (42) is Director of Broadband Technology Development at Bell Canada. Since graduating from the University of Waterloo (Canada) in 1984, Clayton has held various Professional Engineering and Management positions in the Oil, Atomic Energy, and chemical and telecommunications industries. His current focus within Bell Canada is towards bringing new broadband technologies and entertainment solutions to residential and business customers. Some recent successes include advancing Bell into the Digital Cable TV and DTH businesses, High Speed Internet access, a Digital Video Network and more recently Full Service architectures. Clayton was elected President of the FS-VDSL committee and is a member of several Canadian information technology boards.

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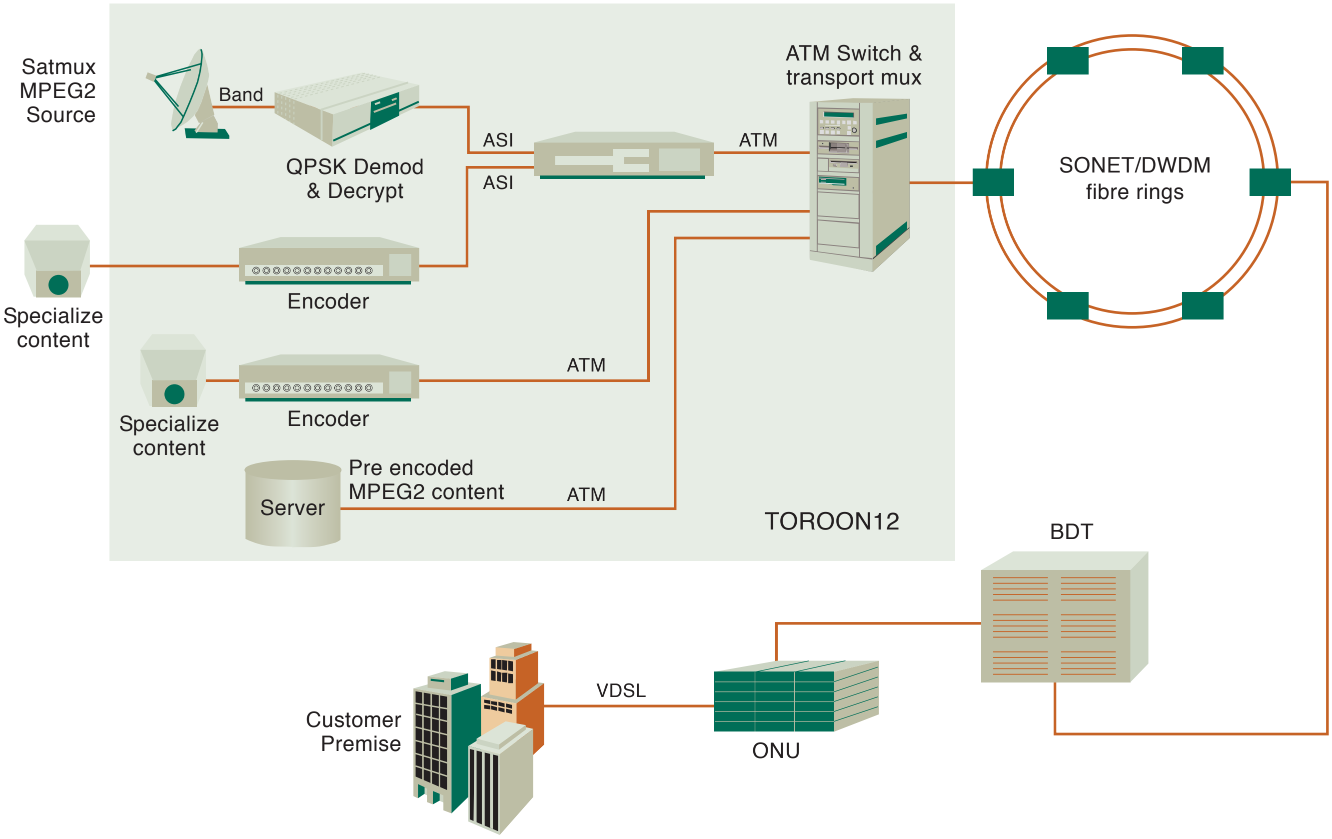
The city of Toronto has become the setting for an advanced VDSL (Very high speed Digital Subscriber Line) service that gives Bell Canada customers three streams of digital video, high-speed Internet service, and telephone service – all using a building's existing copper wiring. We will initially offer this complete broadband package to Toronto apartment and condominium residences, with the potential to expand to other major cities. The service bundle follows a successful field test that has run flawlessly at Palace Pier, a lakefront, luxury residential building. "No new wires – no muss – no fuss" has been our motto, and we are living up to it! The VDSL based access platform gives us a strong competitive offering against aggressive, well-entrenched competition in an important market: multi-dwelling units (MDUs), which make up 35 to 40 percent of our service area. Both cable TV and wireless providers are moving very quickly into the high-speed data access market, as well as providing digital cable services. The capability to provide standard voice services on cable TV is not too far from reality either. The VDSL solution has the ability to deliver to each residence 26 Mb/s data speed in addition to the voice services via the existing copper risers. This enables Bell Canada to construct its own full suite of competitive digital services. For our customers, the battle will come down to who offers the most value and highest quality service. The VDSL system gives us the edge with a very attractive offering.

Bell Canada currently uses Next Level Communications NLevel^3 Unified Access Platform for the access equipment necessary to provide video, high-speed data and telephony services over copper twisted pair. This also includes a single Next Level's N^3 Residential Gateway set-top box for video and data. Customers have high-speed Internet service with the choice of three data speeds, advanced telephone features and up to 350 digital audio, video and Pay Per View channels. The system supports three televisions playing different programs simultaneously, without having to install three separate set-top boxes. Each television has access to the entire channel line-up and has its own customizable Interactive Program Guide. A caller ID service displays caller identification information on the television. This information can also be stored via the Interactive Program Guide.

The Next Level VDSL distribution system consists of two main components. The Broadband Distribution Terminal (BDT) located in a Central Office and a multiplexer shelf located at the interface to the copper loop facility. Each multiplex shelf is linked to the BDT by one fiber. Each shelf is capable to support up to 144 VDSL full service customers. In order to get the targeted bandwidth of 26 Mb/s to each customer, the copper loop that carries the VDSL signal must be within 1 km. This is not an issue in the MDU environment as we locate multiplex shelves in the basement Inside Terminal (IT) or in a nearby hub location. Adding a customer simply means adding an additional line card to the shelf and installing a Residential Gateway set-top box. This approach has a huge advantage in that most of the investment is made after we sign-up a customer. "No new wires – no muss – no fuss!" The Palace Pier – a 433-suite, 46-storey building overlooking Toronto's lakeshore – proved to be an excellent choice for the field trial. The age and condition of the 25-year-old condominium's existing wiring, coupled with hardwood and marble floors and concrete walls presented many challenges if we were to meet our "no new wires" mandate. With the creativity of the Bell field team, these challenges were effectively and creatively overcome. The Palace Pier is now full commercial customer and we managed to retain 100 % of the customers.

The ability to control the up front investment gives us a strong competitive advantage to promote the introduction of VDSL. The density of

Palace Pier Condominiums, Toronto, Canada



VDSL headend & system schematic

the multiplex shelf reduced the fiber requirement for a large scale building like Palace Pier to 3 fibers which is very affordable in a metro environment. Future technology enhancements through the introduction of wave division multiplexing may reduce the fiber need to 1 per building. The investment in fiber cable to an MDU also provides a further opportunity to introduce digital loop carrier technology to the building and convert the building to a completely fiber fed entity. In the near term, this optimizes the overall copper feeder spending while for a new building, this eliminates entirely the need for new copper placement. In the long term, we are a step closer to the introduction of the ultimate FTTH architecture.

At the service level, the VDSL in MDU architecture enhances the quality of High Speed Data service. The uniform loop condition and -length will guarantee every subscriber achieving the highest access speed of the service tier that is subscribed. This “clean loop” advantage is in contrast to service delivered by ADSL where the access data rate is highly dependent on the distance of the home from the multiplex location. Our subscriber’s data access rate will definitely not degrade as neighbours go online. A single Residential Gateway set-top box device which serves as both the data service modem and digital TV set-top box allows us to install the data and video services at the same time. Our pilot deployment of VDSL into the residential marketplace has shown a much higher multiple services subscription rate than the population of subscribers served by separate architectures for delivering data service and digital video service.

Another unique advantage for our customers is the ability to subscribe to the same digital TV service from Bell ExpressVu as 1.2 million subscribers enjoy today. Bell ExpressVu is Canada’s leading Direct to Home (DTH) satellite digital TV distributor. The VDSL system shares with the DTH network the same common source of content, the same set of procedures to subscribe and activate services, and the same billing system. The ability to share with the DTH network minimized the start up cost on VDSL. The negotiating power with content providers for VDSL during its start up is greatly enhanced by the size of the DTH subscriber base.

To integrate the Bell ExpressVu content into the Next Level distribution equipment, a compact VDSL Head-end was constructed. The integration betwen the Tandberg Television digital Head-end system and NLC enables the re-use of the same signal that is available to the DTH subscribers and re-multiplexes the signal into a format compatible to the VDSL architecture. The entire re-multiplexed channel line-up is then transported by any SONET compatible optical carriers from the VDSL Head-end on a drop and continuous basis to every Central Office that is

A compact, efficient head-end

equipped with a Broadband Distribution Terminal (BDT). The ability to re-multiplex the existing MPEG2 encoded content via a specialized Head-end reduces the costs, complexity, power consumption and floor space in the order of 80 % of a conventional CATV Digital Head-end. For a line-up of 350 channels, the Head-end only occupies a space of merely 4 equipment bays.

In order to maximize the service quality while optimizing the VDSL bandwidth, we have deployed both Variable Bit Rate (VBR) and Constant Bit Rate (CBR) capabilities to match the source DTH content running both Fixed and Stat-Mux encoding. The 2 Mb/s VDSL downstream capability is a good fit for a three Digital TV channel plus High Speed Internet services offering. Maintaining the VBR feature is important as it provides a marked enhancement in the video picture quality. VBR also provides the extra bits required for high motion video while keeping the average bandwidth at a much lower value, thereby optimizing the overall content transport cost throughout the entire network.

MDUs: A New Revenue Stream From VDSL

The country's largest telecommunications operating company, Bell Canada, is a subsidiary of BCE. Sister companies under the BCE umbrella include Bell ExpressVu, and Bell Sympatico, which provides dial-up Internet access services as well as high-speed connections via DSL. Within our market, the VDSL triple play offering has wide potential use beginning in the highly competitive MDU marketplace and strategically migrating into the single family home environment as remote DSLAM (for ADSL) get deployed closer to the end customers. VDSL also makes sense in the small-to-medium enterprise business market, where direct fiber connectivity would be costly and time consuming to deploy. The technology also has potential in new "green field" home developments where fiber facilities can be placed without disruption to the streets and landscaping. VDSL is a key component in our Access Network architecture strategy. The benefits of rolling out to the MDU market are obvious: high competition, develop relationships, more effective service promotions/marketing, low cost of entry, improved time to market, pay as you play variable costs, maximizes use of existing investments, a single appointment, a single installer, a single truck roll and a single point of contact for our customers. These efficiencies are extremely attractive to the bottom line cost of doing business. Additional cost-savings are gained thanks to the Next Level's N^3 Residential Gateway, which contains the VDSL modem, the high-speed Internet port, telephony vertical services as well as all three digital TV signals.

Processes and Management Systems: Critical to Success

Poor internal processes will not only lead to poor service and poor economics, but more importantly will lead to a poor experience for the customer. Having a very strong and recognised brand is not enough to retain a solid customer base in this highly competitive marketplace. In light of this situation, much attention was placed on fine tuning our operational process in the areas of customer acquisition, service provisioning and service assurance. These processes must be structured to bring out the value of VDSL to our customers and yet remain cost effective to ensure that an economic advantage can be realized.

Based on a core competence of customer services, Bell Canada has developed a very unique operational support system which integrates well established operations processes into the new VDSL technology. This new system is called ICSIS (Integrated Communications Support Information System). ICSIS interfaces with all of the related service provisioning and service assurance systems and completely automates information exchange: billing, TV listings, assignment records, workforce management, inventory control, vendor specific element management / service provisioning systems and other legacy systems. It is an entirely automated process where customers contact a single Customer Service Representative to order data, video and voice services and one technician visits the customer to install and activate the selected services. Customer priority remains #1 = One number, one order, one truck roll.

Future Plans: Web Browsing and More

Bell Canada's data / video / telephony offering is just the beginning. In our Ottawa-based System Integration labs, our engineers are testing higher performance systems and exciting new services. In addition to the existing switched Digital Video, high-speed Internet access and advanced telephony features, the VDSL architecture will provide the ability to deploy interactive entertainment and educational applications. The Set Top Box "middleware" will act as a framework for applications such as Web Browsing, Calendars, Instant Messaging, E-mail, Information Pages, Community Bulletin boards, Close Circuit TV, Video/Music on Demand and Network based program recording.

With the success of our field tests and early deployment activities, Bell Canada now has proven that it can deliver a complete, competitive offering of digital services using the existing copper plant. This is a market long in need of competition, and our customers will be the direct beneficiaries.

The Telenor HB@ Interactive Broadband Service Trial

LEIF AARTHUN IMS AND HARALD LOKTU

Telenor has during 2000 and 2001 tested how different access solutions may be combined in order to provide a comparable offering of next generation interactive broadband services in cities, townships and rural areas – from the far south to the far north of Norway. The *Telenor HB@ (hybrid broadband access) interactive broadband service trial* project has tested hybrid solutions based on combinations of fixed network upgrades with VDSL (very high speed digital subscriber line), wireless systems like LMDS (local multipoint distribution system), interactive and DTH (direct to home) satellite systems and the DTT (digital terrestrial TV) network. The pilots have been carried out at four different places in Norway; Stavanger, Oslo, Beito and Svolvær. Home network alternatives have been tested in the project. The target on the service side has been to provide the users with offered next generation TV- and PC-centric interactive broadband services. In this paper, the Stavanger pilot is given the most in-depth coverage. This was the largest of the pilots and had the most advanced technology and service portfolio.

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Harald Loktu (39) is Research Scientist at the Telenor R&D program for Broadband Networks. In the 2000–2001 period he was responsible for the trial platform development in the Telenor Corporate project Hybrid Broadband Access. He is currently managing the technical platform development for VDSL. Mr. Loktu has contributed to various international research and standards initiatives including ACTS, EURESCOM and CEPT/ERO within the area of broadband wireless networks.

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1 Introduction

Next generation interactive broadband services are expected to require broadband access networks with a capacity that gives the end-user interactive digital TV with several simultaneous TV-channels, in addition to high-speed Internet access and telephony services. This service set may be offered by a variety of technologies. However, the costs of providing this infrastructure vary significantly between various geographic areas, and depend on the technology applied. Simultaneously, market stimulation and corresponding revenue streams require broadband content providers and the infrastructure providers to target a wide service footprint.

Telenor – the incumbent telecommunications operator in Norway – is in a rare position, as it owns and operates a wide range of different access networks today:

- The twisted pair PSTN and ISDN network. ADSL introduced in 1999/2000;
- Norways' largest cable operator;
- Broadband wireless (LMDS) – operations abroad and licences in the domestic and foreign markets;
- Terrestrial broadcast network in Norway – currently analogue transmission only;
- DTH satellite operations – Europe's third largest satellite operator.

This paper presents the approach of Telenor towards a market driven deployment of next generation networks for interactive broadband services, with particular emphasis on the findings from a large scale pilot operation (1–4). The main characteristic of the pilot operation and the strategy is a hybrid approach, which seeks to utilise the strengths and market opportunities of combining different access network technologies to provide a comparable interactive broadband service offering with a footprint extending beyond the urban and highly competitive areas. This approach is expected to benefit the end user, the service and content provider, and in turn the network operator. It is also addressing the growing concern about a possible future digital divide caused by limited access to broadband infrastructure.

2 What is Interactive Broadband?

In the television world the word *interactive* usually means that *films* or information pages are *broadcast downwards* to the television terminal and the return communications means click or select upwards. We call this *TV-centric interactive broadband*. The dominating content is characterised by entertainment and used to be closely linked to the service provisioning.

In the PC or data world, interactivity usually means *file transfer in two directions, e-mail, home office applications* and *Internet*. We call this *PC-centric interactive broadband*. In this case the content is highly user specific and not strongly linked to the service provider.

Traditionally *TV distribution* is *one-way broadband*, in the sense that broadband signals are broadcast to the user (every film represents 2 to 6 Mbit/s digital capacity or some MHz analogue bandwidth). However, there is *no interactivity* in this service. The *PC-centric broadband* is completely different, since interactivity means file transfer two directions, e-mail, home office applications and Internet. These broadband services are of course the focus of public and political interest, since these services are widely seen as having a potential to influence the new way of working, learning and living in the so-called information society.

Moreover, the well-known triple play strategy consisting of bundling digital TV, high-speed Internet service and telephony assumes that the consumers want one fat pipe to their homes. This gives them the opportunity to easily plug in and get digital TV (more channels and interactive services), telephony and PC/Internet with no waiting time, as it should be when you work or have fun at home. Thus, if this bundling strategy proves successful, the broadband access provider will very likely be facing a requirement for providing a full service set offering to a large portion of the consumer base, encompassing both TV-centric and PC-centric services.

3 Technology Convergence

During the past ten years, a dramatic change has been witnessed in the way access networks have developed. From being dominated by analogue transmission of a single service per technology (for instance PSTN telephony, PAL and MAC based TV broadcasting, FM radio broadcasting, NMT mobile telephony), access networks are about to become converted to digital transmission standards being able to carry a varied bouquet of services. This transition from analogue to digital formats is mainly being fuelled by digitisation of content and delivery media together with the ongoing deregulation of market for communication services.

The access network design approach in the analogue era was clearly network centric in the sense that a single service was distributed to a multi-customer segment. When adopting the multi-service approach, this is turned upside down in the sense that a tailored bouquet of services is delivered to individual customers preferably through a single transmission medium. Hence, a customer centric approach to access network design is needed in order to address the development/implementation of broadband access networks.

There is a wide range of access network technologies deployed worldwide today, and even more emerging broadband access technologies. The two major categories for delivery of broadband services are *fixed service* and *broadcast service* access networks. Originally, the broadcast access networks were designed to provide services shared between many customers in a uni-directional point-to-multipoint connectivity. Conversely, the fixed access networks were designed to provide individual services to customers with a symmetric bi-directional point-to-point connectivity. In a multi-service scenario, a convergence between these rather different architectures is foreseen enabling joint delivery of fixed and broadcast service to customer.

However, the significant variations in access network costs and cost profiles between converging broadband access technologies will impact the way future networks are designed. This is discussed in the next chapter.

4 The Investment Challenge

In today's domestic market Telenor owns a twisted pair telephony network, a cable television network, a terrestrial broadcast network and a satellite operation. In addition the company has been awarded national and international licences for broadband wireless access.

However, there is a significant geographic diversity in Norway, with the population distributed as follows:

- Large cities:
  5 municipalities > 100,000 inhabitants;

- Cities:
  34 municipalities 20,000 – 100,000 inhabitants;

- Towns and villages:
  99 municipalities 7,000 – 20,000 inhabitants;

- Rural Norway:
  290 municipalities < 7,000 inhabitants.

There are approximately one million inhabitants in each segment, though with drastic variations in infrastructure costs between the segments for upgrading to interactive broadband service capabilities. Thus, a market driven roll-out of infrastructure must seek to utilise the strengths and market opportunities of combining different new access network technologies and existing infrastructure resources. The aim then is to provide a comparable interactive broadband service offering with a footprint extending beyond the urban and highly competitive areas. This approach is expected to benefit the end user, the service and content provider, and in turn the network operator.

The costs of broadband access have been estimated in several projects, internally and through international co-operative projects (5). Figure 1 illustrates the relation between cost of different network solutions as a function of coverage and capacity provided. The results are mapped to the above geographic segments. The cost of providing high quality broadband services to all the four groups by establishing fibre nodes closer to the customers in combination with VDSL or LMDS drops is indicated. Indicative cost figures for satellite (direct to home, DTH) and DTT (digital terrestrial television network) service

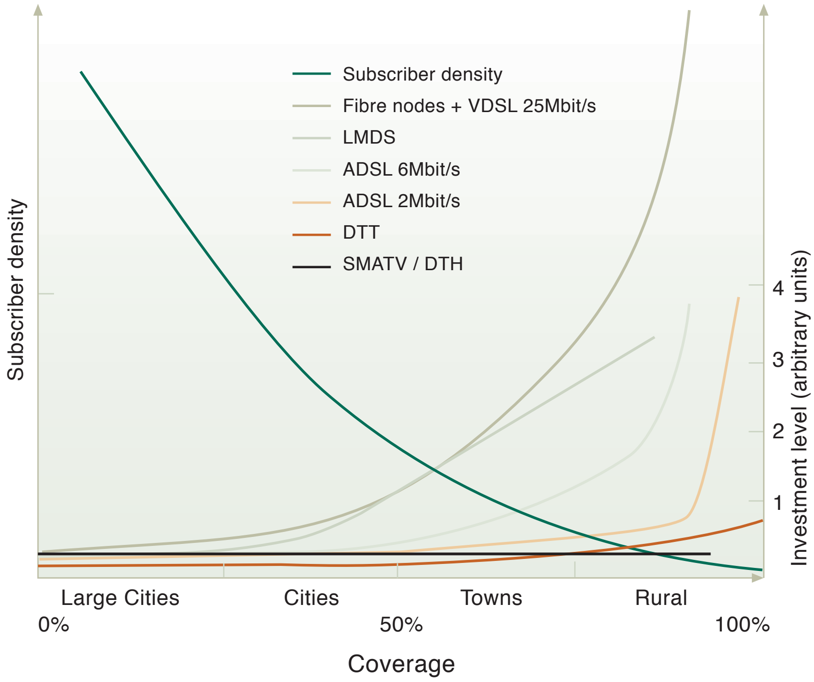


Figure 1 Illustration of the relation between cost of different network solutions as a function of coverage and capacity provided (arbitrary units)

provision are included. The main results presented in Figure 1 are all discounted investments, based on a five to ten year infrastructure roll-out project. The expected future price evolutions of the different infrastructure elements are included in the analysis. The reference market scenario is based on an assumed average 20 % take-up of broadband services over the project period. We have however assumed slightly different take rates between consumer and SME market and between regions in Norway.

