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The basic principles behind a television set have not changed much since the 1960's, but the present transition from analog to digital TV is said to be disruptive to the industry, and is compared with the shift from analog to digital network technologies in the mobile communications industry (for an analysis of technological life cycles in the mobile phone industry see Dalum et al. 2002; West 2002). Digital TV is not only a different way of broadcasting with better quality pictures and sound, it also offers the possibility for interactive services. Instead of broadcasting analog signals, the digital signals are transmitted as compressed digital data, which requires less bandwidth. This allows for more channels within the same frequency band and makes it possible to add different services to the TV signal. The most interesting new features of digital TV are the possibility for enhanced content and interactivity. Interactive digital TV however requires a backward channel that is a link between the user and the service provider mainly provided by the telephone line through a modem or cable network. This allows the viewer to be directly involved in the program content and opens possibilities for many new services e.g. games, email and e-commerce etc. The television set itself, is still analog and it requires a converter (set-top box) to access the digital signal and services, but digital TV sets are emerging[1]. Japan was the first to launch digital TV in 1989 and other countries have followed since or at least planned to do so. The transition to digital TV has proved to be less simple than planned and even though many governments has set a date for turning off the analog broadcasting signal usually a 10-15 year period e.g. US and Germany in 2006, Sweden in 2008, these countries still have a low penetration of digital TV. This is partly related to the differences in standards for broadcasting, receiver devices and software platforms. The broadcasting standard affects the possible transmission method that set requirement for the receiver device, but these are also influenced by the software platform that allows enhanced content.

Digital TV services can be broadcasted by satellite, cable and terrestrial (the signal can be received by an ordinary antenna) or through optical fibers. Fixed line Internet can also be used as a mode of delivery, but a high bandwidth is required for digital signals, which not have been possible within reasonable costs until recent. The technological development within optical fibers and the demand for broadband Internet connections have made it possible with 'direct to home' optical fiber. The Internet combined with compression techniques for digital signals, have also created possibilities for video-on-demand, download of (pirate copied) movies and other services.

[1] Some TV manufactures have developed a digital TV set supporting the MHP standard e.g. Sony

Broadcasting of digital TV by satellite is dominating in Europe since this transmission method was standardized first, the industry is less regulated and has more competition. In addition the development of terrestrial based digital TV has caused many problem. The satellite broadcasting companies have gained a lot of power in decisions for the industry, since they have used proprietary standards e.g. a set-top box for each TV station. Likewise has the satellite receivers and set-top boxes been sold with subsidies from the TV companies. The technical change in the digital TV industry is very rapid and several sub-standards for broadcasting and services have emerged, but these are mainly proprietary. However, in Europe, the interest of governments has moved towards digital TV based on open standards and in particular the DVB (digital video broadcasting) standard with the substandard for interactive services MHP (multimedia home platform). Since the industry is highly regulated through licenses, public service TV stations and the transmission network the power of governments is considerable. The digital TV industry may potentially be disrupted by Internet technologies, since the features of interactivity and transmission of data/pictures are somehow overlapping. The entrants in the digital TV industry come from both traditional TV/consumer electronics and from the computer industry, where the firms are developing set-top boxes, MHP software etc.

In the case studies[2] we find different approaches in the move towards Digital TV from the traditional TV side as well as from the computer/Internet side. The traditional TV industry is heavily regulated with licenses, allocation of frequencies, public service and license fees, whereas the computer industry and especially the Internet has been widely unregulated. The first case is a field experiment in North Denmark with terrestrial transmitted digital TV with interactive services and enhanced content. The success of the field experiment is highly dependent on the policy decisions concerning the implementation of full scale terrestrial based digital TV in Denmark, since that decision would open the market for digital TV equipment and services. But we also find that the existing equipment on the market still lacks many technological features before interactivity can be fully explored. The second case is a manufacturer of consumer electronics that is producing a DVD player with Internet access, TV-tuner, hard disk and represents the computer alternative to digital TV, since the computer or DVD player becomes a TV, when the screen is added. The third case is about optical fiber to the home i.e. a 'true broadband' Internet connection that gives access to digital TV and video-on-demand services[3].

1 Digital TV standards

Several different standards for broadcasting digital TV exist in Japan, Europe and US. Implementing a standard like digital TV that requires very large investments has many challenges. In Funk (2002) it is described how the standard setting for digital TV in US involved several new parties. In addition to the consumer electronics TV producers, also manufacturing firms from the computer industry entered, since they saw opportunities to enter the TV marked, where their computers could be used as television receivers. Also the cable operators that are a major player in the US TV market

[2] The case studies are made from desk research and interviews with and Peter Hinrup and Jesper Rom Knudsen, Flextronics, Bent Bjørn, TV2 Nord Digital, and Kjeld Jensen from the Digital North Denmark (DDN) secretariat. Likewise is information used from more informal talks with participants and formal presentations in the DDN policy program during the DDN project partner seminars in 2001-2003.

[3] Broadband is usually defined as a 2Mbit/s or faster network connection.

and Hollywood that was worried about intellectual property protection joined the committee. The manufactures were the main driver behind the standard, but the involvement of many different and new parties, lead to various problems; The broadcasting and cable companies were mainly interested in the technology to offer more channels than higher quality programming and new services, Hollywood demanded copy protecting[4], and the computer industry wanted the standard compatible with their video graphics standard. The latter problem was solved by not specifying the display format, but the copy protection problem has delayed development of digital TVs. The US digital standard was introduced in 1996 but it favoured a high definition digital scheme that is more costly and difficult to implement compared to the European and Japanese standards. On the market side problems also emerged since the broadcasting industry operates in a highly regulated market where the government has allocated frequency spectrum and licenses, but in the case of digital TV there were no new entrants in broadcasting. This has hampered competition in introducing digital services since the incumbent service providers mainly wanted digital TV to broadcast more channels and not introduce new services As a result a chicken-and-egg-situation has emerged with the users waiting for services, before buying the digital receivers and the broadcasters waiting for customers before installing the expensive equipment for transmitting digital signals. These problems have lead to a very slow implementation of digital TV in US, whereas Europe and Japan are more successful (Funk 2002).