5 The Hybrid Broadband Access Approach and the Pilots

The broadband infrastructure is expected to be implemented through an optimal combination of new technology and existing infrastructure resources, such as the twisted pair telephony network, the cable television network, the terrestrial broadcast network, satellite systems and broadband fixed wireless solutions. Telenor, which today own all these existing infrastructure resources, have trialled different network infrastructure options for interactive broadband services. The reference architecture is shown in Figure 2 (left side) (1–4).

Hybrid solutions based on combinations of fixed network upgrades with VDSL (very high speed digital subscriber line), wireless systems like LMDS (local multipoint distribution system), interactive and DTH (direct to home) satellite systems and the DTT (digital terrestrial TV) network are deployed in the pilot. 1000 pilot users are connected to the trial, all of which are offered an advanced interactive broadband service basket. The pilots are located in Stavanger, Oslo, Beito and Svolvær, as illustrated on the right side of Figure 2.

6 The Pilot Services

The objectives of the service provisioning in the trial were to:

- run a large-scale service and content pilot for up to 1000 homes via the various technologies;
- carry out investigations, including service preferences, usage patterns and willingness to pay;
- obtain practical experience in the provision of content.

The trials received various constellations of the services. These included TV, high-speed Internet and telephony in their repertoire of services. The services have been gradually introduced

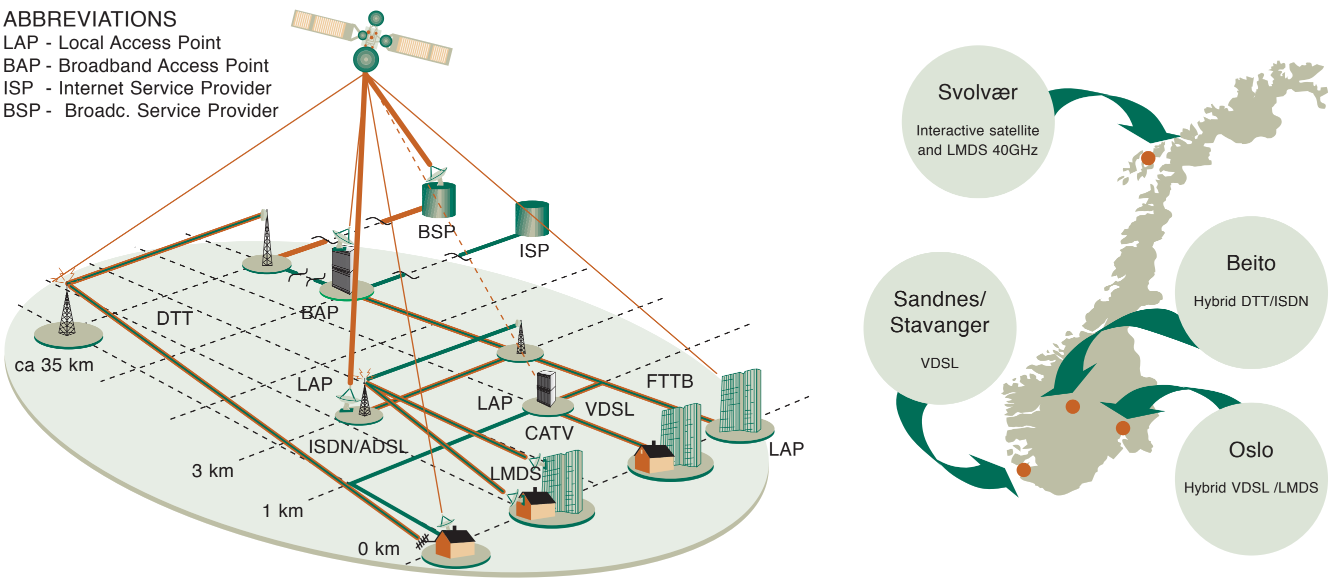


Figure 2 Hybrid broadband access reference architecture (left side) and pilot locations in Oslo, Stavanger, Beito and Svolvær (right side)

over time during the trial period, starting from a basic set of services. The timeline for the service introduction is shown in Figure 3.

When considering the TV offering as many as three parallel transmission streams and as many as 35 TV channels were offered to the users. Figure 4 shows the TV channels available.

Additional services were offered, such as and electronic program guide (EPG), e-mail and SMS via the TV, as well as web browsing. In the Oslo and Stavanger pilots a video-on-demand service was launched in early November. The content available comprised 50 movies and more than 150 hours of archive TV material was available to the users. The PC/Internet offering included "always-on" functionality and high-speed access to the Internet. Finally, the telephony service consisted of either ISDN or traditional POTS. A general overview of services offered in the various sites is provided in Table 1.

The users were offered a TV portal, also called a walled garden. The Zonavi "look and feel" was used for the portal. Examples of the TV portal screens are shown in Figure 5.

Examples of the video-on-demand screens are shown in Figure 6.

7 The Svolvær Pilot – Hybrid Interactive Satellite/LMDS

Next generation interactive satellite systems may give the customer up to 2 Mbit/s return capacity, and is a particularly interesting solution in more sparsely populated areas, in which the investment levels of broadband access based on DSL

Figure 3 The pilot service timeline

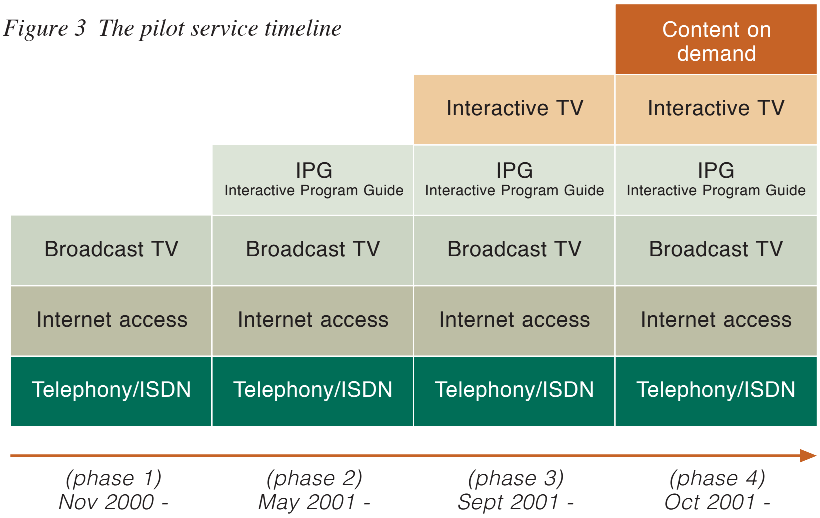


Figure 4 The TV channel line up in the trial

Table 1 Overview of services offered in the project

	Stavanger	Oslo VDSL	Oslo LMDS	Beito	Svolvær DVB-RCS	Svolvær LMDS
TV-centric services						
Multiple broadcast streams	3	1	1	1	1	-
Digital TV channels	35	8	33	13	22	
Local TV channels	2					
Pay per View						
Near video on demand	✓		✓			
Video on demand	✓	✓	✓			
Interactive Program Guide	✓	✓	✓	✓	✓	
Caller ID on the TV-screen	✓					
Web browsing on the TV	✓	✓	✓			
TV e-mail	✓	✓	✓			
Interactive game playing	✓	✓	✓		✓	
Text TV	✓	✓	✓	✓	✓	
PC-centric services						
Always on PC Internet access	✓	✓	✓	✓		✓
TV viewed on PC screen				✓		
High speed data port	✓	✓	✓	✓		✓
Telephony services						
ISDN and POTS	✓	✓				

Figure 5 Examples of the TV portal screens

Figure 6 Examples of the video-on-demand screens, main page Oslo (left) and store frontpage Oslo (right)

are very high. The purpose of the trial in the town of Svolvær and the surrounding areas of the Vågan municipality was to deliver broadband services by means of the combined use of broadband radio (LMDS) and interactive satellite systems (DVB-RCS). Figure 7 illustrates the home network installation in the Svolvær pilot.

The trial was in operation from early August until the end of December 2001, with seven users located in Svolvær served by the LMDS system. The infrastructure for this LMDS hub in Svolvær included a leased 34 Mbit/s line from Oslo to Svolvær, mainly carrying Internet traffic. The DVB-RCS system, for 43 users, was put into operation in the first half of this year.

The services initially intended for offering by both the DVB-RCS and the LMDS systems are PC-centric. TV broadcast to the DVB-RCS users was only made feasible by the introduction of a special diplexer solution added to the antenna receiver part. The main end user equipment unit was common to both LMDS and DVB-RCS; a set-top-like box with router functionality, provided by the main systems manufacturer as part of the total systems deliverables. The DVB-RCS private home installation included this router box, a PC, a commercial set-top box with descrambling mechanism and a TV set. The PC was equipped with a conventional Ethernet card for Internet access. Most LMDS users only had the router box with an Ethernet connection to a PC. The original ISDN/POTS services were provided on the existing copper line.

8 The Oslo Pilot – Hybrid LMDS/VDSL

LMDS in combination with VDSL will suit areas with mixed building structures, consisting of single-house dwellings and apartment blocks/multidwelling units, e.g. in medium sized cities (5). Typically the LMDS node (base station) might be co-located with the VDSL node in a

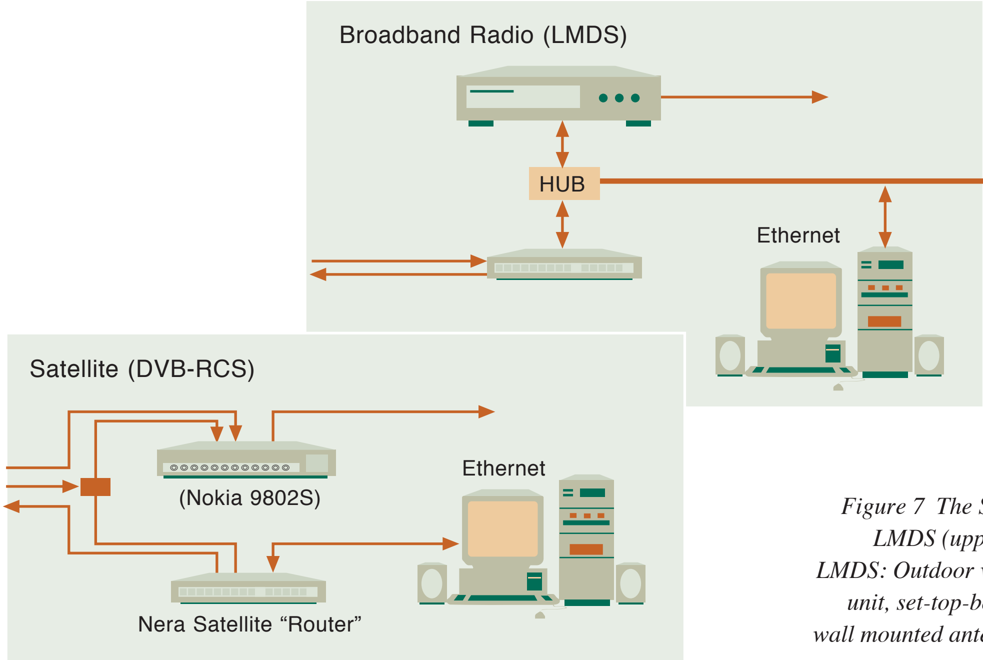


Figure 7 The Svolvær home network installations. LMDS (upper part) and DVB-RCS (lower part) LMDS: Outdoor wall mounted antenna, indoor radio unit, set-top-box, TV and PC. DVB-RCS: Outdoor wall mounted antenna, indoor satellite router, set-top box, TV and PC

high rise building, and the customers in the area may be offered broadband access either through LMDS or VDSL. The purpose of the Oslo pilot was to deliver broadband services to the residential market in a suburban area in Oslo, based on a common infrastructure platform with different access technologies. Broadband radio (LMDS) and broadband on copper (VDSL and ADSL) technologies were deployed. Pilot users located in multi-dwelling units (MDUs) were connected using VDSL, re-using the existing in-house twisted-pair wireline network. Customers located in single-dwelling units (SDUs) were connected using LMDS, distributed from an antenna site at the roof-top of the MDU. Parts of the pilot have been in operation from May 31 2001 until November 2001, followed by a full, integrated operation in the last half of November and December. Figure 8 illustrates the home network installation in the Oslo pilot.

During the trial period 65 users were connected to VDSL, 39 were connected to to ADSL, whilst 47 were connected to LMDS. The VDSL users were connected with an overall access capacity of 10 Mbit/s downstream and 2 Mbit/s upstream, of which 704 kbit/s downstream and 128 kbit/s upstream capacity were dedicated to PC-centric

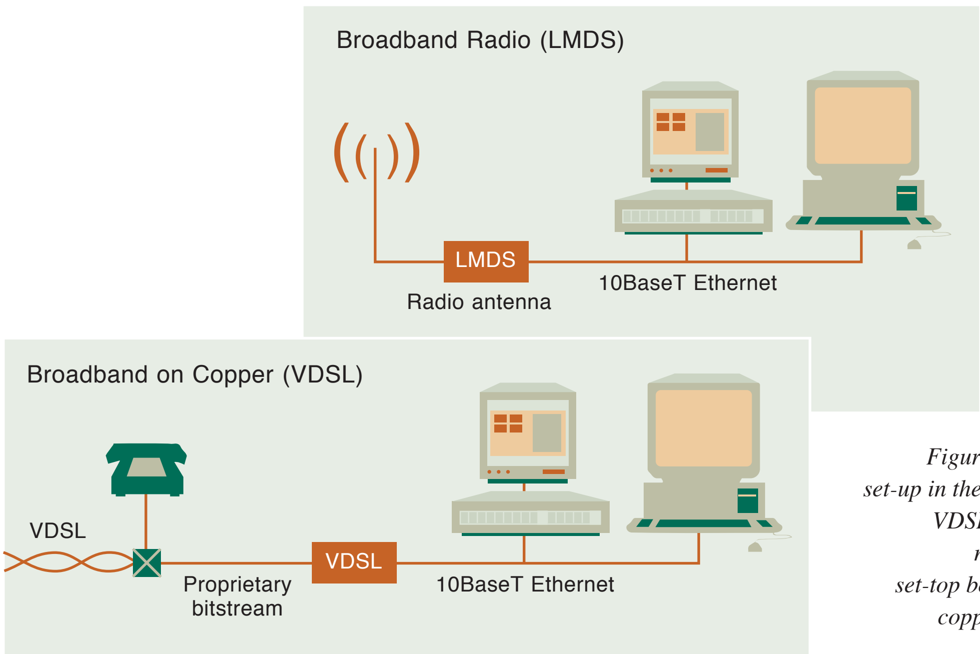


Figure 8 The complete home installation set-up in the Oslo pilot, LMDS (upper part) and VDSL (lower part) LMDS: Outdoor wall mounted antenna, indoor radio unit, set-top box, TV and PC. VDSL: Twisted pair copper wire, ISDN filter, VDSL network termination, set-to

Figure 9 The LMDS installation in Oslo. The base station site (left) and a wall-mounted LMDS antenna (right)

services. The LMDS users were connected with an access capacity of 6 Mbit/s downstream and 532 kb/s upstream dedicated to TV-centric services. For PC-centric services a symmetrical capacity of typically 1.6 Mbit/s was offered, but burst capacities of up to 5 Mbit/s were often achieved. Figure 9 shows the LMDS installations in Oslo.

The services offered included POTS/ISDN, and always-on high speed Internet access. The TV-centric services offered included up to 33 digital TV channels, Interactive Program Guide (IPG), Video-on-Demand (VOD) and web-TV. The interactive TV services as well as the Internet delivery are passed through transparently. Subsequently, the content delivered on top of IP over ATM is processed and displayed either on the TV screen or on the PC monitor.

The home installation includes one digital set-top box with a single MPEG decoder. The PC is equipped with a conventional Ethernet card for Internet access. The original ISDN/POTS services were provided on the exsiting copper line.

9 The Beito Pilot – Hybrid DTT/ISDN

The purpose of the Beito pilot was to test terrestrial digital TV networks (DTT) or DTH in combination with ISDN or POTS return as a hybrid access solution enabling interactive broadband service offerings in places without other available infrastructure. The trial in Beito, a small ski resort in a rural mountain area of southern Norway, included 46 homes. The Beito pilot is one of the first of its kind, as it utilises the terrestrial broadcast network in combination with an ISDN return channel for providing high speed connections to the Internet in a very remote area. The trial was in operation from August to December 2001.

In Beito about one in three of the pilot users had access to only the two or three main TV channels (NRK 1, NRK 2 and TV2) previous to the trial. The remaining group was satellite TV subscribers who had access to more channels. In the project the Beito users received 13 channels with EPG and teletext, and high speed Internet access with typically 1 Mbit/s downstream capacity and 64/128 kbit/s (ISDN) upstream channel for their stationary terminals (PC). In addition, it was intended that the system in Beito could handle mobile terminals with a wireless return channel that could be based on either GSM or GPRS. However, no vendors had such terminals available.

The home installation included one digital set-top box. A dedicated PC card was used in a PC at the receiving end for downloading from the Internet, connected to an ISDN line. The PC could also display the TV channels. Figure 10 illustrates the home network installation in the Beito pilot.

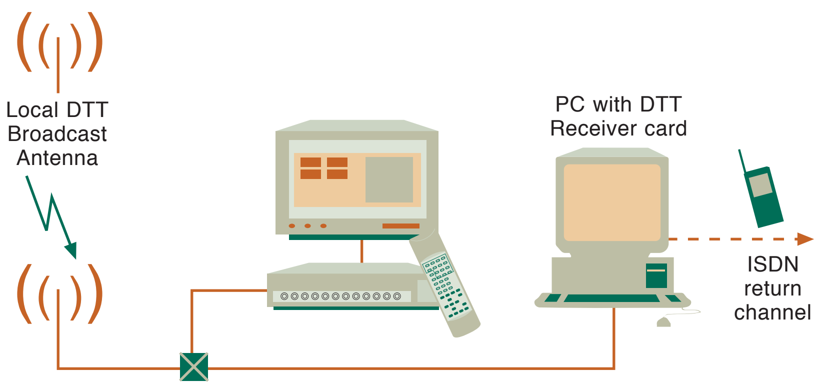


Figure 10 The complete home installation set-up in the Beito pilot. Receiving antenna (table or outdoor wall mounted), set-top box, TV and PC with DTT receiver card

10 The Stavanger Pilot – VDSL

The VDSL technology deployed in the Stavanger pilot is considered the technology of choice in urban areas in Norway. VDSL technology (very high-speed digital subscriber line), with a promise of being able to provide up to 52 Mbit/s access capacity on existing telephone lines, is widely regarded as the technical solution for the incumbent entering the triple-play arena of Internet, telephony and digital TV. In addition, operators like Telenor consider the potential market segments for VDSL to be small and medium enterprises (SMEs), telecommuters/home-offices and 3G cellular operators in need of base station capacity.

10.1 The Market Trial Layout

The VDSL trial in Stavanger and Sandnes was in operation from November 2000 until December 2001 (6,7). The main deployments in the pilot are in the Lura and Forus areas, which both have a 50/50 distribution of single dwelling and multi dwelling units. The project only targeted single dwelling units. The pilot users were connected with an access capacity of 26 Mbit/s downstream and up to 2.5 Mbit/s upstream. The trial area is an established, suburban, single-house dwelling area, as shown in the map in Figure 11. The trial roll-out required new ducts to be deployed for installation of new fibre cable, as well as placing new outdoor cabinets in the access network. 17 fibre nodes, each hosting VDSL DSLAMs (digital subscriber line access multiplexers), were installed. 10 of these nodes were cabinet located nodes, whilst 7 nodes were installed in existing central offices. The 17 nodes were connected with fibre optic transmission to two broadband digital terminals. The area covered had approximately 15,000 potential users within 1,000 metres on twisted pair copper from the fibre nodes. Currently 750 users are connected.

10.2 Pilot User Characteristics

In general, Norway is an advanced telecommunications and information technology market. Norway has the highest penetration of ISDN subscriptions in the world, a mobile phone penetration of 80 %, and amongst the highest penetrations of Internet accesses worldwide. Thus, despite the rather rough topography and limited size of the market, Norway is a good "laboratory" for testing next generation services and technologies.

The users in the trial area live in technology rich homes, exceeding the average of Norwegian homes. They are typically upper middle class and generally positive towards technology. Various types of investigations are carried out during the trial, including questionnaires, focus groups, log of call centre activities and test of willingness to pay. Figure 12 shows the equipment for trial homes in the area compared with the general Norwegian population (8,9).

Figure 13 shows the number of different devices in each home in the area.

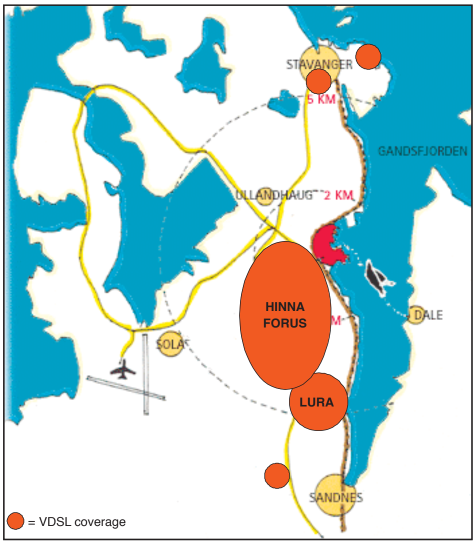


Figure 11 The VDSL market trial layout

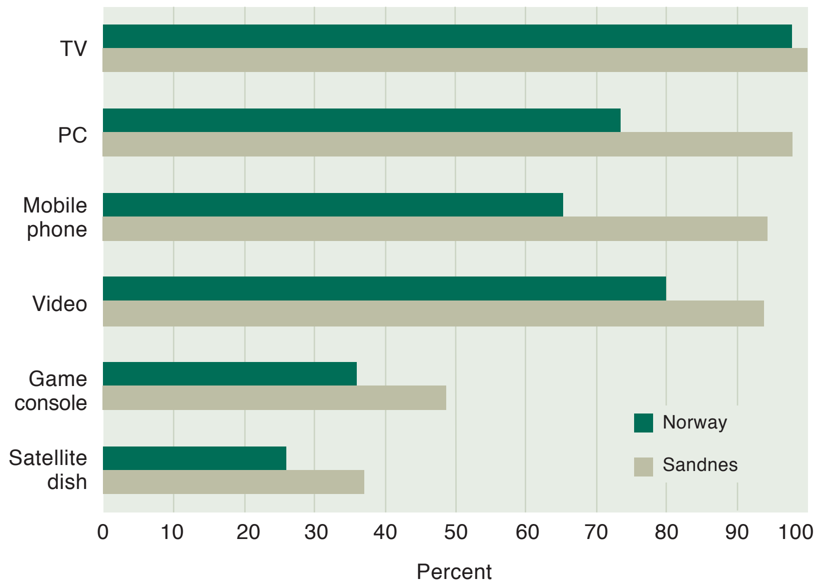
10.3 Customer Premises Equipment and Trial Services

The pilot users are offered 26 Mbit/s access capacity, and the twisted pair copper pair is connected via a low-pass filter to a set-top box. The set-top boxes used in the trials can carry three parallel TV channels (that is, it has three hardware decoders) and it can also offer a 2.5 Mbit/s Ethernet Internet connection for a PC. The customers are fitted with one set-top box that connects the TV sets and the PCs in the home as illustrated in Figure 14.

Figure 15 shows the home installation of one of the trial users and his "control room". As can be seen from the picture, some of the broadband users of today have already built their own "future home".

The trial services in Stavanger are described in chapter 6. The Internet access is offered with a 704 kbit/s downstream capacity and 128 kbit/s

Figure 12 Equipment for trial homes in the area compared with the general Norwegian population



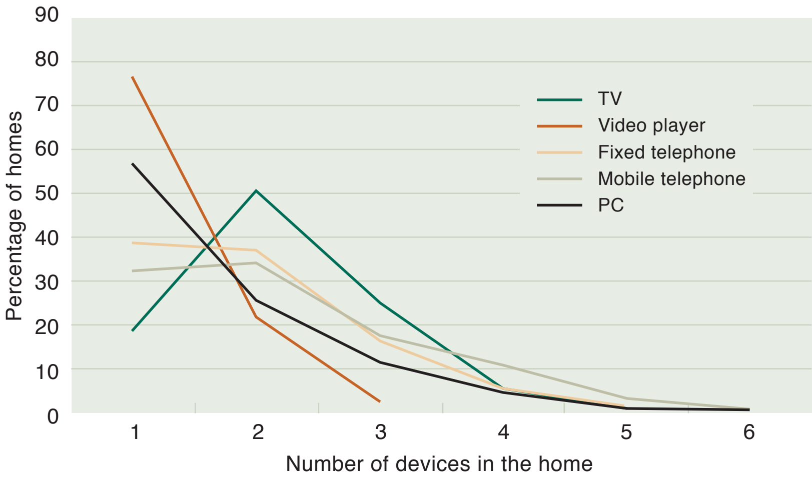
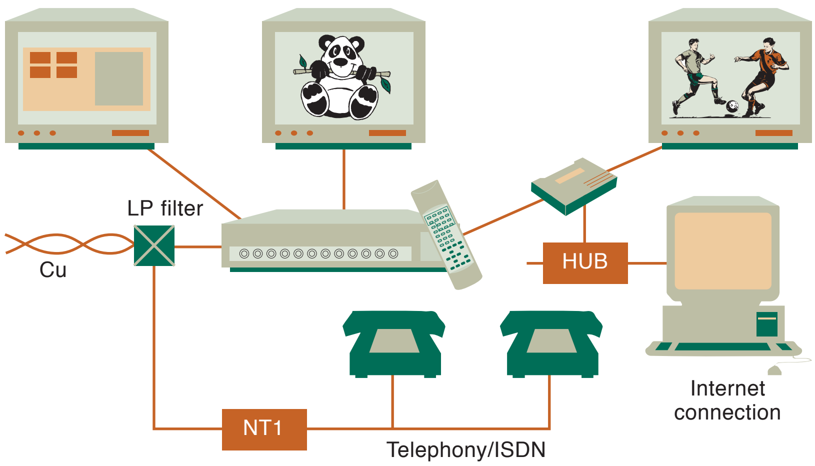


Figure 13 The number of devices in the home

Figure 14 The customer premises installation in the Stavanger VDSL trial



upstream capacity for the majority of the users. Some users are given an internet access with 2 Mbit/s downstream capacity. The Internet access for users' PCs is being supplied by the Norwegian ISP Nextra.

10.4 The Stavanger Pilot Network Infrastructure

The fibrenode and VDSL access network architecture deployed in the trial are illustrated in Figure 16.

The network interconnection and service platform consists of equipment installed at Telenor Research and Development at Kjeller outside Oslo, and equipment located in the Stavanger local exchange. The latter is the primary connection point of services and management of the Stavanger VDSL pilot, with the main parts of the local network interconnection and service platform equipment placed in this location.

The technical installations at Kjeller include the video encoder, or so-called head-end, accompanied by a satellite antenna directed toward the position *1 degree West* and another satellite antenna directed towards position *5 degrees East* for the reception of TV signals. These signals are transported in digital form on an STM-4 circuit from Kjeller to the Stavanger local exchange (a distance of about 500 km) and the digital TV channels are fed into the broadband digital terminals (BDTs) at Lura and Forus. In addition, there is a local head-end in Stavanger for the reception of two local TV stations that are not distributed by satellite today.

The Internet connection to the Internet service provider (ISP), Nextra, is carried from Oslo on a 155 Mbit/s STM-1 circuit to the Stavanger local

Figure 15 An advanced VDSL home installation with backlit projector screen and surround system (below), and the control room with the projector (left)

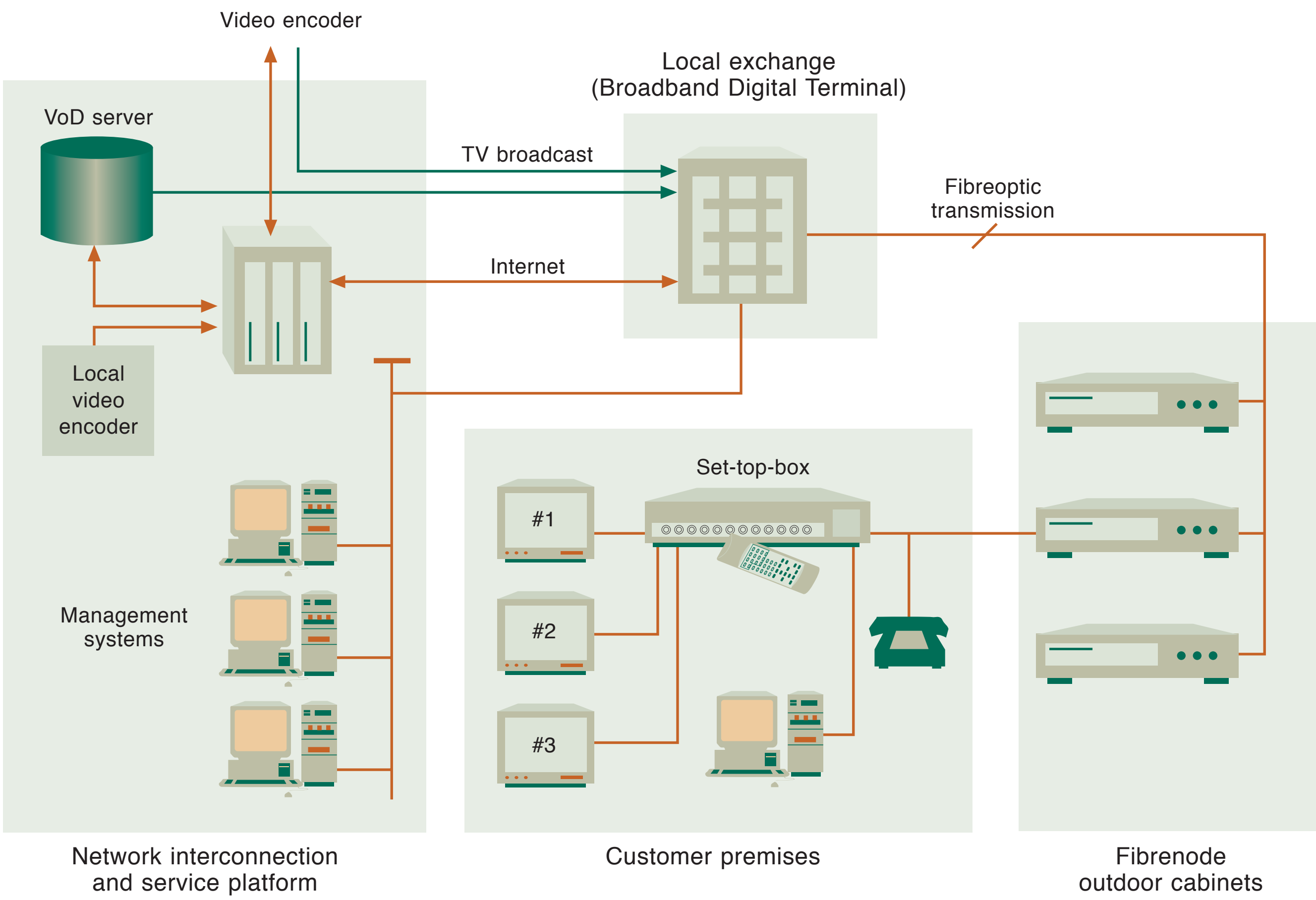


Figure 16 System architecture overview of the Stavanger VDSL pilot

exchange, where the signals are distributed to the Lura and Forus broadband digital terminals.

The management platform for the VDSL access network installation is also located at the Stavanger local exchange. The system consists of three servers. In addition the video-on-demand server infrastructure including ATM switching and IP-routing infrastructure is located in the Stavanger local exchange.

The broadband digital terminals (BDTs) are located in so-called broadband access points (BAPs). Each BAP connects a number of local access points (LAPs), i.e. fibrenodes, which are fitted with access multiplexer shelves. Some of the users are served directly from the local exchange, alleviating the need for outdoor fibre nodes. Shown in Figure 17 is the BDT and access multiplexer installation in the Forus local exchange.

In total 17 fibre nodes, each hosting VDSL access multiplexers have been installed. Ten of these nodes are cabinet located nodes, whilst seven nodes are installed in existing central offices. Figure 18 shows fibre node installations in the Stavanger trial. In establishing the ten outdoor cabinet nodes in the trial five different cabinet types have been deployed, capable of housing from three to ten VDSL card shelves. Shown in Figure 19 are photos from the installation of the cabinets, and some of the different cabinet types used.

The VDSL transmission is run on the twisted pair copper from these fibre nodes. The frequency plan used in the trial is a proprietary solution, different from Plan 998, which is one of the two approved bandplans in ETSI. In connection with the VDSL trial in Stavanger several methods for deploying fibre-optic cable have been tested, including conventional digging and directional boring (Figure 20) as well as installing trenches and ducting:

- Conventional digging, installation of trenches with 3 * 40 mm subducts;
- Conventional digging, installation of direct burial ducts;
- Directional boring, installation of ducts.

Directional boring is a solution with the potential of alleviating the need in connection with conventional civil works for time consuming and costly opening of the road surface, including reinstatement of tarmac after the fibre cable is deployed. Directional boring is a technique in which the boretip may be directed sideways, vertically and horizontally. As the boring pro-

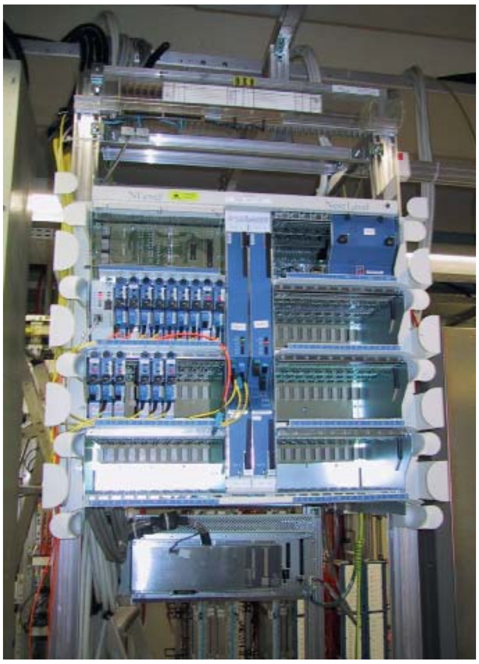


Figure 17 The broadband digital terminal installation in the Lura local exchange

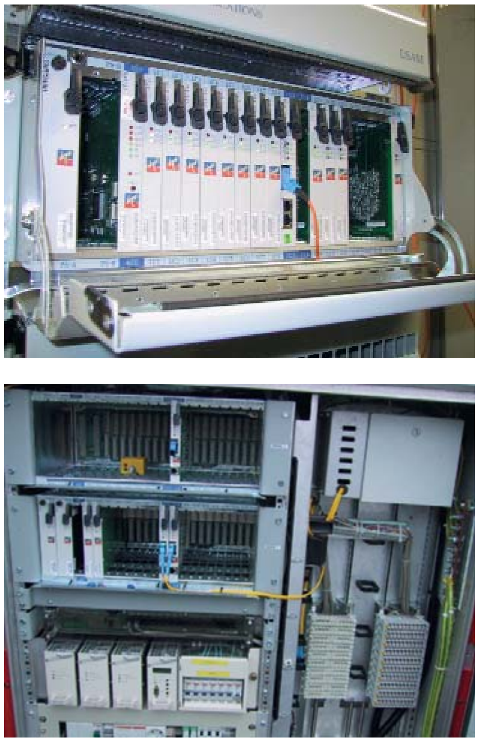


Figure 18 Access multiplexer installations in the Stavanger trial

gresses the borehead is extended with 3 m strands up to 300 metres of total length. Typical progress of such a process is 20 metres per hour, assuming light soil. The majority of the civil works was carried out by the use of conventional digging.

The set-top box is connected to the twisted pair copper line entering the customer home. The phone line is terminated in a wall outlet. From this position a common twisted pair cable is connected to a filter dividing the VDSL signal and the POTS/ISDN signal. This filter is a diplex type, where one port goes through a high pass filter and the other through a low pass filter.

From the filter, a twisted pair cable carries the VDSL signal to the set-top box. From the set-top box the data stream is being output a speed data port. The three MPEG decoders in the box transform the digital TV streams into three separate (analogue) TV signals. From the set-top box all three TV programs are separately transmitted as AM modulated TV programs at UHF channels E22, E24 and E26 (478 – 526 MHz). A local cable-TV-drop network has to be installed in each home in order to reach the individual rooms in the residence.

10.5 Infrastructure Experiences in the Stavanger Trial

The overall finding from the trial is that VDSL is well suited for converged service delivery of ISDN, TV and Internet. The VDSL access solution as such has actually proved very reliable,

Figure 19 Cabinet installations in Stavanger (left and right)

and to the extent that there has been malfunction on the infrastructure side, this has been in the network interconnection and service platform. During periods of the pilot operation, instabilities have affected the delivery of the Internet services and the digital TV service. This reflects that providing end-to-end digital video services in switched networks is still a technological challenge, even if several commercial operations of such systems are now running. The lack of fully internationally standardised systems implies variations in network systems for European markets compared to, say, North-American markets.

Outside plant cabinet deployment remains a key issue, both in terms of deployment of equipment size, installation techniques, functionality and economics. During the trial Telenor has tested five different cabinet types, all of which have strengths and weaknesses compared to the requirements imposed by an eventual large scale deployment of fibre nodes.

The experiences from the testing of methods for deployment of fibre-optic cable were somewhat disappointing. Directional boring is an environmentally friendly and time saving technique, and the progress on the first 120 metres was very good. But due to rocks in the ground it proved a limited success in the completion, and as such it was decided to go ahead with conventional digging for the remainder of the trial. The costs per metre for conventional boring are estimated at around 1000 NOK, which makes it an alternative in some circumstances, given that there is no need for deploying new tarmac afterwards.

The installation at the customer premises were carried out by teams of installers, subcontracted by Telenor on commercial terms. The installers received dedicated training before the trials. Each installer took care of the whole installation at the customer premises, including cabling, installing the filter, installing new cables, turning up and connecting the Residential Gateway, connecting the PC to the in-home wiring network, installing an Ethernet card in the PC; installing the software drivers, and logging into the ISP. This process requires skilled installers, and even the trained teams used often needed up to four hours of installation time to complete installation with one user. These costs are significant, and constitutes a significant challenge for the business case of an eventual commercial service offering.

11 User Experiences and Test of Willingness to Pay

Data collection regarding the user investigations employed both qualitative and quantitative research methods. There have been telephone interviews with all the trial users, focus groups, in-home depth-interviews, a willingness to pay investigation, traffic logging, Call Centre logging and additional advanced types of analysis like conjoint analysis (11).

Figure 20 Carrying out directional boring

There is still limited availability of interactive broadband services and content, as well as standardised enabling technologies such as middleware. Getting access to content for Video-on-Demand services has been a major problem. Agreements have been reached with the Norwegian National Broadcaster, NRK, and with between five and ten film distributors. The issue of copyrights and intellectual property rights has been a difficult one.

The results from the questionnaires show that the digital TV consumers are demanding customers, i.e. the users with experience from digital DTH (direct to home) satellite services are used to a good quality service and expects the same quality from a VDSL based digital TV delivery.

The homes participating in the project are generally better off than one would expect from a general sample of homes in Norway. Looking at the lower end of the income scale, where in the general population one finds about 10 percent of the homes in the 100 to 200 thousand NOK per year income category, there were far less than 5 percent in the project sample. Ownership of TVs and PCs is shown in Figure 21.

The test pilot required installation of a technical apparatus in the users' homes, consisting of: settop boxes in Stavanger, Oslo, Beito and Svolvær, new remote control in all pilot sites, wireless keyboard (in Stavanger and both Oslo pilots), wireless mouse in Oslo (both VDSL and LMDS) and additional running of cables in all the pilots. In Beito the trial users also borrowed a multimedia PC from the trial project. The users' reaction to the use of the system and implications of installations are shown in Figure 22.