The work on a pan-European platform standard began in the early 1990s. The European Launching Group was founded in 1991 and among the participants were a broader group of manufactures, broadcasters and regulatory bodies. The group drafted and signed a memorandum of understanding in 1993 and thereby setting the rules by which the standard would be established and implemented. The group was renamed to the Digital Video Broadcasting (DVB) Project and worked on developing a complete digital television system based on a unified approach. The European Telecommunication Standardisation Institute (ETSI) later turned these specifications into a European standard. The European DVB organization however quickly realized that the satellite and cable would be the first deliver the broadcast of digital TV since the technology was less difficult and the regulatory system less strict. Digital satellite and cable broadcasting systems was to be developed quickly and the terrestrial to follow[5]. Consequently three standards were agreed upon DVB-C (cable), DVB-S (satellite) and DVB-T (terrestrial).

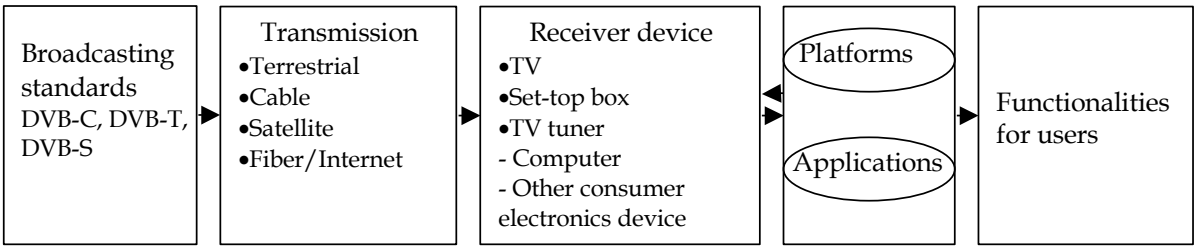
2 Digital TV

Digital TV can be broadcasted by satellite, cable, and terrestrial or through optical fiber directly to the home, but even though the content can be the same, the DVB broadcasting standards DVB-S, DVB-C and DVB-T are not compatible, since they apply different modulation methods[6]. Transmission of digital TV by satellite, cable or terrestrial uses the same frequencies as a similar transmission analog TV, but the three forms of distributions have different capacity. The bandwidth i.e. capacity of satellite broadcasting is slightly higher than cable and both are much higher than terrestrial broadcasting. The signal can be seen on a digital TV, but since almost all existing TVs are analog, a set-top box is needed to convert the signals. In satellite transmission a digital receiver is used to convert the signals. Digital

[4] Since it is possible to make perfect digital copies of a digital TV transmission without loss of quality.
[5] http://www.dvb.org
[6] Modulation is a method to modulate or change a carry wave to contain the desired information.

TV can also be viewed on a computer or any other consumer electronic device with a TV tuner card. The receiver/converter device varies with the transmission method and it has a conditional access function that can be used to allow certain users to receive specific content. The development of the DVB standard is moving towards IP (Internet protocol) by DVB that is the set-top boxes get an IP address. The receiver device also holds another function since it can be equipped with a return channel, that allows for interactivity and thus a possible wide range of services. In analog TV the extra services provided by broadcasting e.g. text TV are transmitted continuously, but with a return channel and the users has the opportunity to participate actively in the transmission, this can be further developed when a hard disk is added. The platforms on the receiver device in digital TV has mainly been running on proprietary operating system software, since the set-top box or satellite receiver has been subsidised by the TV stations. In the development of set-top boxes for terrestrial digital TV with enhanced content and interactivity the focus has been on using the open DVB 'sub-standard' MHP (multimedia home platform). The applications based on the platforms are various, but the electronic program guide (EPG) seems to be required from the governments for terrestrial digital TV. See figure 1.

Figure 1 Digital TV



Broadcasting digital TV requires less bandwidth than analog TV, since the digital signal can be compressed by different techniques. Without compression, the digital signal would demand too high capacity to be feasible. The compression[7] removes all the unnecessary information from the TV pictures before they are broadcasted and as a result, only the changes in the picture are transmitted. The capacity used to transmission varies according to the level of action in the content, the compression technique and the quality. High quality pictures e.g. high-definition TV (HDTV) requires more capacity than standard digital TV, but even with the same standard resolution, digital TV has a better quality picture than analog TV.

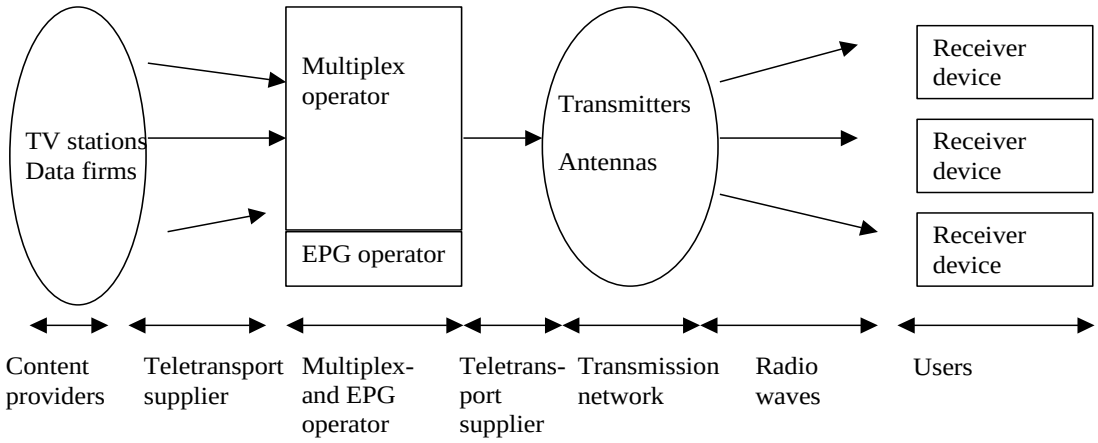
2.1 Terrestrial digital TV

Broadcasting analog terrestrial TV requires one transmission network per TV channel, and in comparison a minimum of four digital TV channels can be transmitted in a multiplex using a single network. This number is depending on resolution, compression, the number of services in the programs and the receiver conditions e.g. stationary, portable or mobile[8]. Within the multiplex a

[7] The MPEG-2 compression technique is used for digital TV.
[8] Stationary reception with a fixed outdoor antenna eases the requirement for error correction and allows for many channels per multiplex. Portable reception with a fixed indoor antenna sets higher requirements for the transmission network and mobile

number of TV channels can be broadcasted and the surplus capacity can be used for services, interactivity, enhanced content or sold to data transmission (Skouby 1998). Since the multiplex can contain more than one channel, a transmission network can be shared between different TV stations and the role as multiplex operator can also be separated from the TV stations. As a result the broadcasting structure for terrestrial digital TV changes, see figure 2.

Figure 2 Terrestrial digital TV broadcast structure



Source: Adapted from Skouby 1998

The broadcast structure for digital TV has possibilities for a new division of the tasks performed, where the functions can be combined in different ways or separated, depending mainly on policy decisions. The content providers have traditionally been TV stations with several suppliers, but firms specialised in data services can also emerge depending on the distribution of capacity. The multiplex operator is multiplexing the content from the content providers and organises the surplus capacity that can be sold to other services i.e. the operator becomes a broker. The role of the multiplex operator depend on the role of the public service TV stations, since these might occupy a large predefined share of the capacity. The EPG operator can be a part of the multiplex operator and is collecting the information from the TV stations and presenting the combined TV program guide. EPG is a political demand for digital TV, but is also important for the selection of programs and a personalised TV program guide. The transmission network with antennas and transmitters is a technical function that also can be performed independently. The transport of signals from the content providers to the multiplex operator, and from the latter to the transmission network can be done by different telecommunications service firms (Skouby 1998). The digital TV broadcast structure can be divided into several operators, but since many of the separate functions in figure 2 are technologically connected and dependent on each other, a total separation might not be attractive. This is however a political decision with emphasis on competition, culture, economics, regulation, technology and power. The EPG operator is reliant on information from the TV stations and the multiplex operator is depending on the capacity demand of all programs to maximise the use of the capacity surplus to be used in data casting. The level of competition depends on decisions regarding which TV channels that are to be transmitted e.g. only the public service channels or also commercial channels, and the

reception reduces the number of channels due to error correction. However it has to be decided from the beginning what kind of reception should be possible since mobile reception means loss of capacity in the network.

convergence between the TV infrastructure and the Internet network structure. The culture political issues are related to the transmission of public service TV compared to commercial channels. Regulation is important since the broadcasting structure can be divided into different functions in which the power relations are not equal and still unsettled. The traditional regulations of TV channels by the distribution of frequencies and licenses can't be used in digital TV, which sets new demand for regulation. Likewise can new problems emerge since data casting is under the Telecommunications Act and not under the Radio and TV Act. Pay TV and other payment services also add new problems to regulation. Regulation regarding the transmission and receiver devices is very important to avoid that programs and services use different standards and create proprietary receiver devices. The use of the MHP platform standard for interactive services and enhanced content is supposed to increase competition in the receiver market and drive prices down.

The terrestrial digital TV market is highly dependent on policy decisions and the future broadcast structure is determined by policy decisions. In countries with some degree of licence fee financed public service TV, the government will most likely secure that these TV stations will not be in a worse situation when broadcasting digital TV. However several problems in key areas seem still to be unsolved; Set-top boxes based on the MHP platform are still sparse and it still lacks certain features to allow all the services, interactivity and enhanced content that digital TV is supposed to provide.

2.1.1 Multimedia Home Platform

The political interest in digital TV has been on using the open MHP standard for enhanced content, interactivity and other services. The MHP standard was approved by the DVB organisation and made a standard by ETSI in 2000. The MHP platform is a common API (Application Program Interface) that is independent of the hardware platform it is running on. Content from different providers becomes available through a single device that uses the MHP common API. The MHP standard is independent of the hardware platform and can also be used to transmit digital TV through the Internet. The MHP platform might also change the digital broadcasting structure described in figure 2, since it allows other content providers than TV stations to enter the market. Support of the MHP platform in the set-top boxes has been a bit complicated since different versions of the MHP platform exists and only the newer and forthcoming versions can support interactivity and other services[9].

2.1.2 The set-top box

Since most of the TVs still are analog set-top boxes are needed to convert the digital signal. The set-top box is very important since it also enable the services that digital TV is supposed to provide. The satellite payment TV stations has dominated the digital TV market and subsidised the set-top boxes. Consequently they have had a lot of power in the set-top box market using proprietary standards but since the number of satellite users is lower than terrestrial (often the satellite users also uses ordinary antennas for some TV stations), the market for set-top boxes will change. The development of set-top boxes has been slowed down because the digital TV market not has evolved as quickly as supposed. However the political interest in digital TV has been on using the open MHP standard for enhanced content, interactivity and other services. By using the MHP platform it allow the user to see programs from different TV stations on the same set-top box. The large consumer electronics producers has

[9] http://www.mhp.org

waited for the mass market to develop, which has given the small electronics firms the opportunity to be in the technological front on the market with set-top boxes supporting the MHP platform. In the case on the field experiment on terrestrial digital TV by TV2 Nord Digital, they searched the market for set-top boxes supporting MHP and interactivity. The support of MHP was important since they wanted to broadcast digital TV with enhanced content and they found that most of the boxes had severe technical problems and could only display the enhanced content slowly at best. Since the users are 'supposed' to buy a set-top box to receive digital TV, the technological development of set-top boxes becomes important. In Sweden the introduction of digital TV was a failure since the user had to pay more for digital TV than analog while the programs was the same, except for a better quality picture. Many of the new interactive services, enhanced content, data casting etc. that are the main argument for switching to digital TV also rely on the set-top box and especially on features that are not added to the box yet. While the manufactures can't supply the needed technological solutions, there seems to be possibilities for new entrants to enter the market.