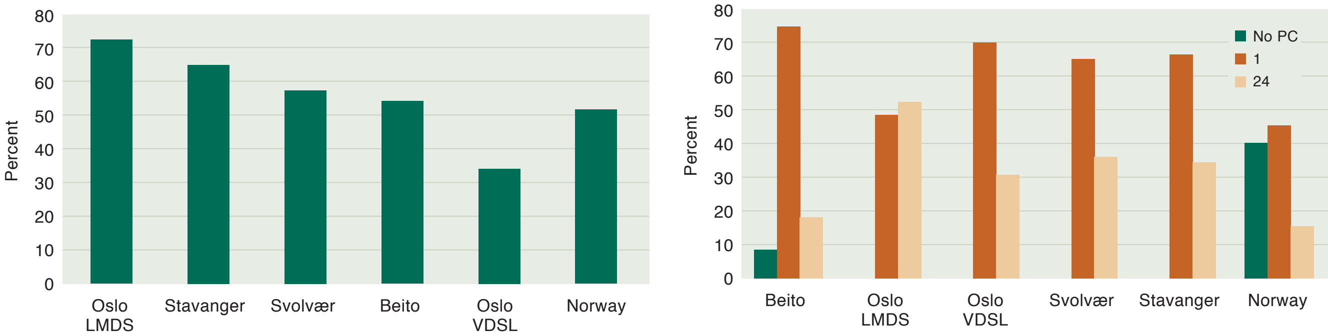


Figure 21 Ownership of multiple TVs (2+) (left side) and PCs (right side) for homes in the project

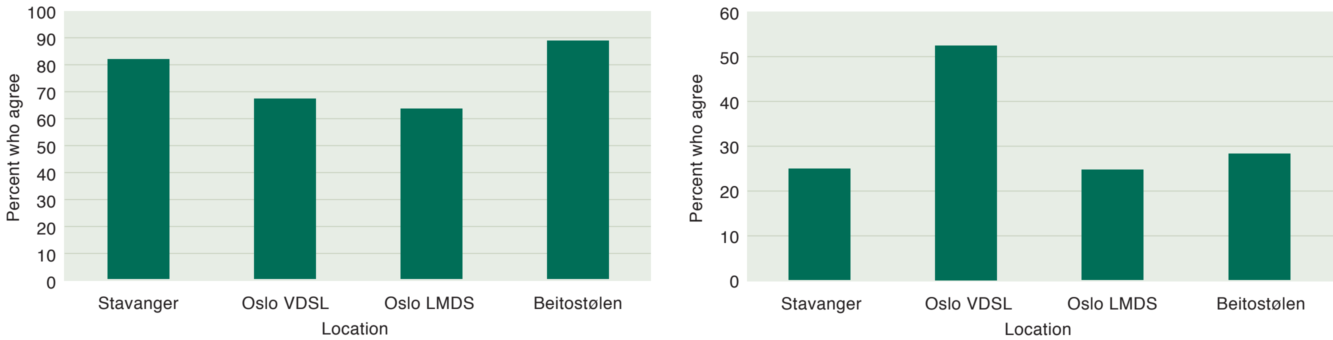


Figure 22 The perception that the system was easy to use by location (left side) and the percent of those who felt that it was confusing to have more than one remote control (right side)

The trial users in Stavanger and Oslo (LMDS and VDSL) had the possibility to both send and receive e-mail through their TV portal offer. Both the pilots had wireless keyboards and in the Oslo pilots they also had a wireless mouse. Figure 23 shows the users' feedback on using the TV as a communication tool.

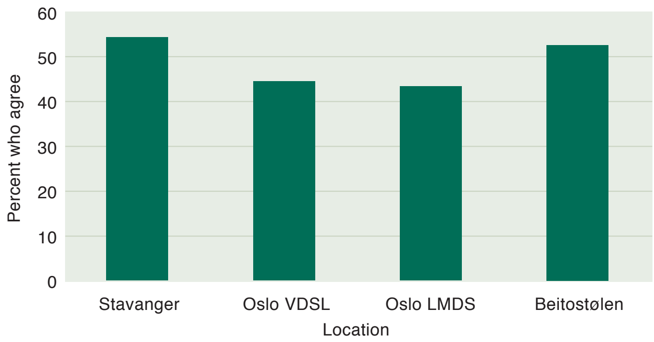
In the Stavanger pilot the users had three parallel TV streams available. Figure 24 shows the percentage of users in Stavanger who felt that it was an advantage to have several parallel TV streams. The benefits of this was first and foremost appreciated by former satellite systems subscribers as parallel TV streams at no extra charge were a unique and much-wanted feature of the project and something they had missed (in order to take advantage of their vast channel universe). Households with no prior experience with cable or satellite did not appreciate parallel TV streams to the same full extent, as they had not faced a large channel universe before. Through in-home interviews and the focus groups in Stavanger we were left with the impression that parallel TV streams are valuable in families with children and teens and families with more than one TV set:

> *It's for me. And of course for the teens. Especially if it is families who will have TV, and there are three TV sets in the house, so of course it is an advantage to have the multiple TV channel offer on all the TVs. To avoid conflicts around the remote control.* (Man, focus group 1, Stavanger May 2000)

The same attitude has been seen in earlier studies (10). When children grow up and get their own TV program preferences the family buys an extra TV set to avoid conflicts within the home.

Always-on was for the trial users a new concept of Internet access. The "always-on" and no flat rate pricing idea were unconditionally popular. The always-on functionality was perhaps the most popular utility of the system behind that of high-speed Internet. Respondents in the qualitative analysis pointed out that this makes new uses possible and alters existing use patterns due to both price and time. It facilitates things such as downloading, file sharing, use of digital media, etc.

In some respects, the ability to access instantly one's computer and the Internet puts these sys-



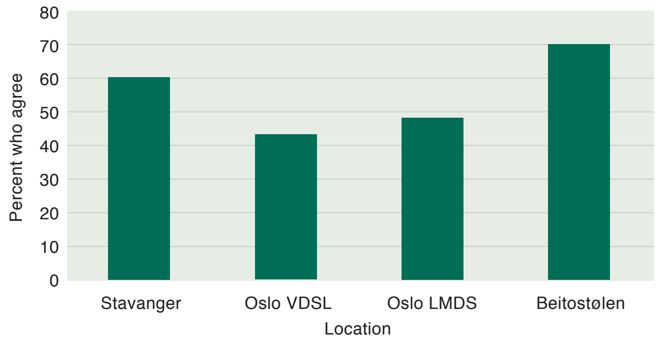


Figure 23 Percentage who felt that they would use the TV for interpersonal communication via e-mail and SMS (left side) and the respondents' attitude towards surfing the Internet via the TV (right side)

tems and services onto an equal footing with the TV. People are well aware of the advantage of the always-on concept. Among those asked in the qualitative analysis, many households would only turn off their computer at night. This was particularly true with "teenaged" homes. "I never turn off the computer, why should I", as one teenage girl said referring to the PC she had in her own room. When asked why not she said that she would not because she used to download music while doing something else. The easy access to an e-mail account was also mentioned as a good thing about always-on. There was an advantage to not start up the PC and log in every time you wanted to read e-mail.

Upon the connection of all 750 users in June 2001, 400 simultaneous connections to the ISP covered the needs of the users. That is, at any one time no more than 53 % of the users were logged on to the Internet. Presumably as a result of the users' adoption of the "always-on" concept, the project needed to increase the number of available connections. This points to the popularity of this functionality.

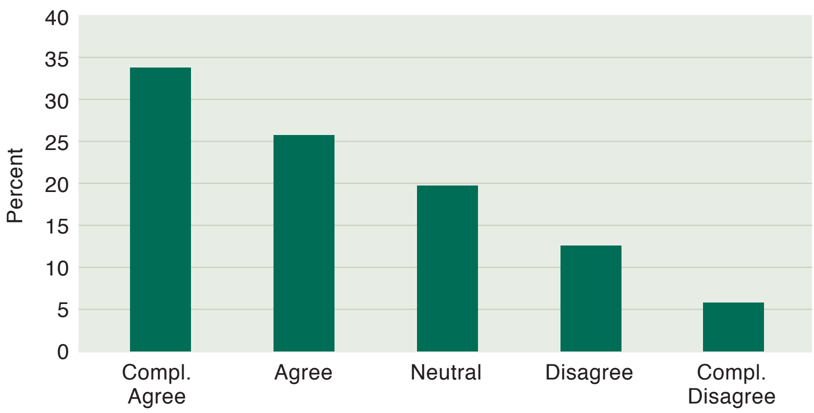
The service package preferences have been analysed through conjoint analysis. The point of the analysis is to reveal the elements in a multidimensional package that excites the most interest among users. We carried out such an analysis in the project based on five dimensions. These included 1) speed of the Internet connection, 2) number of TV channels available in the system, 3) number of parallel TV streams, 4) access to VoD, and 5) access to an EPG.

The results of the analysis are shown in Figure 25 and indicate that, in general, it is the speed of the connection in a package offering that is the dominant element. If all elements sum to 100, access to high speed Internet can be seen as having a weight of almost 50 %. Interestingly, access to an EPG is the second most important element for the users. This variable claims about half of the remaining importance with a weight of 23 %. The final three elements, in order of diminishing importance are the number of channels which one has access to (13 %), access to VoD (11 %) and access to several parallel streams of TV content (4 %).

When looking at the same material divided by those who have only one TV versus those with several TVs, as well as an analysis of those who have a satellite dish vs. those without – in both cases there are only marginal differences in the weighting.

During the project a 16-7 Call Centre was established. Analysis shows that the users' experiences vis-à-vis the Call Centre was generally positive. The data from the Call Centre logs is of interest since it provides one insight into the types of issues that prompt users to actively call. All calls into the Call Centre were recorded and categorized by the person handling the call. These were placed into eight broad categories that included questions and problems with VoD, home installation, the telephone, the TV surf box, the PC, questions regarding the willingness to pay study, the net, and the TV. In many cases these general categories were further broken

Figure 24 Percentage of users in Stavanger who felt that it was an advantage to have several parallel TV streams



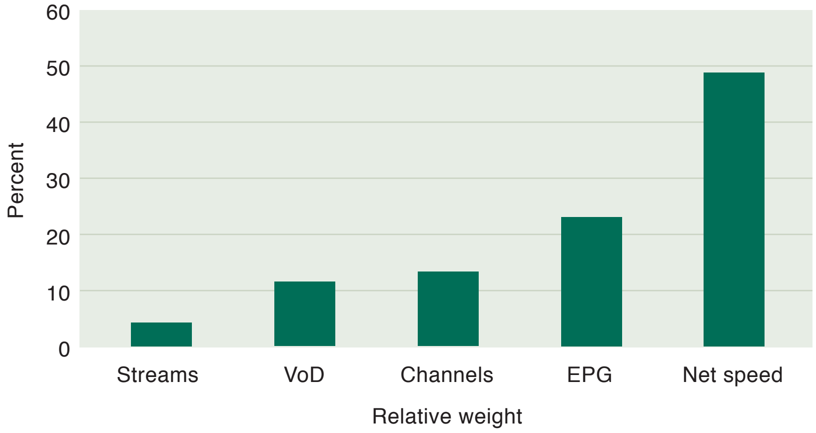


Figure 25 Service package preference

down into several sub-categories. Figure 26 depicts an overview of the themes logged in the Call Centre.

At a general level, the material from the Call Centre draws attention to two issues in the users' experience of the project. The first is the issue of the PC installation process and the second is the eventual reliance on the television programming. Looking at the first issue, one can see that during the first portion of the trial, PC-related issues dominated the logged material. This issue gave rise to as many as 50 % of all calls during the first portion of the trial. In some respects, this result underscores the complexity of the PC world. The PC is still an immature technology.

The second general trend shown in the data is an increasing tendency for calls regarding the television portion of the trial in Stavanger. One also sees the effect of the willingness to pay. However, the data shows a constant stream of questions and issues related to problems with television channels. This arose in particular in late autumn. The increase in TV-related calls accompanies the installation of the VoD service. This serves to underscore another issue, i.e. the need for stability in the TV portion of the trial. While the PC is an immature technology, the TV is a very well established fixture in our lives. This means that the expectations regarding its accessibility and quality are well entrenched. The material from the Call Centre in the latter part of the trial underscores this point. In week 45 there was an electrical problem. This had consequences for the TV channels.

The willingness to pay for bandwidth in the 'near future' interactive broadband-access market has been estimated based on tests carried out in the Stavanger/Sandnes VDSL pilot. The experiment was motivated by the desire to monitor real use and estimate actual demand functions for next generations broadband access capacity and look into convergence in the residential markets between classic telecom, broadcasting and data traffic. The experiment only gives results that are specific for the actual area at the actual time and with the actual services. However, due to the size of the samples and the services provided, we believe that the experiment provides information regarding the "next generation DSL services".

The experiment took place in the period 15.10.2001 – 15.12.2001 among nearly 700 trial users in the Stavanger/Sandnes region. During the experiment period the users were offered a menu of choices of Internet bandwidth and the possibility to receive up to three simultaneous digital TV streams. The prices of the various alternatives changed twice a month. During the experiment period each user thus made four choices on Internet bandwidth and TV streams. This experiment set-up enables us to estimate the demand functions for Internet bandwidth and capacity to receive simultaneous TV stream.

In interpreting the results from the test of willingness to pay it is important to bear in mind the following: First, one TV stream along with 33 TV channels and a 64/64 kbit/s Internet connection was always offered for free. Hence, the results measure the willingness to pay for *additional* TV streams and *extra* Internet bandwidth. Secondly, the experiment is designed to measure the pure willingness to pay for capacity or bandwidth. Payment for *content*, including TV channels subscription is thus not included.

During the test period about 50 % of the sample chose one, or both, of the payable alternatives. 26 % chose to pay for more than one TV stream, giving a monthly TV stream average revenue per user (ARPU) of about 156 NOK. About 42 % chose Internet bandwidth of 386/128 kbs or

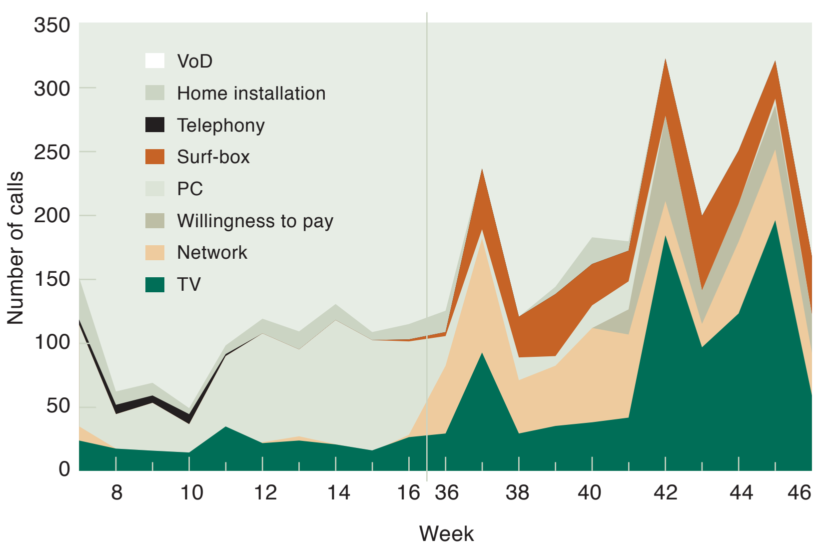


Figure 26 Overview of the themes logged in the Call Centre

higher, giving a monthly average Internet ARPU of about 288 NOK. The average total monthly ARPU is about 328 NOK.

Availability of web-on-TV *seems* to have a strong effect on the demand for additional TV streams and the lowest Internet bandwidth classes (but not on the two highest). This suggests that it may be profitable to subsidize the web-on-TV devices. Further analyses are required. Availability of an electronic program guide (EPG) is strongly correlated with the demand for additional TV streams. However, the causal effects are not determined and need to be further analysed.

12 Concluding Remarks

The scale of the pilot operation as well as the diversity of the geography and technologies used have enabled a range of investigations to be carried out. The findings and recommendations from the project trials can be summarised in terms of the following:

- **Broadband content is available – now the broadband networks must be built.** The trials have shown that broadband content and first generation interactive TV services are available today (though still in limited quantities) for large-scale implementation. The challenge is to enable high quality TV streaming in volume in switched networks.

- **Always-on, high-speed Internet is a highly appreciated service!** High-speed Internet via the PC was the service in the trials that was most appreciated by the users, regardless of gender (even if it is even more true for men than for women). The always-on feature changes the usage of the services, and leads to new ways of using broadband, e.g. increased use of music and movie downloading.

- **Hybrid access solutions can offer broadband access covering the major part of the population in a cost-effective manner.** The inherent flexibility in the hybrid approach enables differentiation of service offering (i.e. limited versus full service set) and choice of technology to accommodate customer demand. The hybrid technology approach may comprise utilisation of different forward and return technologies as well as two (or more) different forward technologies. A hybrid market deployment may be based on large area segmentation (urban versus rural) or local area segmentation (*single houses versus multi-dwellings*).

- **The VDSL technology (broadband on copper lines) is ready for roll-out and commersialisation in 2003.** The large-scale VDSL trial in Stavanger has proven that VDSL technology functions reliably in a pre-commercial deployment environment. The technology shows stable operation, is scalable, is well suited for converged service delivery of ISDN, TV and Internet. VDSL is economically viable as the tool for a triple-play offering on telephone lines with standards expected in 2003.

- **LMDS technology (broadband radio) is technically mature for broadband service offerings in the consumer and business markets.** The trials in Oslo and Svolvær have shown that LMDS access technology has high stability, high flexibility and high feasibility for competitive broadband service offerings in the consumer market. LMDS has a considerably improved service capability compared to ADSL, enabling higher access capacity and interactive TV service offerings.

- **The digital terrestrial broadcast network (DTT) is well suited for the combined delivery of digital TV and Internet access.** The Beito trial has shown that the digital terrestrial broadcast network may be used for provisioning of both Internet and digital TV services. Thus, DTT in combination with ISDN is an alternative way of providing high speed Internet access in areas where alternatives like ADSL or cable modems are not relevant.

- **Interactive satellite technology (DVB-RCS) is not mature as a consumer market technology.** The experiences from the Svolvær trials show that neither technical implementation nor functionality today are according to requirements for volume deployment. The current outdoor terminals are too expensive, and dynamic allocation of capacity will be a fundamental requirement in order to make this an economically viable solution. Commercial products may be available by 2004–2005.

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Challenges in Telecommunications

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1 Introduction

Before 1995 telecommunications was simple. This statement does not imply that the telecommunications technologies were simple – the technological complexity was certainly close to the limit of what could be constructed at that time – but rather that the business landscape of telecommunications was easy to understand and manage: telecommunications was mainly concerned with person-to-person communications, spoken or written. Data communications existed both as the Internet interconnecting universities and research facilities and as closed X.25 networks mainly interconnecting the branches of the same company or public sector. However, the applications of data communication were few and simple. Distributed computing where several computers are interconnected in order to perform a common task hardly existed.

What happened then in 1995 or thereabouts that changed this picture of peace and stability? First we got mobile communications. By 1995, GSM had become a mature service. Allowing people to communicate when they were moving did not change the picture. What did change the picture was that the market of mobile communications became liberalized, changing the market of telecommunications from monopoly to oligopoly. The second event was the World Wide Web that changed the whole concept of data communications – bringing data communications down from the pinnacle to the reach of the common man. In 1995, the WWW had become the driving force of the new evolution. The third event was that telecommunications services such as GSM and intelligent networks required distributed computation where geographically remote computers were interconnected in order to process services. Distributed computing in business management was emerging at the same time.

When we talk about telecommunications today our minds are focused on mobile communications and the Internet. We have the impression that these types of telecommunications have been with us forever and we forget that we are talking about phenomena that are less than ten years of age – less than the time it usually takes to develop a radically new technology such as GSM and UMTS from idea to business.

Several challenges facing the telecommunications industry are described below. These are summarised as follows:

Knowledge explosion. The telecom company can only survive if it is able to absorb the vast amount of knowledge that is generated in the science of telecommunications, or rather the merger of computer science and telecommunications, ICT. More than 2000 new university textbooks and other scientific books on ICT are published each year. There are more than 200 scientific journals in the ICT area alone. This corresponds to a publication frequency of several thousand papers per year. In addition, more than ten times as many papers are presented at international scientific conferences yearly.

This wealth of information is increasing exponentially.

To most people the Internet came as a surprise – they had never heard of it before. Not so to the research communities in telecommunications and computer science. They had used the network for more than 20 years. Therefore, the ICT industry was well prepared to meet the technological challenge that the Internet represented.

Keeping up its knowledge base is therefore the best insurance the ICT industry can buy at a time where the uncertainty and complexity of the telecommunications technology and the computer science are great: there may be other wild cards than the Internet. The technology of transmitting bits on the electric grid and distributing them to the homes was such a wild card. The technology is simple as soon as you start looking into the details; most of us had not done that, so it had not crossed our minds that the technology was indeed feasible.

Effects of natural growth. The processing capacity of computers doubles once a year. The processing capacity of a modern desk computer is one billion times larger than that of a desk computer of 1972 of the same physical dimensions. The information concerning payable and paid bills, teletraffic, users, topological and topographical network data, performance statistics and other data that telecom operators store in their databases is doubling two or three times a year. Markets are usually increasing by a fixed percentage per year. If this percentage is 7 %, then after ten years the market is twice as big as it is now; that is, the doubling time is 10 years. Phenomena such as the above that double after a constant time interval are called natural growth. The mathematical form of the growth curve is the exponential function.

It is simple to operate in a market increasing slowly. It is much more difficult if the market increases fast. Slow increase does not bring the business far out of equilibrium; fast increase does. As a rule of thumb, the uncertainty also increases exponentially, so that fast increase means larger uncertainty: the net present value of a project depends more on future cash flows than on early cash flows. Therefore it is always possible to show that projects with *expected* large growth become lucrative sooner or later: just choose the accounting rate smaller than the growth rate! According to an Ovum analysis undertaken seven years ago, video-on-demand would now have money pouring in. However, the service never materialised – though there are telecom managers who still live in the hope.