Enhanced content gives the user a possibility to change the content on the TV screen e.g. viewing a football game from a different angle or get information on players etc., but this is not interactivity (even though it often is advertised like that) since the enhanced content is broadcasted continuously like simple text-TV in analog TV. Interactivity requires a backward channel from the user to the service provider. The backward channel allows the user to send information to the service provider and in so doing participate active in the services and allow the service provider to send specific services or information to the user. This is a key feature for many of the new services in digital TV e.g. e-commerce, e-mail etc. The backward channel can be any kind of data transmission connection, which mainly is a telephone modem, but could be a cable modem or a GSM mobile telephone modem. The needed transmission capacity and speed should not matter that much for interactive services.

Another problem with the current set-top boxes is the need for storage of data i.e. a hard disk is needed. Many of new the digital TV services require a hard disk to avoid the problem of using the transmission capacity to transmit the same content over and over again, and to enable new services like e-mail, video mail, service information, video-on-demand etc. The price of storage capacity has declined steadily the last decades and storage capacity for a couple of movies etc. can be added for a reasonable price. Since the data transmission capacity in the terrestrial digital network is constant all day, it is possible to use the periods of the day with none or only a few programs to transmit large amounts of data. With IP by DVB it will be possible to transmit targeted information to specific groups e.g. a video mail. The set-top box still has a limitation in only converting the digital TV signal for one TV set in the household. Since many households have more than TV in the house, more set-top boxes are needed. This will increase the price of receiving digital TV and reduce the demand, until the set-top box can function as a sort of home server.

The development of set-top boxes is slow, since the demand is low. The producers of set-top boxes seem to be waiting for the diffusion of digital TV before up-scaling the development. The transition from analog to terrestrial digital TV will open a mass market, but when, where and how much, depends mainly on political decisions.

3 The emergence of digital TV in Denmark and the role of policy

Broadcasting digital TV by satellite is dominant in Europe, but terrestrial broadcasted digital TV is emerging and Internet by optical fiber to the home is becoming a real alternative as a transmission mode. The satellite companies has a head start in the diffusion of digital TV, since it is technologically less difficult than terrestrial broadcasting, the regulatory regime is more flexible and the competition is higher. The first introduction in UK and Sweden was unsuccessful since the consumers didn't want to buy converter equipment (set-top box) and pay extra for the digital broadcasting. In UK the business model was changed and digital TV has become more successful. In Finland is terrestrial digital TV also broadcasted, but it is only in the city-state of Berlin in Germany that has implemented terrestrial digital TV 'fully' by turning off the analog transmitters. The broadcasting of digital TV has, however, mainly been a good quality picture and sound and a better text TV, that is, converting the normal analog signal into digital and not utilizing the possibilities for new interactive service and enhanced content. As a result the diffusion of digital TV is still sparse.

In the mid 1990s several European countries were preparing the diffusion of digital TV and in some countries had transmission of digital TV by satellite begun. A EU directive from 1995 on standards for transmission of digital TV signals had urged the member countries to push forward the development of advanced digital TV services (Skouby 1998). In 1996 the Danish government decided to allocate the available frequencies of a possible third nationwide terrestrial transmission network to the future digital TV services. In Denmark there are two nationwide public service TV stations broadcasting terrestrial analog TV and several TV stations broadcasting by satellite, but the public service TV stations were not to be in a worse situation with digital TV than before. The Danish government wanted the cheapest and easiest transmission of digital TV with national coverage. It should also be possible to transmit regional programs, transmit many channels, have the possibility for portable reception, and allow for interactive services etc. The transmission method should fulfil most of the demands but also be the cheapest possible for the user and the TV stations.

In 1998 a workgroup appointed by the Minister for Culture delivered a report on Future Digital TV in Denmark. The Skouby (1998) report compared the four possible transmission methods with respect to the demands of national coverage, economy, costs and competition etc. The report recommended terrestrial digital TV, since the transmission method had a wide range of advantages fulfilling the demands compared with the other transmission methods. This method was preferable even though most Danish TV viewers receive the TV signal through cable, followed by terrestrial and satellite. However the cable network is not one big connected network, but several smaller networks of which some is satellite master antenna TV, that is local cable associations receiving the signal from terrestrial antennas and satellite and provide the members by cable. It is possible for these to transmit the raw DVB-T signal through the cable or convert it, but the latter option will mean loss of the interactivity. The report found that national coverage is easy obtainable with terrestrial based digital TV since the users can receive it with an ordinary antenna[10] and the users don't have to buy a satellite receiver. Likewise is it possible to upgrade the existing terrestrial analog TV network structure to digital TV. Digital TV by cable was not possible since the costs would explode when providing national coverage in one big cable network. Since a Radio and TV Act regulate terrestrial TV whereas the satellite TV is

[10] It is said that terrestrial digital TV can be received in perfect quality with a knitting needle as antenna.

not regulated by the act, there was a political demand for terrestrial digital TV. By building a terrestrial transmission network the public service stations can stay independent of paying foreign international satellite companies for transmission. Since the TV network is a part of the Danish war and emergency alertness, the government need to keep some kind of control. In satellite transmission the two public service TV stations would have to compete with many channels, while they would have an advantage in the terrestrial transmission. The satellite transmission has a higher bandwidth, but reception of terrestrial digital TV is uncomplicated and can be portable and mobile. The economic calculation also supported terrestrial digital TV, since it is cheaper for the TV stations and the users. The report recommended the establishment of a third terrestrial digital TV network and a transition period from analog to digital TV on 10-15 years. And after the analog transmission was turned off, the two networks could be used for extra TV channels (Skouby 1998). First mover advantage for the Danish service industry in digital TV was also considered as being 'not unimportant'. Competencies and knowledge on DVB services and DVB products could be very valuable, since digital TV was in an early phase and most of Europe was supposed to shift to digital TV (Skouby 1998). As a result the government decided to implement the recommendations in the report.