The fact that the promise of exponential growth may lead to economic ruin is evident from the unrealistic expectations concerning the future of e-businesses a few years ago.

The way to handle exponential growth is to understand how to handle uncertainty. Exponential growth is one phenomenon which shows that, in order to do business on telecom, decision tools beyond those of standard economic theory must be applied.

Technological complexity. Only a tiny fraction of the ideas that are published on ICT in journals and in conferences reach the markets as products, services or systems. Even the survival ratio of standards is small: although there are more than two thousand standards concerning the Internet, only a few of them are actually in use. The rest have fallen into oblivion.

R&D stands thus at the centre of ICT. ICT can only evolve in a Darwinian sense; that is, by trial and error. Sometimes the idea never reaches farther than the researcher's drawingboard; sometimes it reaches the market before it is abandoned, having claimed a lot of money. Only the ideas the market finally accepts yield money.

Successful operation in the future then means that the company is good at R&D.

Value creation. Telecommunications is a network economy. It is neither a Porterian value chain nor a value shop, though minor parts of the company may be chains or shops.

Competition and cooperation between network economies take other forms than competition and cooperation between value chains. Networks often gain from cooperation, and sometimes two network enterprises both cooperate and compete. This is called coopetition.

Therefore, it is important to analyse the different operations of the telecom company in order to determine which form of market behaviour is most profitable: competition, cooperation or coopetition.

Imperfect markets. In network economies there may be network externalities (there is not always network externalities as is often believed). This means that there exists positive feedback from the market. In such markets, one of the competing companies usually wins the whole market. There are several examples of winner-takes-all markets (or markets with lock-in) in ICT. Operating in such markets is difficult and requires strategies adapted to what is to be achieved: generate lock-in, manage the situation of being pushed out because of lock-in, enter a market where lock-in already exists, find a product complementary to a product with lock-in, and find products that together with other products cause lock-in, none of them capable of doing it alone.

Network externalities thus make the market imperfect in the economic definition since it always leads to one dominating player.

Most telecom markets consist of only a few competitors. This is called an oligopoly. These markets are also imperfect because any actions of one of the competitors will change the market conditions for all of them. Oligopolies can be analysed effectively by game theory. It often turns out that the game played in the oligopoly is the worst of all games: the prisoner's dilemma. The difficulty of operating in an oligopoly is seen from the thousands of papers published on the prisoner's dilemma game.

Complexity and uncertainty. The telecom business and the telecom technology are complex – one of the most complex structures ever made by humankind. Decision making is a complex science. Decisions can only be made when the uncertainties are identified and understood.

Flexibility is the capability of choosing among several alternative decisions and is closely related to uncertainty.

Real options are tools that can be used in order to assess numerically the impact of different decisions on the value of a project. Real options are concerned with decisions such as deferring the start of a project, terminating a project, scaling the project up or down, or switching to a different technology or market.

The huge investments in ICT projects and the uncertainty concerning the response from the market indicate that the real options are suitable tools to reduce losses and prevent wrong decisions.

Innovation and unpredictability. The predictability of which innovations will lead to profitable business in telecom is very small. We also observe that it takes much time to develop complex technologies: ten to fifteen years is the norm. The long time from idea to market increases the uncertainty of the business potential of the project. However, such long-term projects must be carried out because this is the only way in which renewal of telecom can take place.

These long-term projects are developed in international standards organisations or in formal cooperation between industries. This is in fact the execution of a real option: shall I develop the technology alone or in cooperation with my enemies? Or in other words: cooperation before competition. The decision is simple: it is not possible to develop complex technologies without such cooperation. This applies both to manufacturers and to operators and is a consequence of the network economy: telecom is a value network where it is profitable to cooperate in one period and then to compete in the next period. The cost of the GSM specification was one billon NOK (in 1990) divided by about 20 telecom operators and 10 manufacturers. No one would have invested that much alone in the development of such a system.

On the other hand, only minor incremental innovations, that is, improvements of already existing products, can be made in a short time. These innovations sometimes lead to more revenue, sometimes to no increase in revenue, and sometimes it is not possible to judge whether the innovation improved branding or reputation of other products.

Probably the most complex issue facing the managers in the telecom industry is to innovate and take advantage of the innovations.

2 Knowledge Explosion

Telecommunications and closely related areas such as computer science are the areas where most papers are published each year. More than 100 scientific journals cover all aspects of the telecommunications field alone. The largest publisher of scientific journals, the IEEE[1)], has launched three new journals in mobile communications, mobile computation and versatile (Internet) computation this year (2002) and one journal on nanotechnology in addition to some 80 journals on ICT they are publishing already.

Several hundred scientific conferences are held each year, among those the largest of all international conferences, the International Switching Symposium and the World Multi-conference on Systemics, Cybernetics and Informatics. At these conferences, thousands of papers are presented in areas that are not mature enough for publication in journals.

More than 1000 new scientific books on telecommunications are published each year. Most of the books contain material of a general nature that has been published earlier but there is still a large number of books containing ideas and thoughts never published before.

In addition, the large standardisation organisations (ITU, ISO, ETSI), engineering organisations such as the IEEE and ACM, and interest groups such as the Internet Engineering Task Force (IETF) churn out thousands of pages of new standards every year.

Much of this wealth of knowledge leads to nothing in terms of new products, systems and businesses. However, out of all this knowledge unexpected results sometimes emerge that change the rules of the game leading to entirely new concepts such as the World Wide Web. For the telecom operator "being there" is important when such emergence happens; that is, having updated knowledge and hands-on experience with the novelties [1].

The amount of knowledge is growing at an exponential rate, doubling in volume every few years. One challenge for the telecom operator is to afford enough brainpower to absorb this increasing knowledge and to filter out the good products and ideas from all the bad ones in time to gain market advantage.

Another challenge is to understand that knowledge has become a major production factor of our advanced products. In earlier and simpler economies only three such factors were observed: land, labour and capital. Knowledge and the way in which it is stored and disseminated thus change the rules of economics since it may replace the need for land, labour and capital compared to how goods and services were produced earlier. It may replace land because knowledge has made it possible to produce services and goods not requiring much more space than a database. One example is dissemination of books that can be done electronically downloading the text. You may then decide yourself whether you will read the book on the computer display or print it on paper. In this way, the printing office has been removed. Using the same example, knowledge in terms of mastering the new technology has also reduced the work-

[1)] *The Institute of Electrical and Electronics Engineers.*

force and the need for capital since we neither need printing machines nor employees to operate these machines. In many areas we have entered an economy where we cannot improve our economy by reducing land usage, the number of employees and the requirement for new capital. The only way in which we can do that is to improve the production process making the product smarter and cheaper by increasing our knowledge.

The semiconductor manufacturers are not building ever larger factories in order to produce memory chips and microprocessors for larger and faster computers but by improving the knowledge of how to make the production process more efficient: making purer silicon crystals, interconnecting the active devices on the chip in new ways, and improving the resolution of the lithographic mask used for etching the chips, for example, using the difficult technology of X-ray photography.

Knowledge has also changed the land usage of telecommunications. One of the largest buildings in London housed the largest electromechanical telephone exchange ever built. A modern exchange handling the same amount of traffic can now be stowed away in one of the corners of the cellar of that building.

It is fair to say that the evolution of the industrialised world was only possible because of the perpetual increase of human knowledge [2].

3 Effects of Natural Growth

Natural growth means that the *increase per unit of time* of some variable is proportional to the *current value* of that variable. The human population, for example, increases at a rate of 1.7 % per year, that is, the population next year is 1.7 % bigger than it is today, and the year after it is 1.7 × 1.7 = 2.9 % bigger than today. Natural growth follows the exponential curve. This curve has one characteristic often poorly understood, namely that the value of the variable, e.g. the human population, doubles at a constant rate. In fact, in 2050 there will be twice as many people living on Earth than there are today, that is, 13 billion people. In 2100 the number of people will be twice as big as this number, namely 26 billion people – provided that the birth and death rates of humans do not change [3].

For the last 25 years the computational power of computers has been doubled every year. This is called Moore's law. The strategist George Gilder claims that the bandwidth requirement of telecommunications doubles twice a year; however, this law must be take with a pinch of salt since it is based on observations over just a few years [4] where the bandwidth requirements have been driven by unrealistic expectation of the evolution of the Internet.

The amount of data concerning network traffic and usage, system performance, customer information, network configuration, network maintenance, and other diverse statistics that telecommunications operators are storing in their databases are doubling or tripling every year. Much of this information soon becomes outdated but the transaction intensity is so high that there is simply not enough processing capacity to both service the transactions and to remove the garbage from the database: it is more efficient to keep the garbage and buy larger databases to store more garbage!

Moore's law also implies that the technological complexity increases exponentially: the NMT system of 1982 had far less computational capacity than that required for the radio interface of GSM; the CPU and memory of GSM terminals of 1992 required for handling all functions of the terminal – radio interface management, data security, signalling, and speech encoding and decoding – were too small to even accommodate the software required for demodulating the radio signals of UMTS of 2002. According to Moore's law, the computational capacity of the computers used in mobile terminals has increased by a factor of 1000 over each of the decades 1982–1992 and 1992–2002: a PC of 2002 is 1,000,000 times as efficient as a PC of 1982!

Moore's law then leads to exponentially increasing technological complexity that again leads to an exponential increase in the publication of scientific papers at conferences or in journals since all this innovation must be reported somewhere. It is probably encoded in the human genome that the evolution toward more and more complex knowledge is inevitable.

As industry, we also prefer to operate in a market that increases exponentially. We are talking about markets increasing by 5 %, 8 % or 10 % per year, the latter being the preferred case – the faster the market increases the better is the prospect to earn money. However, we have to be careful drawing this conclusion, as illustrated by the following example (Figure 1).

In the example the size of the market doubles once a year (the curve in Figure 1 a)). We have chosen this tremendous market increase in order to make the illustration simple to understand. What is often the case is that the investment required to serve the market is roughly proportional to the market size. This is shown in Figure 1 b). In order to get the business going we invest initially 1 million USD. Supposing this invest-

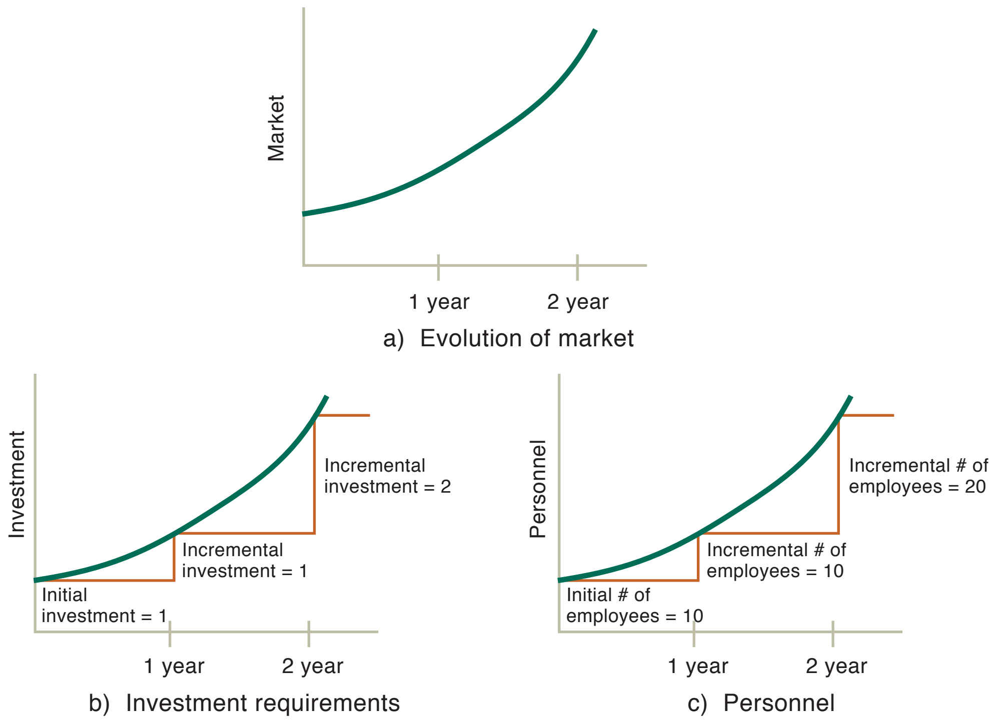


Figure 1 Market doubles once a year

ment takes us through the first year, at the end of year one we have to make a new investment proportional to the amount by which the market has grown that year. Since the size of the market has doubled, we have to invest at the end of year one just as much as we did initially, i.e. 1 million USD. This may not seem problematic. The problem emerges at the end of year two because then, since the size of the market has again doubled, we have to invest 2 million USD in order to serve the market increment. At the end of year three we must invest 4 million USD; at the end of year four we have to invest 8 million USD, and so on – at the end of each year we must invest just as much as we have invested before. One reason why this may become a problem is that we often have to make the investment first and then gain the revenues. The exponential growth then implies that the size of short-term loans also increases exponentially and it may be harder to find the required money as the market increases.

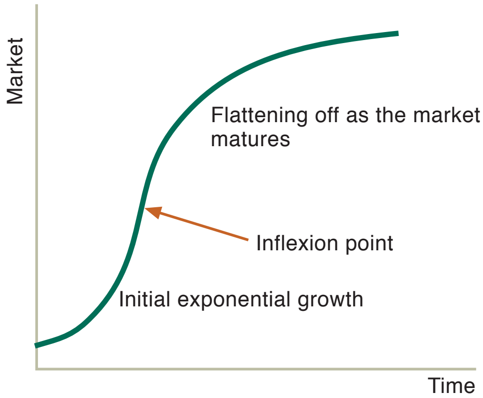
What makes it even more complicated is that the bigger the market becomes and the more investments are required, the more uncertain is the investment decision: only small fluctuations in the market may have enormous impact on profitability. Since investments and capital cost increase exponentially, it is reasonable to expect that the fluctuations in profit because of uncertainty will also increase exponentially. This may just be what is observed when large and solid companies run into financial problems from one day to the next. When this happens, we are always taken by surprise! And we always try to find the causes. However, rapid growth is seldom, if ever, regarded as the reason behind the crisis.

A related business aspect is shown in Figure 1 c). The number of employees of a firm is also approximately proportional to the size of the market it is serving [5]. Suppose that in our example the firm has 10 employees initially. After one year the market has doubled and so must also the number of staff. This means that at the end of the first year, the firm has to take on 10 new employees. After another doubling of the market size, the number of employees must be increased by another 20 persons and so on.

What will this company look like at the beginning of the tenth year? We have invested a total of 1 billion USD during the first nine years and we are employing 10,000 people at the end of the ninth year. This is easily verified taken into account the effect of doubling the market once a year. At the beginning of the tenth year we are faced with the problem that in order to match the market growth we have to invest another 1 billion USD and employ 10,000 new people!

The example may seem highly exaggerated but it is not. Market growth showing doubling once a year has been seen in the ICT business. One example is the initial growth of the NMT systems when it was put into operation in the Nordic countries in 1981. The initial market growth was at least as big as in the example. Because of the unexpected market growth, it became hard to purchase enough base station

Figure 2 Nothing can grow into heaven



equipment on time to meet the market demand. Within a short time the original frequency band in the 450 MHz range became too small and a new version of the system had to be built in the 900 MHz range. The Inmarsat system showed a similar development over a short period in 1982–83 when the Nordic Coast Earth station started offering automatic telephone and telex services: the station got saturated by traffic already before it was officially opened for commercial traffic. This took only one week. The Internet more than doubled its market size per year initially and is still growing at a violent rate. SMS has also shown such growth.

Was not the expectation the financial market had concerning the business opportunities of the IT industry a few years ago also an expectation of such unreasonably fast growth?

In the second half of the 1990s, it was a real concern that the universities were not educating enough ICT engineers to meet the increasing demand for employees in the ICT industry. It was claimed that in Finland the demand was several times higher than the rate by which Finnish universities poured out new engineers. This problem never happened because of the general decline in the ICT business during the last two or three years.

Natural growth is also the major driving force of the world's economy: the value of the stock exchanges increases exponentially even though the increase sometimes is disrupted by a sudden crash. After the crash, the exponential increase continues as if nothing has happened [6]. One manifestation of economic growth is the inflation, that is, the value of money is decreasing – or equivalently the prices are increasing – as a function of time. This is good if the inflation is small. Large inflation leads to problems. The opposite, deflation, also usually leads to crises even if the deflation is moderate. Inflation seems in some way to be related to the increase in entropy in thermodynamic systems where the entropy is a measure of the amount of energy in a system that cannot be used for work. This amount of energy increases over time: if any work is going to be done in a thermodynamic system, the entropy must increase. In analogy, it is therefore tempting to conjecture that if social wealth shall continue to increase, inflation must take place, at least in the long term. The world gets exponentially richer and the gross world product doubles every 25 years. At the same time the world's economy moves more and more away from stability: the inequality in the division of wealth between rich and poor increases, the relative proportion of poor people increases, the gross domestic product per capita in the richest countries increases by more than 5 % per year while that of the poorest countries decreases by 5 % or more [7].

What is worse is that there is no single theory concerning causes of inflation, deflation, unemployment and other large-scale economic phenomena [8].

Natural growth cannot continue forever. At some point the growth must flatten out as shown in Figure 2. The critical point where this occurs is called the inflexion point. If investment requirements and size of staff are proportional to the size of the market, then problems may occur close to the inflexion point where the increase starts flattening out. If the emergence of an inflexion point is overlooked, this may lead to over-investment and overstaffing. This is probably a recurring problem in the industry since the growth curve is not as smooth as shown above: the growth curve will rather consist of periods of frenetic growth followed by periods of stagnation again followed by frenetic growth. Such a growth curve has multiple inflexion points and just as many strategic traps: the company is likely to be overstaffed when stagnation and recession occur and understaffed when the growth again accelerates – in both cases the company loses money. At the moment the ICT industry has entered a period of recession throwing many companies into deep problems.

Natural growth thus represents a huge challenge for the industry, in particular the ICT industry because the main prerequisite to survive in this business is to be able to match the rapid growth of knowledge in ICT. The growth of knowledge is perpetual and is not correlated with the performance of the market. The real challenge for the troubled ICT company is not to save money by neglecting its knowledge base: if the market again enters a period of accelerating growth, the company having depleted its knowledge base may run into real and unrecoverable problems.

Another phenomenon that increases exponentially is the number of malicious attacks against the Internet and the computers connected to it – that is, attacks on the most vital parts of our society. This number doubles approximately once a year as reported by the Computer Emergency Response Team (CERT) at Carnegie Mellon University [9]: in 2001, 50,000 incidents were reported to CERT; in 2002, more than 100,000 such events are expected; in 2003 there will be 200,000, and so on. This includes incidents such as the Nimda and Code Read worms and the 'I love you' virus, costing society billions of dollars to recover after the attacks. These were mild attacks causing no lasting damage on society's infrastructure or on commercial businesses, contrary to what we may expect in the future. There is no way in which we can foresee when such attacks will happen, on which information systems they are aimed, which weapon that will be used, and the damage they will cause. What is scaring is that the likelihood that a disastrous event will take down vital infrastructure also increases dramatically as the number of malicious incidents increases at such a violent rate.

The long-term drivers of the ICT industry are exponentially increasing forces. The players in the ICT business must be adaptable to such processes in order to survive. This includes brainpower producing and absorbing the amount of new knowledge generated each year, innovativeness matching the increasing technological complexity resulting from Moore's law, business agility meeting society's changing demand for telecommunications and computation, and consciousness of society's increasing vulnerability against information attacks on infrastructure and business. These are the most demanding challenges the industry is facing today.

4 Technological Complexity

There exist two fundamentally different types of telecommunications: the traditional applications of which telephony is the representative; and the new applications derived from the Internet. There are then also two not necessarily commensurable ways in which we do business in telecommunications.