But nothing happened until 1999, when the two public service stations in Denmark began a test transmission of digital TV on two transmitters to experiment with digital TV[11]. In 2000 the government appointed a new workgroup to see if any of the recommendations and conclusions had changed since the last report in 1998 and examine the possibilities to combine interactive broadband services with terrestrial digital TV. The new report concluded that provision of digital TV by the broadband services available at that time was not the best solution due to the requirement of national coverage and price (Skouby 2000). Digital TV was, however, seen as a step towards the creation of the information society. The conclusion and recommendations was not changed, but the report stressed the importance of beginning transmitting digital TV with interactive services as soon as possible, not to fall behind the rest of Europe and since the transition period was recommended to be 10- 15 years (Skouby 2000).

The government decided in 2000 to create four digital TV transmission networks with multiplex, thus allowing 15-20 channels of which four was reserved to the public service stations. Negotiation regarding the frequencies began with the neighbour countries and since the first set-top boxes not was expected on the market until 2002, allocation of channels and transmission of digital TV was supposed to begin in 2002. However there was disagreement between the parties behind the agreement. Especially problems regarding the economy of the project and the distribution of the 15-20 available channels, led to disagreement. The unsuccessful introductions in UK and especially Sweden with very low penetration ratios, added to the problems and the decision on when to begin transmitting digital TV was making slow progress. In 2002 the new Danish government decided to invite tenders for the new digital transmission network. Existing operators or program suppliers with a dominating position on the Danish market was not invited to submit tenders and the government wanted to turn off the analog transmission network in 2007. The decision was changed in early 2003 due to the economy in the project and in September 2003 a less ambitious plan was finally accepted[12]. Instead of four multiplex with four channels each, it was decided to build a single transmission network for terrestrial TV with four channels. The four channels are to be divided between the two public service TV

[11] http://www.dr.dk/omdr/teknik/dvb/rapporten.htm
[12] http://www.kum.dk

stations. It will not be new channels, but existing channels broadcasted digital with enhanced content and interactive services. The TV stations are required to develop new digital programs and services, but analog broadcasting is expected to continue for another 10-15 years. The digital TV will not be payment TV, but the users will have to buy a set-top box. The industry have been invited to a consultation regarding the establishment of a terrestrial digital TV network, that is supposed to be completed and broadcasting the 1st July 2005 at the latest.

This plan seems to be put into work after seven years of discussion and four decisions to build a terrestrial digital TV network, but Denmark seems to have lost the opportunity to become first mover or even between the first, even though the diffusion of digital TV has been slow all over Europe. The industry is still in a phase of disruption, which might hold some opportunities for the Danish digital TV industry, but the home market seems not to be the main demand driver. The new plan is not ambitious and has unfortunately some similarities with the Swedish approach. This raises a question of who will buy a set-top box, when the services and TV channels are few for the next many years? The potential opportunities created by being an advanced user seem to be replaced with a reluctant user following behind the lead users.

4 Terrestrial digital TV: TV2 Nord Digital[13]

In 2001 the local affiliate in Northern Denmark of a national public service TV station, TV2 Nord, founded a new company with the purpose to begin broadcasting terrestrial digital TV. The idea behind the TV2 Nord Digital project was formed when the region of North Denmark in 1999 was selected as a region for the Digital North Denmark (DDN) ICT policy program. When the project offers began in early 2000 it was accepted and supported with 6 million Dkr (0.8 million €), which was less than 1/6 of the total amount in the project. The project also got support from the European Objective 2 funds. There were several partners behind the project e.g. a TV station, which was to supply the employees, a large bank interested in the possibilities for e-commerce via digital TV, a science park that wanted to support the local activities in the digital TV industry, the local municipality and several content providers. The project was to begin in early 2001 and the first broadcasting in late 2001. The partners behind believed that terrestrial based digital TV had finally been decided on politically in Denmark with the law on the media effective until 2004 and the Danish Minister of Culture allowed the transmission network to be digitalized and the project to begin broadcasting. The law was changed in 2003 with a less ambitious plan for terrestrial digital TV as described in section 3. The purpose of the project was:

> *"The citizens of North Denmark may be the first to have digital TV available in a version that makes the contents interactive, and creating a convergence between the Internet and Television. … With the digital channel, TV2/Nord will be able to broadcast a lot more regional news than today... In the new digital channel the Internet or parts of it is integrated in the TV set. E-business and home-banking should be made available over the remote control, and it is planned to establish a*

[13] http://www.tv2nord.dk/default.asp?kategori1=program&id=207

regional activity and event calendar with text supplemented by film and video clip."
(Project description on www.detdigitalenordjylland.dk)

TV2 Nord Digital was founded in 2001 and the employees were mainly freelancers or employees on leave from the mother TV station.

4.1 Technical problems

Terrestrial digital TV was known from other places in Europe, but not with transmission of enhanced content or other interactive services based on the open MHP standard. Terrestrial digital TV consists of video, audio and enhanced content, but the combination of the three is very difficult. When the project was known, many companies who wanted to sell MHP applications and set-top boxes contacted TV2 Nord Digital. Most of them did however only have technical solutions based on proprietary standards and due to many problems regarding software suppliers the company decided to develop its own basic software tools to be used in developing MHP applications for making TV programs. New specifications of the MHP standard version 1.01 and 1.02 was released in the development phase, which was a clear improvement compared to earlier versions. In this early phase the development of applications for games, betting, e-business and home-banking etc. was given a lower priority. Instead the focus was on creating enhanced content. They found out that the promised technical possibilities in digital TV are many and widespread, but at present there are also many limitations in the MHP standard and set-top boxes. Even though the project progressed fairly slowly with delay, it attracted a lot of attention from other TV stations, whereas interest from the large equipment manufactures was sparse. A group of test persons have tested digital TV with enhanced content for six months and a new group are receiving digital TV with interactivity (backward link through a modem) and a small hard disk for a few months now. The results of the first round of test are still being processed, but the first preliminary results show that the users have been more positive than expected, even though the first group had experienced some technical errors and omissions, and had high expectations of the new form of TV.