The two types of telecommunications networks have to do with the capabilities of the user terminal. Telephones are simple terminals not capable of doing complex computation. The services offered in the telephone network include freephone, premium rate, call barring and presentation of calling number. Since the telephone apparatus cannot process these services alone, they are implemented in telephone exchanges or intelligent network (IN) nodes. In other words, the telephone service is offered on stupid termi-

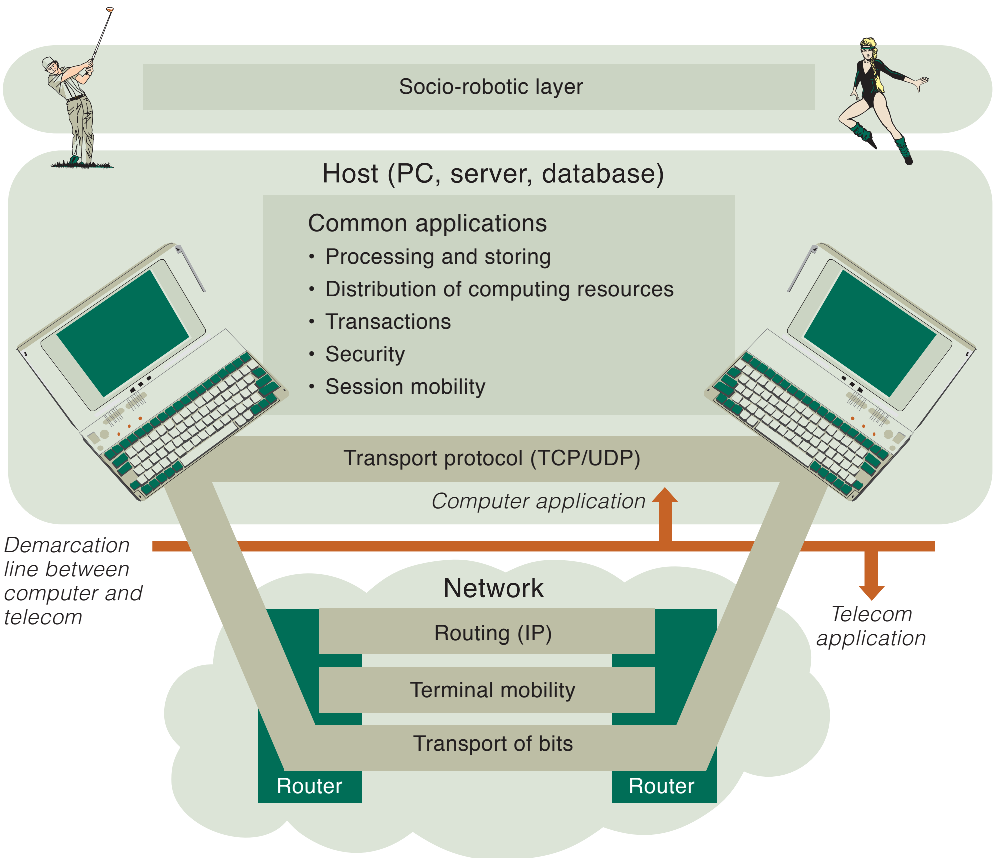


Figure 3 The Internet

nals requiring the support of an intelligent network. The important observation at this stage is that these services are implemented in the network of the telecom operator.

Let us then look at the Internet model of telecommunications. The Internet is radically different from the telephone network. We may express this difference as follows: the Internet is a stupid network offering access to intelligent terminals. Below we shall see why this is so.

The Internet is shown in Figure 3. The Internet consists of three layers:

- The telecom applications are implemented in the *network*.

- The computer applications are accommodated in the terminals or *hosts* connected to the network. Terminal or host is any type of computing device: PC, server offering different services to the user of the system (work space, e-mail, Internet, security), database, workstation, mainframe computer, and so on.

- The actual user software is running on the hosts. We call this layer the *socio-robotic layer* reflecting that the user of the Internet can be a person speaking, videoing, mailing, transferring information or retrieving information, or a machine or a piece of software such as a heat sensor, accelerometer, pressure gauge, database or mobile agent software.

The network offers three basic functions: transport of bits between one access point and another, terminal mobility (radio mobility or mobile IP) allowing terminals to be used in different geographic locations, and routing of information from the terminal of origin to the terminal of destination. IP or Internet Protocol offers transparent flow of information, that is, the information field of an IP datagram can contain any type of information: speech signals, video signals, or structured remote procedure calls supporting distributed computing. Note that the web protocol (http – hypertext transfer protocol) is a combination of both structured and unstructured information: unstructured transfer of text and picture files and structured transfer of operations for manipulation of the web page (requesting transfer of information, inserting hypertext pointers to related information, and preparation to load a new web page).

Every node or router in the network analyses the IP header in order to determine where the datagram is to be sent next.

The most important protocols using IP are TCP (Transmission Control Protocol) for transfer of structured transfer of information, and UDP (User Datagram Protocol) for transfer of unstructured information. The all-important observation is that the format of *TCP/UDP is not analysed or acted upon by the network*. TCP/UDP resides in the hosts or terminals. This is then true also to any application using TCP/UDP. Therefore, the telecom network ends at IP. None of the applications using the Internet are handled in the network. The telecom operator offers the network including the IP. The telecom operator offers no services above IP in the network. Before we look at the implications of this statement, let us consider the remaining structure shown in Figure 3.

In the computing layer, a number of functions are included: processing and storing information including remote log-on on servers, distribution of computing resources among several processors (e.g. supporting remote sensing and control, cooperative work, interactive education), transactions supporting secure transfer of information such as money and contracts, security functions including authentication, electronic signatures and encryption, and session mobility supporting processing of for instance mobile agent software. The reason why I have put these functions into a separate category is that they need to be standardised in such a way that they can be offered on any host: all of them are concerned with how computers can cooperate in order to execute common tasks.

The final layer is the socio-robotic layer containing the actual application. Examples of such applications are remote sensing and control of the energy consumption in homes, fire and burglar alarm systems, transfer of money between banks, electronic banking from home, automatic road payment systems, e-mail, and remote interactive education. Some of these applications may be designed in accordance with open standards (e-mail, road payment) or being the property of the company offering it (banking, remote education).

There is also a significant difference in the time required to develop new systems and applications at the three layers of the model. Developing new network concepts such as GSM, ISDN, WLAN, intelligent networks and UMTS takes ten or more years before the product is ready for the market. The reasons are that the technology is usually very complex and beyond the scope of what is possible to manufacture during the early stages of the development, the technology is a combination of software and hardware requiring different design tools, the product must be based on an international standard where much time is required to obtain consensus on the principles on which the design is based, and the investment required for implementing the new standard is huge.

The design of the common computer applications may also take much time to develop. Platforms for distributed computing have still not reached the market after 15 years of development. Development of platforms offering advanced security functions such as authentication, electronic signature, public key management and nonrepudiation has shown a similar slow evolution. Platforms for session mobility have hardly reached the drawing table. The reasons are the same as for the development of new components in the network: complex ideas, difficult consensus processes, and high economic risk. In some cases the risk is associated with economic network effects: the risk for early adopters is much higher than for late adopters. This may cause a wait-and-see stalemate position (security services, IP version 6, IP telephony). There are applications that can be developed faster, for example transaction services and remote log-on because they are simpler or are required urgently by an organisation.

Applications on the socio-robotic layer include a large variety of products. The introduction of many of these products is low-risk and the users may experiment quite freely with them. Products at this layer may offer several benefits to the user but they may have insignificant economic value. The combination of much usage and low value sometimes leads to disastrous business decisions where the business potential is misjudged. Electronic newspapers belong to this category, and so do many other information retrieval services and Internet portals. Common to such services is that the users are extremely sensitive to cost (little value for much money – Internet portals) or that the pricing is wrong as compared to substitutions (poor functionality at a stiff price – electronic newspaper).

Figure 4 compares the telecommunications system with the computer. The intention is to better understand the functionality of the Internet described above. The computer consists of three basic "layers":

- The hardware consisting of electronic circuits for information processing and storing, and circuits for operating peripherals such as hard-disc, CD-ROM, keyboard, display and printer. The hardware is analogous to the network in telecommunications systems.

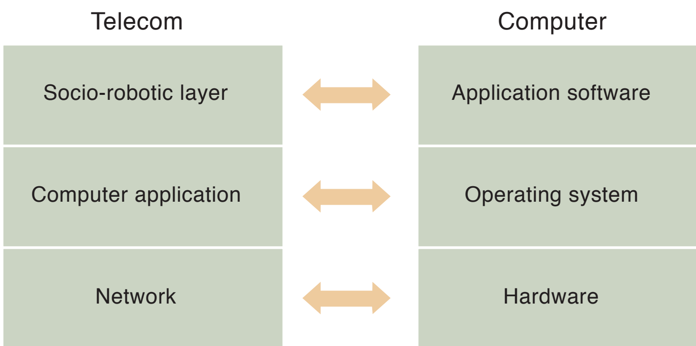
- The operating system of the computer is the environment on which the applications are written. Examples of operating systems are DOS, Windows, Linux and Unix. The operating system can be adapted to any computer hardware. The functions included in the computer layer of Figure 3 offers the equivalent standardised basic function in telecommunications.

- Finally, the computer contains user software such as office products, banking services, database management, information retrieval, performance monitoring and remote control of hardware, e-mail, and e-learning management. These are in fact the same applications that exist at the socio-robotic layer.

A typical instant of cooperating computation services such as e-banking, e-learning and e-commerce is shown in Figure 5. The configuration may consist of any number of interconnected hosts (servers, PCs, mainframe computers, databases, peripherals). The number and types of hosts usually change during a single computational session. The main points are that there exist independent IP sections in the network between the participating computers. All of them are individually interconnected by a TPC connection over which the common computer services or applications exist. The TCP also supports the socio-robotic layer consisting of pieces of software compiled in the different hosts in the system. It is just this distribution of socio-robotic applications that requires the whole menagerie of common computer applications and the network elements interconnecting the hosts. Understanding Figures 3 and 5 is important when considering how the different types of businesses earn money in the telecommunications business.

We observe that there are three places where business can be done in this network: in the transport network, by offering common computer application services, or by offering socio-robotic software and processing. All three layers require independent platforms for distributed computation. All three layers must support dif-

Figure 4 Comparison of computers and telecommunications systems



Equivalence between concepts

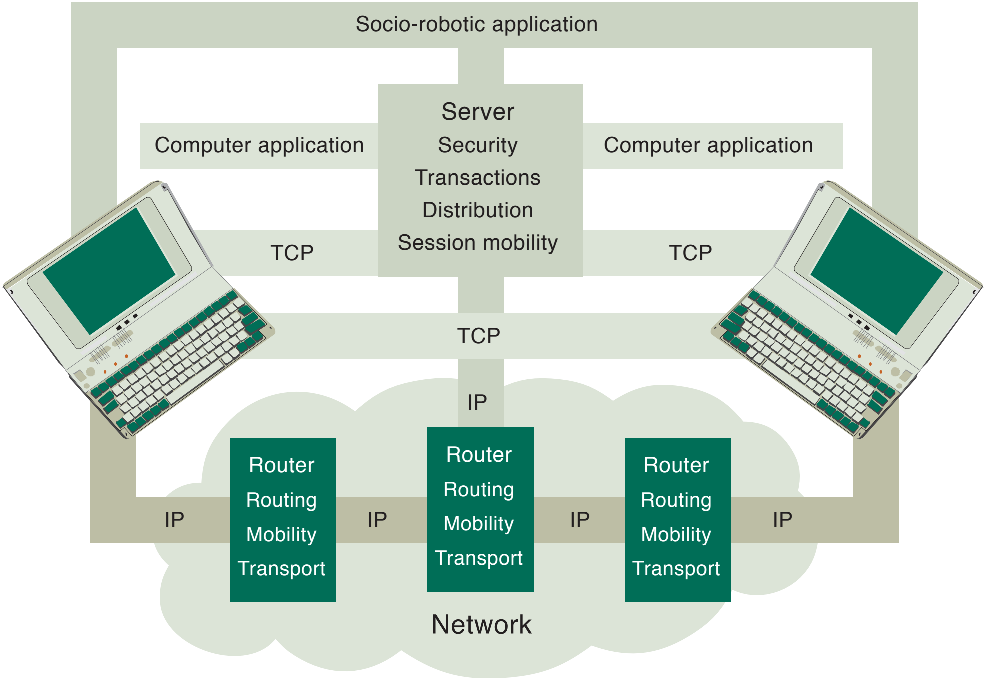


Figure 5 Distribution of socio-robotic applications over several computers

ferent types of mobility: terminal mobility, personal mobility, and session mobility.

The easiest business to understand is that associated with the network. Telecom operators provide twisted pairs, radio access, routers, switches, cables, fibres, satellites and other equipment required for transporting and routing bits from one host to another. The telecom operator may get paid for the capability of being connected, for the number of times the user accesses the network, for the amount of bits they are sending, for the bit rate by which information is transferred, for the duration of the connection, for the number of users being connected, for the distance the bits are sent, for the number of operators the bits have to pass, or whatever else the operator may measure. The final price may consist of any combination of such elements. The price may also depend on the time of day, the day of the week and the date, the average amount of traffic or the peak traffic the network is designed to carry, the traffic in the network just now, priority given to the traffic from that user, the delay for delivering the bits, and so on and so forth. The price may depend on still a number of factors: it may be a spot price offered just now, a buy-option price offered by the operator one week ago or five minutes ago and for a certain premium, a sales-option price suggested by the user two month ago for a certain premium, a contractually fixed price independent of usage, or a promotion discount for the next 100 calls or for the next 24 hours.

Finding the right price in a complex oligopoly is the real art of strategic pricing and earning money. The term oligopoly is used on purpose: in each geographic area there are just a few network operators – fixed or mobile – competing for the same customers. There is no place in the market where there are several competing operators and the decisions of a single operator have no impact on the market as a whole. On the contrary, every move made by a single operator influences the business of all the other operators. This implies that the market is certainly neither perfect nor monopolistic and therefore cannot be understood from simple economic theory. We will come back to this in Section 6 below.

The business at the computer application layer is more difficult to understand for the telecom operator. The business may consist in developing and selling general software for support of security, transactions and session mobility. The provider will then get paid for the software (such as Microsoft) or for the licence to use the software. The telecom provider can, of course, enter this business – Microsoft is one good example showing that there is much money in the business. However, developing and selling software is not part of the core business of the telecom provider and the telecom operator will have no competitive advantages. It is more likely that the telecom operator has several disadvantages, the most important being that these markets are often dominated by one player holding its position because of positive feedback from the market (network externalities). Here again Microsoft is the best example.

The provider of computer application services may also offer functionality in terms of equipment supporting complex functions (i.e. the server in Figure 5). The provider may then offer transaction services, security services, firewall protection, database services, mail handling facilities, call centre and so on. Many of these applications are new and poorly developed as yet as businesses. One example is security services where the operator offers secure electronic signatures, trusted third party databases for encryption-key management, and notary public services for protection against repudiation, i.e. denying that a certain activity (e.g. payment) has taken place. Again, this is not the core business of the telecom operator so that it has no natural advantages in the market. However, there are other companies in the market whose core business this is. They are the competitors the telecom operator will face. However, stimulating advanced businesses at the computer application layer increases the traffic in the network. The telecom operator staying in its core business will then still earn much money from the evolution of general computer applications.

Offering services at the socio-robotic layer is even more difficult. In some cases, the provider of these services distributes pure software applications. In other cases, the socio-robotic application is a combination of hardware and software. Examples of the latter are the personal digital assistant (the PDA), cars that communicate automatically with the manufacturer's computer for fault management, and remote reading of thermostats and control of ovens in smart houses. Neither software production nor development of terminal equipment is the core business of the telecom operator. In all three examples above the hardware and the software are made by industries other than those controlled by the telecom operator. The telecom operator may not even be aware of the existence of such equipment. The use of the SMS is a socio-robotic application where the telecom operator earns money by providing access to the service and not from the service itself. This is a very important observation that is likely to apply to all kinds of socio-robotic services: the revenue is generated in the core business of the telecom operator because the application causes increased traffic in the network. SMS also shows that the socio-robotic applications are risky businesses: SMS rides a wave of fashion that may vanish just as suddenly as it rose.

5 Value Creation

There are three different ways in which value is created in companies known under the concepts of chains, networks and shops [10]. The chain is the factory producing goods and is a linear chain that in its simplest form consists of logistics in (buying raw material), production of the goods, and logistic out (delivering the goods to the retailers)[2)]. The way in which this chain creates value is easy to understand and the principle has been analysed in depth by Michael Porter and other economists. The competition and the way in which prices are formed are both governed by the five-forces model of Porter described in any textbook on competition strategy. The value chain is still the prevailing value-creation principle taught in economics courses at universities.

The network is more complex and more difficult to understand [11]. The network is a business mediating between the members of the market: people or other businesses. Examples are banks mediating between people depositing money and people loaning money; newspapers mediating between the readers of the newspaper and the merchants advertising their goods and services; stockbrokers mediating between sellers and buyers of stocks; publishers mediating between authors and readers; and communication services such as postal services and telecommunications mediating between people exchanging information.

Take the newspaper as an example: the more people who read that newspaper, the more attractive it is for advertisers. Therefore, the major competitive battle among newspapers is concerned with the number of readers they can capture and not so much how well they serve the market of potential advertisers. This may lead to strategies where the price per copy of the newspaper is less than that of its competitors while an advertisement is more expensive. The challenge is then to understand the correlations that may exist in the mixed market in which the company is operating: this is why newspapers are so preoccupied with the number of copies they circulate.

Networks often produce goods that are not stored but consumed immediately. It is not possible to store for later use empty seats in aircraft or trains, surplus energy[3)], unused bits in the telecom network, and empty space in the cargo hold of the truck.

[2)] *In practice, the chain contains more elements in series than these three simple ones and also non-serial elements that are common tasks such as administration. But this does not change the basic principles of the chain; it only makes it more difficult to understand the underlying principles.*

[3)] *An interesting example where part of the energy is stored is hydropower plants where surplus energy is used to pump water back to the reservoir.*

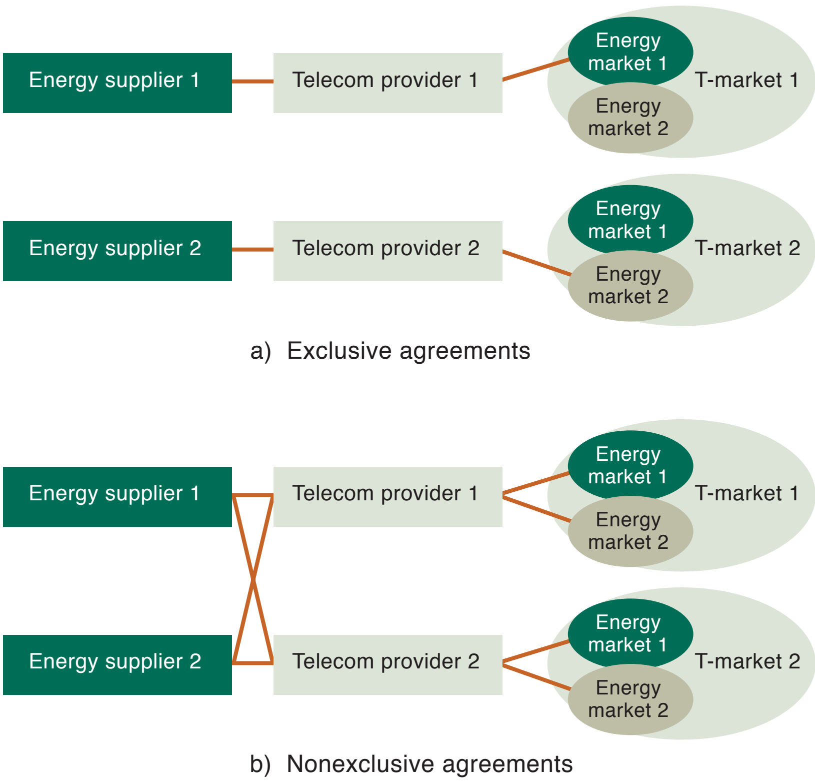


Figure 6 Co-operating networks

Networks can also offer mutual benefits to its members. This is the idea behind clubs of different kinds (literary, musical, bonus programmes, sports): the more members, the more benefit. The insurance company can offer better security at a lower price if many people use it. Banks can adjust their interest rates depending on the number of customers. Several manufacturers benefit from having many people using their product, not necessarily forming clubs. Microsoft is probably the best example of this kind: the more people using their products, the more new customers they get. This is called network externalities. We will come back to this in the next section.

Networks may cooperate in parallel or in series forming rather complex configurations. The more clever they are at cooperating, the more market they may gain. However, this strategy is extremely tricky, as illustrated in Figure 6. The figure shows two ways in which energy suppliers and telecom operators can cooperate in order to serve the smart-house market. Both the energy supplier and the telecom operator are networks in the sense described above. The energy supplier offers remote management of the energy consumption of the smart house. The figure shows two examples of how the market may evolve. In Figure 6 a), there exists mutual exclusive agreements between each pair of energy supplier and one telecom provider. The motive for telecom operator 1 to do this is to persuade customers of energy supplier 1 connected to the network of telecom operator 2 to change their subscription to telecom provider 1. The motive of telecom operator 2 is of course similar. The motive of energy supplier 1 may be to capture the customers of energy supplier 2 subscribing to telecom provider 1. Again, energy provider 2 may have similar motives. The outcome of this competition can be that one of the pairs takes over the whole market of both energy supply and telecommunications because of the network externalities discussed in the next section.

The situation in Figure 6 b) is different. In this case, all energy suppliers cooperate with all telecom operators, virtually leaving the market forces undisturbed. The motive of the energy supplier to go for this solution is to reach all customers. The motive of the telecom operator is to offer the service to all its customers irrespective of who supplies their energy. The situation resembles what is called the prisoners' dilemma in game theory because the worst that can happen is that one energy supplier cooperates with several telecom operators while the other is bound by exclusive agreements with only one of them. We shall not enter into a deep discussion of game theory here however important this theory is for understanding complex markets.

Shops are problem-solving organisations: consultants, health services, engineering companies, and architects. They earn more money the better and faster they can solve a problem and their most important competitive market force is their reputation. Shops may exist within networks or chains. Examples of the former are the advertisement department of newspapers, consultative sales department of telecom operators, R&D departments, and airlines travel agencies. The shop may of course be outsourced to independent companies: the airline may outsource all its travel agency and booking services.

The challenge of the telecom operator is then to understand all aspects of the way in which value is created in the different parts of the company: chains, networks and shops require different types of management. Chains require strict management of processes, timing, production cost and stock. Networks are sensitive to how cooperation is managed and the capability to operate in a combined cooperative and competitive environment. What makes this problem even more difficult is that telecommunications are used as raw material in almost all other products and services: banking, education, oil production, finance, energy delivery, transportation and logistics. This even leads to completely new products such as smart houses where the telecom operator cooperates with energy suppliers and security firms; electronic health services including management of patient journals and remote monitoring of patients requiring cooperation with public health services, private practitioners, social security administration and hospitals; intelligent transport systems requiring cooperation with road authorities, public emergency services, road payment systems, clearinghouses offering information security services, and information providers of several kinds.

Shops should have the capability to form flexible project teams and be able to reorganise quickly in order to solve new problems. It is damaging to shops if they are managed in a hierarchical manner. Such organisation may be efficient in chains but not in networks and shops.

6 Imperfect Markets: Oligopoly, and Market with Positive Feedback

An oligopoly operates in an imperfect market. This is so because one of the companies of the oligopoly may suddenly change the rules of the game by for example lowering the prices dramatically over a period or offer certain services for free. This leaves the competitors with difficult decisions: follow or not follow the move? What makes the decision even more difficult is that the game is often the prisoner's dilemma. The game goes as follows.

Two criminals have been apprehended for possibly having committed a serious crime together. However, there is no direct evidence that these two men actually committed the crime. All that can be proved is an instance of excessive speeding. The prisoners cannot communicate with each other when each of them is given the same offer by the local judge. This is the version presented by Albert W. Tucker in 1951 when he wrote the first paper on this important and difficult problem [12].

"Here's the plea bargain: If you confess to the crime and implicate your accomplice, thereby helping us to resolve the case, I will set you free, and we'll forget about that little matter of speeding. In this case your accomplice will be shut up in jail for ten years, and the whole matter will be closed forever. This offer is valid, however, only if your accomplice does not confess to the crime and thus does not help us in clearing up the matter. If he also confesses, then, of course, your confession is not of much value, as we will know everything without it. In this case, each of you will be jailed for five years. If neither of you confesses, we shall, alas, be unable to convict you, but we'll be very severe on that rather nasty incident of speeding, and you will both be imprisoned for one year. Finally, I must inform you that I made this very same offer to your accomplice. I await your answer tomorrow at ten o'clock. Just think – you can be free by eleven!" – guess what the outcome of this proposal is!

After Tucker's paper, the problem has been analysed in thousands of papers and from numerous angles of attack: by mathematicians, psychologists, social and political scientists, biologists, ecologists, philosophers and economists. The reasons are that the prisoner's dilemma is appearing again and again in real situations – sometimes disguised in such a way that it is not easily recognised [12].

The oligopoly is a repeated game of prisoner's dilemma. Let us describe the competitive game between two companies in a duopoly where the two companies *A* and *B* are competing for the same customers. Assume initially that the two companies have equal market shares.

Company *A*'s analysis of the market suggests that if the price is lowered by 20 %, its market share will increase from 50 % to 75 %, while that of *B* will drop from 50 % to 25 %. Having first gained such a huge majority of the market, it is just a question of time before *B* is bankrupt, and *A* is alone in a comfortable monopoly. *A* has also concluded that if *B* makes the same move without *A* responding, *A* will be bankrupt within two years at most.

Of course, *B* has arrived at the same conclusion.

The prisoner's dilemma for *A* is the observation that the gain is huge if the prices are lowered, and that the loss is similarly severe if *B* lowers his prices. Therefore, the outcome of this game is that both *A* and *B* lower their prices, resulting in a situation where both *A* and *B* still own 50 % of the market but are earning 20 % less money, bringing both of them into financial trouble.

People will claim that they are not stupid enough to fall into such a trap. But are we not? This type of game has been played several times in the mobile market where price wars have been fought several times, either by lowering the price for using the network, or by giving away mobile terminals for free. It has been a recurring event among airlines causing all kinds of economic problems, including bankruptcy. The auctions of UMTS licences were similar prisoner's dilemmas – the bidders where facing the prospect of losing all mobile business in the future. What makes the auctions different from competition is that in auctions the game of prisoner's dilemma is fought only once resulting in the outcome that both parties defect, i.e. all parties try to win the licence. If competition takes place over time, the game is played several times in succession and the competitors behave differently. Over long periods of time they cooperate – that is, not to defect by lowering the prices or making other competitive moves. Then there may be bursts of defection where one of the companies tries to gain advantage by altering the competitive rules. This competitive behaviour has been observed in several countries in the GSM market. This is a true oligopoly since there are few competitors in each geographic area offering a single non-differentiable service.

One serious problem with oligopoly is that it offers two playing grounds. One playing ground is the fight over market shares described above. The companies can almost daily monitor the variations in its market share. The other playing ground is concerned with the financial results of the company. The best result of this game is maximum profit. This is not always the same as maximising the market share. Therefore, different competitive games may be played depending upon which playing ground is chosen. How often are we taken by surprise when we hear that this or that company has run into severe financial trouble? Is the reason that the competitive game was played on the wrong playing ground?

Prisoner's dilemma is a non-cooperative game – that is, it is all about what we understand by competition. Another category of games is called cooperative games. In these games, the players follow certain cooperative rules in such a way that their gain increases as a result of the cooperation, and there is no way in which one of the parties can defect in a way that leads to dilemmas such as the prisoner's dilemma. Such games are likely to be prolific in network economies. However, cooperative games are mathematically very complex and therefore poorly understood. In addition comes the fact that many of these games are played with asymmetric or wrong information.

We shall not go into detail concerning the application of the game theory of von Neumann and Morgenstern published in 1944 for the analysis of certain classes of economic problems. Although the theory is more than half a century old, it is still under development: about 80 % of the scientific papers published in mathematical economy today contain aspects of game theory. Reference [13] introduces the different aspects of game theory without getting too mathematically complex.

Another type of imperfect market arises when there exists positive feedback from the market. This is what is called network externalities or network effects. The importance of these theories were recognised recently and were first analysed in depth by the social economist Brian Arthur [14]. An excellent and easily readable introduction to network effects is found in [11]. While some of the articles by Arthur are heavily loaded with mathematics, the text in [11] is not.

We shall now discuss the performance of such markets using an idealised and simple mathematical model. The strength of this model is not that it describes the true behaviour of the market – for that, the market behaviour is too complex – but that the mathematics is so simple that it is easy to comprehend what is going on. This is just as in physics: the simple laws of classical mechanics and aerodynamic flow tell you in principle how a leaf falls to the ground – in particular, that the leaf will reach the ground sooner or later – but the shape of the leaf and the air currents are so complex that it is impossible to determine the exact path the leaf will follow.

Markets with network effects are characterised by positive feedback: the larger the market, the faster it grows. This growth continues until the product saturates the market. A simple differential equation modelling this market is as follows:

$$dS/dt = \alpha SP$$

where t is time, S is the proportion of customers owning the product at time t, $P = 1 - S$ is the relative number of customers still not having bought the product (potential future customers) at time t, and α is the constant of proportionality defining how fast the product is sold. The number of customers buying the product per unit of time is dS/dt. The proportionality with P reflects the normal behaviour of the market: the number of customers buying the product per unit of time is proportional to the number of people not having bought the product. The proportionality with S represents the positive market feedback: the more people owning the product, S, the more attractive it is for other people to buy the product. Note that a product in this context can be physical goods (e.g. play-stations), software (Microsoft Office), services (e-mail), or any combination thereof. The customers can be ordinary people in search of services and goods such as play-stations, memberships of clubs, or e-mail, or organisations such as energy providers cooperating with smart-house providers with large and stable market shares, or travel agencies benefiting from cooperating with hotel chains at the right places offering good quality – and vice versa, hotel chains cooperating with travel agencies with good reputation. The latter is an example where cooperation mutually strengthens the market position of several partners.

Note that the differential equation above is a very simple model describing this type of market. More complex and accurate models are, however, so complex that the simple and important fact that the evolution of the market depends on both the number of customers having and the number of customers not having bought the product is lost in mathematical obscurity.

Network externality or positive feedback is one of the competitive mechanisms of the network economies explained in Section 5 above.

Figure 7 shows the performance of markets with positive feedback. The solution of the differential equation above results in an S-curve *provided that there is an initial market from which growth commences*. This is what is referred to as Criticality 2 in the figure. If there are no customers initially, the product will not be sold to anyone. This is so because one of the solutions of the equation is $S = 0$. The existence of this solution is referred to as Criticality 1. More precisely, Criticality 1 says that if there are no initial customers, there will be no growth. However, the solution $S = 0$ is not stable, and the first customer to buy the product will cause the S-curve to start rising; however, in reality, if there are few customers, it is most likely that the product will disappear from the market after a short time for other commercial reasons. However, the fewer the initial customers, the slower the market grows initially. The growth rate depends also on the coupling constant α (representing the popularity or visibility of the product): if α is small, the product is not really visible in the market and the market increases slowly; if α is large, the product is attractive and the market increases rapidly. The initial increase is referred to as Criticality 3. The growth may be so slow that the offer of the product is withdrawn because of lack of interest.

These models are closely related to mathematical models of epidemiology. A survey of epidemiological models is contained in [15].

The strategic challenge is thus to obtain a sufficiently large initial customer base and recognition of the product in order to ensure growth. This implies that the real strategic issue for launching products that depend on network externalities, is to find a marketing method that ensures that the sales of the product reaches a critical mass soon enough. Possible strategies that all may lead to other problems later are to give away for free the first products as part of a pilot trial, make the product very visible and attractive through fierce advertising, or bind it to a complementary product (if such a possibility exists).

One example of a market with positive feedback is the SMS market – the more teenagers using the service the more teenagers will adopt it. When the market growth really started accelerating, the increase was violent. In this case every GSM subscriber had access to SMS because it was a feature built into the system. Therefore, it was something else than SMS that took off – SMS was just the vehicle supporting this "something else". The SMS phenomenon is thus similar to several other trends that suddenly take off – and often just as suddenly disappear.

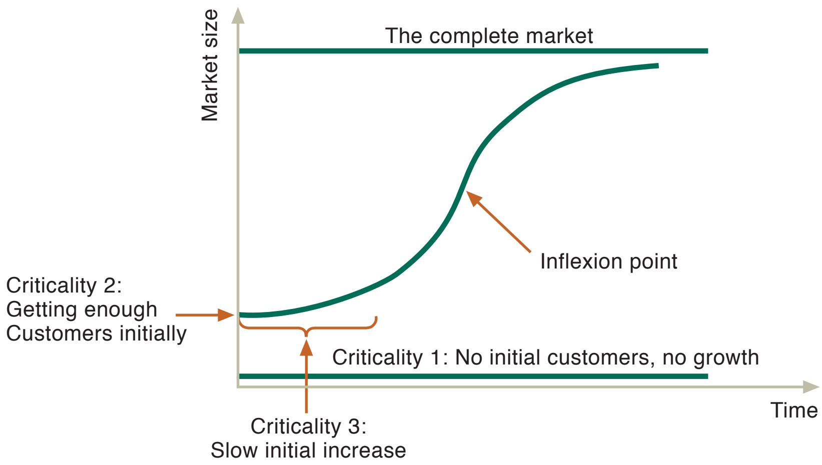


Figure 7 Market with positive feedback

Other examples of such markets are telefax and e-mail. These markets are independent of the number of competitors selling the product only that the product from all the manufacturers can interwork. Here there are several actors involved in providing the service: the network providers must support the service and interwork with one another in order to reach all users, not only their own subscribers. They can, of course, market their own standard thus excluding competitors. Because of the network externalities explained below, this may be a good or a bad decision depending on several other factors such as initial market superiority, complementarity with other products, switching cost of customers, or interference by regulatory bodies.

The videophone is a good example of a service where the coupling between product and market (α) was too small because the terminal equipment was too expensive compared to the value that live pictures add to ordinary telephone services. Multimedia services are struggling with the same problem. Smart-house technologies take off very slowly because the control equipment required in homes is too expensive compared to the energy saving. The smart-house technology is a complementary product to energy delivery and does not create network effects of its own. However, the cost of the terminal equipment is subject to network effects: the more users, the cheaper the terminal. This means that it is risky to be the first mover since the profit is big if the market takes off but the cost is huge if it does not. This problem is common in telecommunications: who will be the first to close down IP version 4 and introduce IP version 6?

The initial slow growth phase can be very slow: it took 100 years before the facsimile service started to increase in volume! This evolution could probably only take place in a monopoly.

Note that the types of market described above are not at equilibrium: they are always moving toward an ultimate final state where all customers have adopted the product.

A related phenomenon is the winner-takes-all markets. This is a combination of positive feedback from the market and competition in an oligopoly. Suppose that there are two manufacturers (A and B) selling products competing for the same customers and there is positive feedback from the market as described above. This leads to a more complicated market model resulting in a set of two coupled differential equations. Again the mathematical model is highly idealised.

$$dS_A/dt = \alpha_A S_A (1 - S_A - S_B) + \beta_A S_B - \beta_B S_A$$

$$dS_B/dt = \alpha_B S_B (1 - S_A - S_B) + \beta_B S_A - \beta_A S_B$$

where S_A and S_B are the market shares of each of the two companies and α_A and α_B are the coupling constants toward the market. The term $\beta_A S_B - \beta_B S_A$ takes into account churning where the first term represents the proportion of customers manufacturer *B* loses to *A*, and the second term is the relative number of customers *A* loses to *B*.

It is difficult to solve this set of coupled differential equations. However, the general solution will be as shown in Figure 8, where the market gained by one manufacturer (*A*) will grow, while that of the other manufacturer (*B*) will decrease toward zero even if the two markets are the same initially. This happens if one of the products attains a superior market share over long enough time for the positive feedback to be effective.

This phenomenon is called lock-in or winner-takes-all. There are numerous examples where the market has behaved like this (see [11] and [14]). The lock-in may occur in competition between technologies (Beta versus VHS, WWW versus ODA, HDTV versus conventional television), systems (e-mail versus telefax and postal services), standards (Internet versus X.25), manufacturers (Microsoft versus Apple), and localisation of industries (Silicon Valley) and residential areas. An upcoming case is UMTS versus WLAN. For the telecom operators it is crucial who wins this battle.

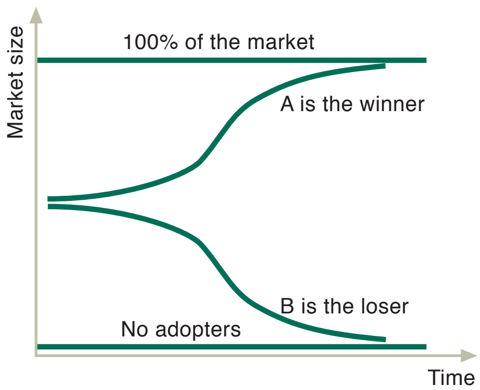


Figure 8 Winner takes all

Competing within oligopolies and in markets where there are network externalities is challenging. Strategies include building an early customer base by offering discounts, putting much effort into branding and promotion, targeting the market toward influential customers, and if possible, joining up with other providers offering complementary products that will increase the market feedback. However, last but not least, it is important to understand the product and how the market perceives it. How big are the switching costs? Does switching depend on other factors such as psychology and how should this type of switching resistance be handled? Does switching depend on complementary products and services? Is it supply-side or demand-side economies of scale or a combination of these? Does the product substitute or complement other products or both? Which flexibility options are there and what are their value or cost? This brings us into the subject matter of the next paragraph.

7 Complexity and Uncertainty

As we have seen above, the complexity of telecommunications is huge. The complexity of telecommunications has shown a sharp increase, in particular during the last ten years; that is, after the telephone network became fully digital and computerised and new applications emerged on the Internet. True, the telephone network interconnecting every fixed and mobile phone in the world was of course complex. However, this system was homogeneous and did not offer much more than interconnectivity. What has happened is that complexity is not only confined to technology but also to the telecom business itself. Telecom is the carrier of all types of information (video, speech, files, money, …) and supports all types of remote interconnectivity (interconnecting sensors in cars and computers of the manufacturer, interconnecting account databases in banks, interconnecting computers in the stock exchange with the computers of the seller and buyer of stocks, …). Telecommunications is ubiquitously present in all the infrastructure of society, in all industries whichever services or products they are making, and everywhere in the public administration. Telecommunications is the new production factor in industrial economy.

Helga Drummond has written a thought-provoking book on the psychology of decision making [16]. It contains numerous examples of good and bad decisions taken by the management of both small and large enterprises, private and public. The size of the enterprise does not enter the equation of whether a decision is good or bad: the size of the company is only one of the parameters determining the effect of the decision. The problem of decision making is that risk and uncertainty are always involved, where the risk at hand and the uncertainty is not even known or perceived when the decision is made. The matter to be decided may *look* simple but is usually embedded in an environment of profound complexity.

Recently the science of complexity has been applied on organisations [17], [18]. These theories explore self-organisation and emergence in order to explain the dynamics of organisations and how patterns are formed, stabilised, and then changed or destroyed within the organisation. At the bottom of this thinking is also the problem of uncertainty.

The decision maker often believes or pretends that complexity and so also uncertainty do not exist and makes the decision based on what he or she firmly believes must be true. This "truth" is often just a rationalisation of the expectations such that the basis for the decision amplifies the belief that the expectations will be met, or as Drummond puts it, "expectations may determine what we see and hear", and "we rationalise what we see to fit our expectations". Which were the rationales behind all e-commerce and all e-businesses that took off at rocket-speed just to crash-land when the e-propellant was used up? Was the decision to participate in this rat race based on a "truth" that was just a reflection of the expectations of earning good money fast? "This is an opportunity that is too good to be true so let's join the other rats!" It was, as often is the case, too good to be true.

Though much can (and should) be written on complexity and organisations, we turn to one concrete method for handling complexity and uncertainty, namely real options.

A practical computation of real options of a telecom project is found in [19]. The paper clearly illustrates that conventional net-present-value (NPV) calculations give rise to decisions concerning the value of the project that are different from those based on real options. Some of the decisions based on NPV may be entirely wrong.

The first book containing the deep theoretical basis of real options was published in 1994 [20]. The understanding of what real options are and how they can be applied in practical situations is thus new knowledge[4)]. A more practical approach to real options is found in [21].

Industries facing huge high-risk investments such as the oil industry and the space industry have already been forced to use the method. The telecom industry has entered an era where the investment risk of new projects has increased tremendously. The Internet rendered most of the investments in X.25 networks useless. Building up the UMTS represents one of the largest uncertainties the telecom industry has ever faced. How can we navigate in order to minimise losses if UMTS is replaced by WLAN or something even more remote, or how can we position ourselves in order to maximise the profit if UMTS really takes off? Real options are concerned with finding positions where the worst case does not hit us too hard and where we are not missing too many opportunities if the best case happens.

Real options are about how to manage risks associated with uncertain cash flows in industrial organisation. The idea is rooted in the theory of financial options that was developed during the second half of the 1970s. Options are one of several financial instruments with the purpose of reducing financial risk. The holder of the option has the right to buy (call option) or sell (put option) a financial asset, if he chooses to do so, at a fixed price (the strike price) on or before a predetermined date (the strike date). The holder of the option has to pay a certain premium in order to purchase it from the issuer of the option. The premium, if correctly computed, will balance the risk of losing and earning money in the deal: if the value of the underlying asset of a call option is higher than the strike price at the strike date, the issuer loses money on the deal; if the value of the underlying asset is less than the strike price at this date, the holder loses an amount at most equal to the premium of the option. The premium of the option is computed in such a way that on average the losses and gains are equal, converting option trading to a two-person zero-sum game with equal probability to lose or win. The financial risk of options is then ideally reduced to zero.

The most important real options are as follows.

The option to defer the start of a project is concerned with the value of the flexibility to wait in order to find the proper time to launch the

[4)] *In order to illustrate how new the concept is: real options are not mentioned in the 1997 issue of Encyclopaedia Britannica!*

project. Ordinary calculation of the NPV of a project gives rise to a now-or-never decision: if the NPV is sufficiently positive, start now; if the NPV is negative or not sufficiently positive, abandon the project. The NPV calculation does not take into account flexibility, namely that the conditions upon which the NPV is based may change over time due to changes in the environment of the project (e.g. external events such as new market regulations, development of the world's economy, emergence or disappearance of trends, or evolution of prices, and internal events such as partnering, change of management, and reorganisation). The flexibility to wait, for example until the price is right or other manufacturers have caused the market to mature, rather than abandoning the project immediately may add additional value to the project. If the project is deferred, the premium of the option is the cost of maintaining expertise or equipment until a final decision to start or abandon the project is made. If the project is not realised, the premium is lost.

The option to shut down the project is concerned with the problem of finding the optimum time to do so. The NPV method, not taking flexibility and uncertainty into account, may give one answer to this problem while the real option method may indicate a different time for shutting down the operation. The strike value of this option is the saving in future investments and running costs. The premium is composed of lost revenues in the future and the cost associated with termination of the project: removing equipment and infrastructure, reorganising or dismissing the workforce, and paying compensations to customers no longer receiving the product. Of course, all this could be included in the NPV calculation had the variables been deterministic. The problem is that they are not, rather they are subject to much uncertainty; that is, only the stochastic value of the variables can be assessed or guessed. Note that there may be much difference between shutting down a value chain and shutting down a value network. The reason can be that the customers connected to a value network will require much more compensation for lost services than the customers of a value chain. It does not concern anyone if a manufacturer of diapers closes down; however, it may cause much inconvenience if a telecom operator or a bank abandon one of their services. Since network products may be interrelated in many complex ways, the decision to abandon one service may cause reactions toward other products and market segments than the service being abandoned. This problem has hardly been recognised in economic theory as yet. Instead of abandoning the project it is also possible to scale it down. This leads us to the next set of options.