TV2 Nord Digital is running many tests on their systems and has gained a lot of experience in building and running a digital TV station. The new TV station is running fully digitalised and in the evenings it is unmanned and controlled by an employee working from home on a laptop[14]. Many foreign TV stations have been visiting TV 2 Nord Digital to gain inspiration and advise. The TV station has also begun some consultancy business in helping other TV stations. The broadcasting equipment is not supplied by the big equipment manufactures, but compiled from many smaller suppliers combined with own solutions. It was possible to buy a complete system from the big equipment manufactures, but the price was too high. The test of equipment has attracted some manufactures and some degree of cooperation has taken place.

The set-top box has created many problems for TV 2 Nord Digital, since they wanted to broadcast with enhanced content in the MHP standard. Many of the manufacturers of set-top boxes did not have the claimed MHP compatibility, this was the same with the broadcasting equipment, and even though they said that their equipment was working fully functional in Finland, Australia or any other place

[14] The live transmission is supplied from the mother TV station.

with digital TV, but it was not true. TV 2 Nord Digital ran many tests on different set-top boxes and only found a few that was able to support enhanced MHP services, but only one set-top box developed in Poland was able to do it with a reasonable speed. They began a close dialog with the firm about correction of errors and future development, and subsequently the company was chosen as supplier of the couple of hundreds set-top boxes for the test users. They have also used the digital TV tuner card for a computer in their tests and have tested a Sony digital TV set that supported MHP.

During the test period, they have discovered several problems with the set-top boxes and need for further technological development. Especially the need for a hard disk is urgent, since it hampers many new possible services. The hard disk will increase the price of the set-top box, but a possible business model can be to subsidise the box by allocating a part of hard disk to commercials, public information etc. The return channel is now working by a telephone modem, but this sets many limitations in speed, location in the house and use of the telephone line. A different form of return channel e.g. a mobile telephone modem would be an advantage. It is not possible yet to use a cable modem as a return channel. Likewise is it a problem that the set-top box only can be used to convert digital signals to one TV set, but many households have more than one TV in the house and will need several set-top boxes. The problem of the return channel has recently been 'solved' by another North Denmark based company, RTX Telecom working with wireless communication technologies. They have signed an agreement with Australian subscription television provider FOXTEL for the development, production and supply of wireless telephone line extenders[15]. The product uses DECT technology in a special configuration that enables the transmission of modem signals at speeds of up to 56kbit/s. This will simplify the installation of modems and the cabling, and the return channel enables interactive services e.g. pay-per-view.

Terrestrial digital TV can only be received with an antenna, which is a problem for the many cable TV users in Denmark. More than half of the Danish households receive TV through cable, which is not able to receive the DVB-T signal and it is inconvenient to put up a normal antenna to receive the signal. Many of these cable TV providers, however, receive the signal through an antenna and transmit it through cable to the households (satellite master antenna TV). It should be possible to transmit the DVB-T signal through cable, without converting it to a cable signal, thus making it possible to access with a set-top box. This solution is being tested at present and the price for this arrangement is expected to a very low amount[16]. An alternative solution is to convert the signal to a cable signal, where the user needs to have a DVB-C supported set-top box.

The integration of an Internet browser in the set-top box is also a possible future technological development that will add to the convergence between TV and Internet. This is a part of the IP by DVB development that is interesting and might change the role of digital TV and give terrestrial digital TV, DVB-T, an advantage compared with the DVB-C and DVB-S.

4.2 Content and business models

Making TV programs with enhanced content demands a new way of planning and thinking compared with traditional TV. One of the experiences with the project is, that it is not sufficient to add

[15] Announcement the 30th September 2003 by RTX Telecom, see http://www.rtx.dk or http://www.foxtel.com.au
[16] The costs is approximately 1300 € per local cable network.

extra content to existing TV programs, it has to be thought into the program from the beginning. After a while it should be feasible to adapt a new way of thinking and it gradually becomes easier to produce the enhanced content. TV 2 Nord Digital has developed MHP application tools that makes it easy to add enhanced content, but is has to be planned before making the program. Programs with enhanced content demands more resources to develop and produce, which creates extra costs that have to be financed. This raises questions whether the user want to pay extra for receiving the enhanced content i.e. does the extra value compensate for the extra cost.

Solid business models are still missing for terrestrial digital TV industry, mainly because the diffusion of terrestrial digital TV is still sparse, but also since the user has to buy a set-top box, before receiving the signal. The price of a set-top box has dropped the last few years and will probably continue this path, like any other consumer electronics products, when the demand increases. The value of the new digital TV services has to be higher than the cost of the set-top box and also higher than a possible higher license fee like in Sweden. It can be a problem to attract a critical mass of consumers, especially since the analog signal will be broadcasted simultaneously in Denmark for the next many years. And the extra cost of producing enhanced content and interactive services is a fixed cost independent of the number of users. Digital TV is a network good as described in Shapiro and Varian (1999) with large sunk costs in establishing the transmission network and broadcasting equipment. Technical problems with the set-top box regarding return channel, hard disk etc. has setback the interactive service that should attract users. Without interactivity or enhanced content, what are the benefits for the users? Likewise has the delay in launching digital TV combined with the increasing number of high speed and broadband Internet connections also put pressure on the future digital TV services, since the users are used to high speed Internet services, so who want to shift to similar services by digital TV? Especially if these are slower, due to transmission capacity and the telephone modem backward channel etc. There are, however, differences in the situations when using the Internet and the TV, since the user of the computer and Internet is actively participating viewed from 2ft, whereas the TV is often used by more than one, focused on entertainment viewed from 12ft. But the services can also be complementary e.g. the TV2 Nord Digital has had a great success with a slimming treatment, where the Internet and digital TV have been used as a complementary combination.[17] Participating in the treatment has been free, financed by commercials and the local county.

The revenue in digital TV is believed to come from games, betting, e-business, interactive commercials and pay per view. Some of these features are possible today, but others await the technological development of the set-top box, broadcasting equipment and diffusion of digital TV. TV2 Nord Digital has already made an interactive commercial service that is being tested by the users at the moment. The commercial is for a nationwide estate agent and has some similarities with their homepage, where the user can click on extra information and search on available homes for sale. There has been some smaller reprogramming of the enhanced content compared to the information on the Internet and the speed, is said, to be comparable with an Internet connection with a 56kb/s modem. This raises the question of why making the digital TV commercial if the speed is rather slow compared with the high-speed Internet connections i.e. why should the user use digital TV instead of the

[17] The users have used the Internet to control the weight etc. and TV programs with enhanced content have been used for recipes etc.

computer. The digital TV commercial can be used by people with no Internet connection and should be easier to use and the idea is to combine it with a TV program on estates. The digital TV, however holds an advantage in the technical possibilities in the use of pop-up notices e.g. in a TV program or shortly after, a notice pops up informing the user of some interesting enhanced content or interactive services, that can be reached by clicking on the remote control. If digital TV services and Internet services are complementary, supplementary or substitutes are still to be seen.

5 Compression techniques, TV-tuners and the computer: Flextronics International Denmark

Flextronics[18] in Denmark is specialized in contract manufacturing of advanced electronics, until recently most mobile phones, but to an increasing extent also DVD-players, Bluetooth headsets, set-top boxes and similar products. The company provides total solutions including prototyping, industrialization/technology transfer, component sourcing, highly automated production, high volume production, total box build concept, worldwide distribution and after sales service. Flextronics is producing a DVD player for a small Danish company, KiSS Technology[19]. This DVD player was the first player in the world, that could play movies in DivX compression format and it also has a built-in Internet connection. This markets appears – until further – to have very big opportunities. The huge consumer electronics giants are apparently locked-in in their more "TV-based" approach at the moment, but that may change, and if/when so probably with dramatic speed.

KiSS Technology has a contract with a Silicon Valley based company providing them with chipsets that can decode all kinds of compression format and also the MPEG 4 standard and the substandard DivX. The compression formats and related programs are becoming better at compressing large amounts of data and the computers are becoming more powerful in terms of speed and RAM, which is needed since the unpacking of compressed data demands a lot of power. Combined with high-speed Internet connections it is possible to download movies, burn it on a CD-ROM, put it in the DVD player and watch in on the TV. Many of the movies that can be downloaded are, however, not legal (pirate copies), but new services are popping up, with legal downloads and video-on-demand. The improvements in the different technologies makes it easier to download, copy and share movies and TV programs. The computer world and the TV world are converging, but are very different. The computer users have control of own network and can add anything they choose, which gives the user many choices, whereas the TV world is closed with carrier control. Free file sharing on the Internet is competing with pay per view on TV.[20] KiSS has been the only firm with a DVD player on the market with support of DivX and the multinational consumer electronics companies seems to be stuck in a 'traditional DVD world', where the consumer rents or buys a DVD in a store. The players also have a network plug, which allow the DVD player to be connected to the Internet, at present it only support emails and Internet radio, but this is changing in the new models. The current version of the DVD player has a hard disk built in. This allows the DVD to be connected directly to the Internet and also function as a personal video recorder (PVR) with many new features e.g. recording and playing on same time, that allow the user to stop a program and resume viewing after a few minutes, thus seeing

[18] http://www.flextronics.dk
[19] http://www.kiss-technology.com
[20] Preben Mejer TDC, Katrinebjerg Innovation Lab

the program with a short delay. This will change the market for TV ads, since the user can start watching with a few minutes delay and skip all the ads. The next step in the development of the DVD player is adding an amplifier and a dual TV-tuner. The dual TV tuner is for analog and digital TV and makes it possible to watch TV if a screen is connected. This development path seems to indicate the TV is changing form. The DVD player connected to loudspeakers and a screen will be the combined TV set. This puts the focus on the development in display technologies, since these easily can be connected to the DVD player. In display technologies there is a move from traditional electron beams screens towards TFT/LCD, plasma and projection or others like organic/polymer LED.

The DVD player is however not the only move from the computer world towards the TV world, since it also is possible to receive analog or digital TV with a TV tuner card in the computer connected to an antenna, cable or satellite receiver. Then it is possible to watch digital television on the computer, or on a connected screen or TV. The computer can be used as a TV and the consumer electronics set-top boxes or DVD players are turning into small computers.

6 Optical fiber direct to the home

The rapid technological development in the optical fiber industry combined with falling prices has made optical fiber direct to the home a real alternative as an Internet connection. Optical communication (transmission with light signals) has usually been used in the Internet and telecommunication backbone, but the increasing demand for data capacity i.e. speed in the network by the ordinary users, has made it clear that the best development path in Internet connections is to pull an optical fiber cable directly to each home. The broadband connections can be used to transmit digital TV signals. Sweden has been among the lead countries in the use of fiber direct to the home. In Denmark has the construction of an optical fiber network with fiber to the home been delayed because the lack of political support and commitment. The idea is to design an optimal network according to the existing infrastructure, households, firms and public organisations and coordinate the digging of fiber according to the overall plan, when telecommunication and other firms are laying down cable or sewer etc. The information infrastructure is as important as the more physical infrastructure e.g. roads and power, but the planning of the information infrastructure is not coordinated and controlled by public authorities. This uncoordinated process is creating an enormous waste since nobody knows who is laying down fiber optical cable, when and where. The price of laying down cable is mainly determined by the digging, whereas the fiber optical cable and an extra empty plastic tube[21] are rather cheap. Especially in the cities, the digging is very expensive. By planning the optimal infrastructure and coordinate the digging activities[22] it is possible to build a complete optical fiber network with fiber direct to the home at a reasonable price. The combined demand from public organisations, firms and private homes will make it economic profitable for one or more operators to build the network or a part of it. The operators can be telecommunications firms, private building associations, district heating firms or power suppliers etc. [23]