Scaling options and *switching options* are concerned with the way in which the company may increase (scale up), change (switch) or reduce (scale down) their activities in different projects. In manufacturing, the scaling option is often concerned with the question to build a new factory or to abandon a factory. It is also concerned with selling out or buying other industries in order to balance or rearrange the portfolio, getting rid of competitors or terminating operations that are losing money. The switching option is concerned with allowing cannibalisation; that is, increasing the overall market by launching mutually exclusive products, and applying new technology to old products in order to make them cheaper, smaller, more fancy, and so on. Industries involved in large construction projects are continually faced with scaling options: allocation of larger workforce to meet deadlines, reduction of workforce to reduce expenses. They are also faced with complex switching options: allocating workforce with the right skills and competence at the right time.

In telecom operation there are also complex decisions to make concerning scaling and switching. At what time should a mobile network be increased – or how many unsatisfied customers can there be before this becomes a threat to the market share? When shall we invest in another technology – or what are the benefits or disadvantages of the new technology to the customers and to the operations of the company? When should a service be abandoned and replaced by another service – or what are the reactions of the market to such decisions?

The staged investment option is concerned with planning a project in such a way that no more money is used at any time than strictly required. The flexibility of the decision at each stage may comprise the consequences of abandoning, deferring or continuing the project, the effects of scaling the size of the project up or down, the advantage of switching to different technologies, and the implications of the decision on reputation and branding. The staged investment option is in some projects a simple go/no-go decision; in other projects it takes the form of a *multiple interacting option* consisting of several options (shut-down option, switching option, deferral option and scaling option). The value of the staged investment option may be difficult to compute because the NPV generated by each simple option cannot be added in order to determine the value of the composite option.

Note that a carefully planned staged investment series may reduce the overall risk of the company considerably because the approach makes it possible to recalculate the value of the project at each stage when the risk associated with the next stages is better understood. For this reason, the resulting NPV may become much larger than the NPV of the same project calculated using standard methods.

Note that the premium of a go/no-go staged option payable at the end of each stage is the cost of the project up to that time.

Another complex option is the *growth option*. By growth we understand here the growth of the overall company. Strategic projects are often recommended even if they have negative NPV because the gut feeling indicates that the project may open other more profitable possibilities in the future. The growth option, or the option to create follow-up projects or new real options, is a systematic way to calculate the value of projects that may lead to more profitable projects in the future. Gut feelings alone may lead to valuation of the projects far above their actual commercial value such as the e-business projects two or three years ago. The real option method may lead to more realistic assessment of the value of these projects.

The discussion of different methods (traditional or static NPV models, dynamic NPV models, decision tree models, and real option models) for assessing the value of a project is found in [21]. The conclusion is that the real options method provides a far better basis for decisions than all other methods combined. The real option method is difficult requiring a heavy apparatus of mathematical tools such as stochastic differential equations, stochastic optimisation and dynamic programming, advanced numerical methods, statistical analysis, and computer modelling and simulation. The commercial implementation of such complex technologies requires the application of the most advanced economic analysis tools there are! However, for a technologist it is depressing to see that the economic tools applied to such analyses are the traditional ones used invariably during the 20th century. Note that the technologist is faced with a more challenging task: much more difficult tools are required to develop radically new technologies such as UMTS and WLAN!

Companies such as telecom operators demand that the technologists evolving and implementing the technologies have leading-edge knowledge of the relevant technologies. I have never heard that a similar claim is put against the competencies of the economists even though it is the economic and strategic decisions that in the end settle the question of whether the company will survive or perish.

Renewal of the economic knowledge is the real challenge of telecom companies.

8 Innovation and Unpredictability

The impressive publication activity in telecommunications is the result of an unusually high level of innovativeness. This innovativeness is a combination of several things. First, the area of telecommunications and computer science (ICT) is one of the largest economies on Earth. Some of the largest companies in the world are either telecom operators, information providers delivering information to fill the radio spectrum, the fibres and the copper wires of these operators, or manufacturers delivering equipment and software to operators, providers and customers. Second, telecommunications and computer science are present in all other industrial activities and ICT has become a production factor in the classical sense replacing workforce, land and capital. This evolution has taken place during the last ten or fifteen years. Third, as discussed in Section 2 above, innovation, as most other activities, is subject to natural growth: the more that exists within a science such as ICT, the more is innovated and the faster the area grows generating more novelties.

Finally, if ICT is abruptly removed from society, we are plunged back to the stone ages: no food supply, no energy supply, no information, and no government to help us. Huge damage can already be done to society by e-bombs and e-grenades: data viruses can take out industries, governments, transport systems, logistic systems, and infrastructure such as energy supply and water supply. Here we are talking of several motives of innovation: earning easy money, destruction of our enemies and protection of our friends and ourselves, or simply having fun.

It is of course impossible to predict what will come out of all this innovation: which ideas that will survive and prosper, which ideas that will be replaced by more vital thoughts, and which ideas that will never leave the desk or the laboratory of the scientist. It ought to be disturbing to managers of the ICT business that the ideas that finally lead to profit are so unpredictable. It is fair to say that ICT is one of the least predictable industries there are. In 1993 no one could dream of the success of the Internet, not even those who were doing research on Internet technology. The telecom operators were implementing the standards of ITU (X.25 and others) investing huge amounts of money on these technologies. Do not listen to those who say – ten years later – that they saw Internet coming. They did not. For them Internet was just another interesting technology. Those who developed X.25 were just doing what the telecom business expected them to do: implementing the standard of the time. So there is no one to blame being reactionary and no one to hail being visionary: researchers and implementers did just what they were paid to do.

Now, after the SMS of GSM became a success, there are people who claim to have been the first to launch this revolutionary idea. The point is that the idea was not visionary, it was the result of the work of a group, and the intention was not to create new business. The idea was to design a system whereby useful information could be sent to or received from car drivers, such as information about traffic jams, road conditions, driver assistance and so on. No one could imagine then that this service would become a craze among teenagers ten years later!

The uncertainty we are facing is huge and the business landscape is complex. The ISDN survived because of the technology replacing it: the Internet! The Internet offers more than the ISDN – despite its name Integrated Services Digital Network – was ever able to fulfil, and the services of ISDN were indeed replaced by the Internet. Still the ISDN survived (at least in some countries) because it offered a bit rate and flexibility at the user access that traditional systems using modems could not match. ISDN may be replaced by another technology – the digital subscriber line xDSL, where x stands for A (asymmetric), S (symmetric), H (high bit rate), V (very high bit rate) and so on. The xDSL is a technology offering broadband services in general; however, it is the capability to support faster Internet access that persuades people to buy it; they are not preoccupied with videophone, television and multimedia.

For the last thirty years[5)], the videophone has been marketed from time to time. The service has never taken off, probably because it does not offer any significant advantages over audio telephony. There are many examples like the videophone. For example, ATM is not what it was intended to be.

The most important challenge now is the future of UMTS. The operators are building the system but no one is able to predict that it will ever create business opportunities as expected during the bid for radio licences. The UMTS technology can easily be replaced by WLAN (Wireless Local Area Network) standardised by IEEE and adopted by other standards organisations. A book published in 2002 with the impressive title “Next Generation Network Services” does not mention WLAN and related technologies altogether [22]!

The evolution of radio-mobile technology is an example of the action of network externalities. It is most likely that the market will select one type of radio access technology as the preferred technology so that all the competing technologies will perish. The reason is that neither can equipment manufacturers and mobile operators afford to invest in two types of system, nor will the customers accept to buy two types of equipment. The initial strategy of the telecom operator may be cannibalisation: adopting both WLAN and UMTS and simply see which technology will survive. Though this type of strategy is expensive, it is a type of insurance where the operator is not entirely out of market if one of the technologies wins. The insurance premium is the net loss of implementing the technologies that perish. However, this type of portfolio management is in fact the execution of a termination option.

We are not talking of technologies that suddenly appear. All technologies take considerable time from the drawing board to commercial implementation. The Internet was not something that appeared out of the blue in 1993. It had already existed under the name of Internet for 15 years. Before that, it was known as ARPANET for more than ten years. What was new was the application we now call the World Wide Web. Compared to the basic technologies of Internet, the Web technology is very simple.

It took ten years to implement GSM, IN and ATM. It took 15 years to develop ISDN and UMTS. The standardisation of WLAN took almost ten years. Work on the CORBA platform, supporting distributed computing, took place during more than fifteen years. The work was done in a consortium owned by 640 partners from industry, research and academia – probably being the largest standardisation effort ever. The platform was implemented, sold and used but turned out to be too complex and out-of-date. There are now several other efforts to develop platforms for similar purposes to be or not to be applied in practicable systems.

All of the above examples represent large inventions. It takes time to develop complex systems. One reason is that the specification of the system is voluminous. The GSM specification consists of 5000 pages; the size of the UMTS specification is 10,000 pages. The specifications of the CORBA and the TINA processing platforms consist of several thousand pages describing for which purpose the platform is designed, which functions it should offer, which software the

[5)] *I was told about the potentials of the videophone in 1974 when it was demonstrated how efficient it is for coordinating businesses: the demonstrator interconnected the top management of the Netherlands PTT and Philips. The videophone was claimed to be the most significant service of the future. When the service was reintroduced 15 years later, the claim was the same. In 2002, is the videophone still the most significant service of the future?*

platforms should support and the design principles that should be applied in order to support interactivity of hardware and software manufactured by different vendors. The specifications are the guidelines for how the manufacturer shall design the system. The manufacturer must convert these specifications into detailed descriptions of the overall system design breaking down the system into manageable modules, produce circuit diagrams showing how the hardware is constructed, develop formal software models, and produce the program listings. The system must be extensively tested during the manufacturing phase, often requiring redesign of parts of the system. Finally, test manuals, operation manuals and maintenance handbooks must be written before the system can be sold.

Another reason why it takes time to invent large telecommunications systems is that it is based on brand new technology that has never been tried before. The GSM system could not be designed before 1990. It was at that time that the microprocessors became fast enough and had enough memory capacity to carry out all computations required for encoding and decoding radio signals, encoding and decoding speech, and supporting the complex tasks of call handling, signalling, encryption and authentication, roaming, handover and several other functions. The microprocessors became powerful enough in 2000 to carry out the equivalent functions of UMTS. Prior to that time UMTS could not be designed. Technological evolution resembles natural evolution: the evolution can only go from simple forms to forms of ever increasing complexity [23].

Large innovations require the collective work of many people with different expertise. Several hundred researchers were involved in developing the standards of GSM, UMTS and CORBA. The innovation of large systems is thus a collective enterprise. Large innovations can only be conducted in this way: they are simply too complex for one person to do. This does not mean that large innovations, or rather innovations having large consequences, are not the work of a single person. Science is full of such examples. But business is the art of bringing such innovations into real life. This is what takes time and money.

Innovations can be radical or incremental. Examples of radical innovations of the ICT business are the telegraph, the telephone, the transistor, satellite communications, and mobile communications. The NMT and the Marisat/Inmarsat systems were radical innovations because automatic, high quality telecommunications to cars and ships had never been tried before. GSM is an incremental innovation building upon the ideas of NMT. GSM is incremental though the technology is vastly more complex than that of NMT. Of course, GSM contains novelties of huge importance such as digital speech encoding, non-interruptive handover, cryptographic authentication, and soft-decision error correction. A radical innovation may not be complex. One such example is the technology of the World Wide Web. The technology is simple – developed by two people; the impact on telecommunications is huge.

Incremental innovations are usually rather minor innovations. These are the ones we usually spend most of the R&D money on because their business potential is simple to understand even if the benefits often turn out to be small. Electronic newspapers, e-commerce and most other e-services are, technologically speaking, minor incremental innovations. The real innovation concerning these services is to find ways in which we can draw business out of them.

Most major innovations take an awfully long time from idea to market; many incremental innovations are quickly implemented. This causes a difficult balance between long-term and short-term planning. It is tempting to put R&D on projects that may show profit immediately. This blocks the company from doing radically new innovations that churn out money in the long run. The challenge of the corporate management is to find the balance between stimulating short-term incremental innovations and putting intellectual forces on problems that may come up with radical innovations in the long run. Note that incremental innovations can be planned; radical innovations cannot.

9 Telecommunications: Quo Vadis?

The concept of telecommunications was changed radically during the 1990s. The most important changes that have taken place were explained above. Figure 9 illustrates the evolution that has taken place in telecommunications and suggests a possible evolution that may take place during the next few years.

Before 1980, telecommunications was concerned with transmission of signals on cables, over satellites and on radio relays. Between 1980 and 1990 (approximately) the driver of the evolution was convergence between telecommunications and computer science. This resulted in new switching idioms, digitalisation of the network and introduction of the first mobile systems. Data communications made remote interconnection computers possible.

More advanced systems such as Internet, World Wide Web and GSM became available in the

• Transmission	• Convergence of telecom and computer technology	• Content • Services	• Interactivity Human-human Human-machine Machine-machine
Before 1980	**1980 - 1990**	**1990 - 2000**	**After 2000**
• Automation • Satellites • Radio relay	• Computer supported switching • Data com • Digitalisation • Mobility	• Internet • GSM • Web • Transactions • E-applications	• Sensors • Peer-to-peer • Virtual terminals • Security • Telecom as production factor

Figure 9 Evolution of telecommunications

1990s. This opened for a new evolution: contents and services. Note that before 1990 there were almost no supplementary services. They were standardised between 1985 and 1995. This led to a rush of new applications such as transaction services, e-mail and all kinds of services with an e- in front of it. During the 1990s the complexity of telecommunications surpassed by several factors compared to what it had been before. The complexity, as we have seen above, is not only of a technological nature but is just as much a commercial one.

Now we see other trends emerging where interactivity and mobility are the drivers: peer-to-peer communications, automatic sensor/actuator networks, wearables and virtual terminals. Interactivity will comprise traditional and SMS-type human-human communications, Internet type human-machine interaction, and a new type of machine-machine interoperation. It is the latter type of interoperation that will be the most complex to handle. This type of interoperability includes systems such as the following. Some of these systems exist already but the technologies and the business concepts are still not mature.

- Smart-house technology includes remote sensing and control of heating, monitoring of burglar alarms, window and door alarms, and water leakage alarms, detecting presence or absence of people, and reading water and energy usage meters.

- Intelligent transport systems include automatic road payment, traffic monitoring, accident supervision, speeding control, road condition monitoring, fleet management, remote fault supervision of vehicles, automatic ticket systems, passenger information services, free-route management systems for emergency vehicles, and route information systems.

- Logistics may include automatic location of containers and goods, location and direction of vehicles, optimum route selection, fault monitoring and assistance services, transfer of customs documents, and shops where the goods keep track of their own logistics.

- Health services including communicating smart cards containing all medical information of a person, interconnected expert databases, computer assisted diagnosis, remote monitoring of patients, and emergency support systems.

- Infrastructure management including energy supply systems, water supply systems, air traffic control, and remote heating systems.

- Earth surveillance including flood warning, tsunami detection, pollution surveillance, drought detection, detection of diseases on crops, and early warning systems of seismic and volcanic activity.

- And many other systems and applications in banking, commerce, education and industrial production.

The least common denominator is that none of the services can be implemented by a single enterprise alone. Road authorities, telecom operators, or car manufacturers cannot implement intelligent transport systems alone: they have to cooperate in order to do so. Public health authorities, hospitals, practitioners, pharmacies, and telecom operators must cooperate in order to computerise (or ICT-rise) the health services. These parties must then cooperate with manufacturers.

These services together represent tens of billions of dollars of revenue even in a small country like Norway. If the telecom operators are able to get ten percent of this revenue, the revenue of telecommunications alone amounts to several billion dollars. Here is the crux of the problem: cooperation is complex because all the cooperating participants have only a minority influence on the business. This is a cooperative game with deep psychological constraints only recently analysed [24].

There is also other research that may have much impact on telecommunications. One such research is concerned with micro-electromechanical systems (MEMS) [25], which are micro-miniature sensors built on silicon chips. The volume of the MEMS is only a few cubic millimetres. Despite the small volume, the MEMS contains optical, electrochemical, electro-thermal or electromechanical sensors; mechanical, optical or electrical actuators, and electronic circuits for computation and storing of information, all built on one silicon chip. The MEMS can be very complex. Examples of MEMS are gyros (a modern fighter aircraft contains MEMS gyros in every movable airfoil), accelerometers (the trigger in the car's airbag), seismometers, chromatographs for micro-chemical analysis (detectors of nerve gas sewed into the uniform of the soldier), and pumps implanted in the body for micro-dosage of medicine.

Nanotechnology is concerned with even smaller structures: machines of molecular dimensions [26]. The MEMS technology exists; nanotechnology does not. However, the research effort in this area is huge and important technological breakthrough is expected in the near future. Nanotechnology will enhance the applicability of the sensor technology, and thus have indirect impact on telecommunications enabling applications as listed above.

Moore's law [26] predicts that if the evolution of the computer continues in the same way as during the last 30 years, the micro-miniaturisation technology will reach its limit in 2020: the size of one memory cell will then consist of just one molecule. The existing technology is safely based on macroscopic physics. When the size of the building blocks approaches the atomic level, quantum mechanics takes over. The behaviour of atomic devices is in all aspects different from that of macroscopic bodies, and the semiconductor technology of today cannot exist at that level. However, the research on devices called quantum computers is accelerating and possible methods by which the devices can be constructed are emerging. Quantum computation will certainly have impact on telecommunications, we do not yet see how.

So, what will happen to telecommunications in the future? People will not stop speaking to each other. Therefore, telephony will certainly exist so long as human societies based on technology exist. Telephony will still be the most important source of revenue in telecommunications. The telephone network and the simple unintelligent telephone apparatus will continue to exist because people will not see any particular advantage in always talking via their PC. The telephone apparatus – fixed or cordless – is handy to use if you only want to talk to somebody else. People will continue to move about, so mobile communications will continue to exist. However, the network providing mobile communications may be something different from UMTS. Perhaps a technology not standardised by the telecom industry will win the market, for example WLAN.

It is also hard to see that the twisted-pair access will be replaced in the near future. Twisted pairs have survived any attempt by cable television systems and information transmission on the electricity grid to replace it. The only real threat is cordless or mobile access made available everywhere: there is no reason that people should be confined to a few places in their home in order to speak with family, friends or neighbours. Therefore, I would not invest all my savings on twisted-pair access.

For all other applications of telecom not much can be predicted, this is the most important wisdom of the abrupt emergence of the World Wide Web, bringing all other data communication services standardised by the industry into obsolescence. Trends may revive dormant services such as the SMS. We cannot predict when and how this will happen.

Figure 10 shows the roadmap to the future. Have a safe journey!

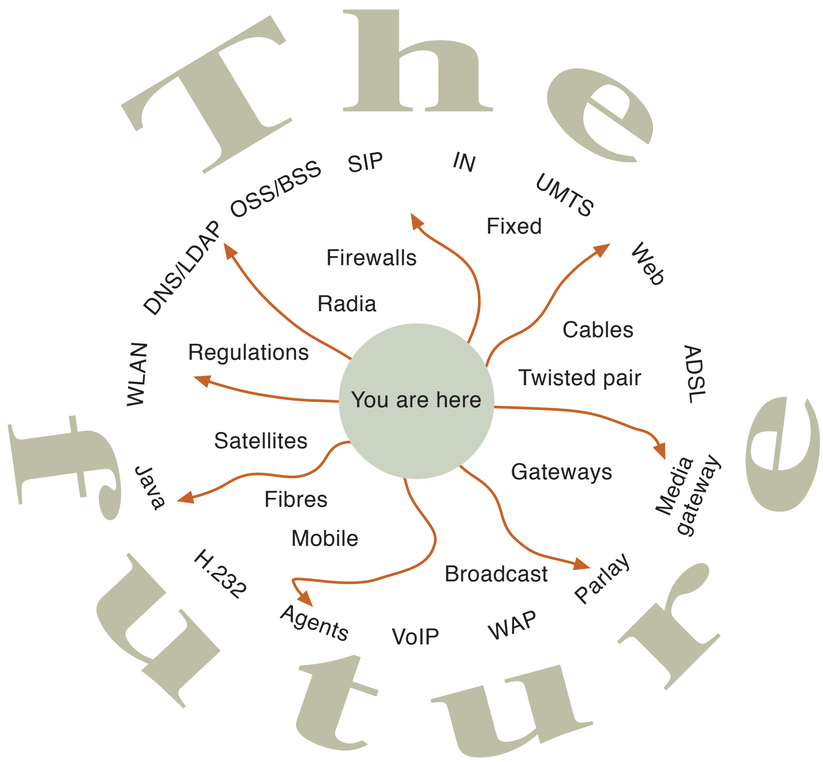


Figure 10 Roadmap to the future

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