[21] With an empty plastic tube it is possible to lay down extra fibers when the capacity is needed, without digging, since the cable can be 'blown' through the empty tube.
[22] Whenever there is digging by telecommunication firms, power plants, district heating firms, public sewer service etc there are to be put down optical fibers or empty tubes.
[23] See also http://www.nordjysknetforum.dk/

Especially the power suppliers have been interested in entering the market for broadband Internet connections. In North Western Zealand in Denmark the power supplier has begun offering optical fiber direct to the home to its customers[24]. At present they only offer the optical fibers to customers in the cities and only in neighborhoods with a sufficient number of interested customers. They are building a network consisting of several local city networks combined with a larger backbone network. The customers can choose between several subscriptions depending of the services they want e.g. Internet, telephony and/or TV. The TV customers get a set-top box with a hard disk, which allow then to watch TV (when it is connected to a TV set) and also use different service e.g. e-mail and video-on-demand[25].

Optical fiber direct to the home is an alternative transmission method for digital TV, but will probably be more complementary to terrestrial digital TV due to the requirement that the public service channels has to have national coverage. The construction of a national, optical fiber to the home network will take some years depending on the political climate, whereas a terrestrial transmission network relatively easily can be built, since less than 20 transmitters can cover Denmark.

7 Key actors who can move or block the process of fusion

Both in the TV side and the computer side we find several key actors that, in the current market situation can play a crucial role in the process of fusion and development of the market for digital TV. The actors can however be divided into demand side, technology side and regulatory bodies:

- In digital TV we can distinguish between different transmission methods, since the most important key actor in terrestrial digital TV is the government. In Denmark they decide whether digital TV should be broadcasted, how many channels, how the market should be regulated, how many channels should be available, when the shift to digital TV should be completed etc.
- After the government decision regarding digital TV, the new key actors are the two nationwide public service TV stations in Denmark.
- In satellite digital TV the key actors are the big multinational satellite TV stations.
- The role of demand in the understanding the opportunities and the services offered by the new technology solutions is important for all digital TV approaches.
- The commitment of public administration to act as a key user in the development and diffusion of optical fiber to the home broadband Internet connections and in the diffusion of broadband services.

8 Interaction between actors

From the case studies be find the following interaction between the actors. The interactions is collected in an interaction matrix, see table 1.

[24] http://www.nve.dk
[25] The selected video is downloaded and saved on the hard disk and the user has 24 hours to see it, but can pause, reverse, stop or see it whenever they want.

Table 1 Interaction and power between the actors matrix

	Interaction with technology providers	**Interaction with technology users**	**Interaction with technology co-developers**
Larger size/power than the other party	**Feature Request** (I.e. a supply contract) **TV2 Nord Digital** (with content providers) **Flextronics** (with KiSS technology)	**Independent design of the technology** (taking into account feedback from selected users, or including as many features as possible) **TV2 Nord Digital** (with users)	**Definition of interface specifications** (with which other developers of other components of the platform have to comply)
Equal size/power as the other party	**Joint definition of features** (provision of feedback for technological design). **TV2 Nord Digital** (with broadcasting equipment suppliers and set-top box developers) **KiSS technology** (with chipset supplier)	**Joint Definition of features** (maybe through a partnership or inside a standard setting forum).	**Joint development of the technology** (possibly inside a standard setting organization).
Smaller size/power than the other party	**"Off-the-shelf" purchase of the technology** **TV2 Nord Digital** (with broadcasting equipment suppliers and set-top box developers)	**Feature Implementation.**	**Compliance with interface specifications** (defined by other co-developers).

Source: Structure adopted from García and Steinmueller (2003)

- **Interaction with technology users**
    - TV2 Nord Digital has interacted with many users testing the services and programs with enhanced content.
- **Interaction with technology providers**
    - Since TV2 Nord Digital is among the first TV stations in Europe to broadcast terrestrial digital TV with enhanced content, they have tested equipment for set-top box manufactures and provided feedback for technological design.
    - TV2 Nord Digital has tested equipment for broadcasting equipment manufactures and set-top box manufactures that have larger and equal size and power than TV2 Nord Digital.
    - In the case of compression techniques, TV-tuners and the computer Flextronics cooperated with KiSS technology in the manufacturing of DVD players, thus reducing the time to market of the product and helped with financing. Flextronics has a larger size and has more power than KiSS.
    - KiSS also interacted with the Silicon Valley based chipset manufacturer

9 Discussion

Digital TV represents a disruption to the TV manufacturing industry. Due to the disruption it could be possible for new firms and diversifiers from different industries to enter the market. But the digital TV industry may itself be disrupted by Internet technologies, since the features of interactivity and transmission of data/pictures are overlapping. The area of refraction in digital TV is especially characterized by the different approaches in the move towards Digital TV from the traditional TV side as well as from the computer and Internet side. The traditional TV industry is heavily regulated with licenses, allocation of frequencies, public service and license fees, whereas the computer industry and especially the Internet has been widely unregulated. The interactions of these groups are adding to the disruption in the industry.

The growth of the digital TV industry has however been hampered, since the roll out has been much slower than expected. This has slowed down the technological development of set-top boxes, software etc., since the firms seem to be waiting for the diffusion of digital TV before up-scaling the development activity. The large consumer electronics producers has waited for the mass market to develop, which has given the small electronics firms the opportunity to be in the technological front on the market with set-top boxes supporting the MHP platform. The transition from analog to terrestrial digital TV will open a mass market, but when, where and how much, depends mainly on political decisions. However several problems in key areas seem still to be unsolved; Set-top boxes based on the MHP platform are still sparse and it still lacks certain features to allow all the services, interactivity and enhanced content that digital TV is supposed to provide. Likewise are business models missing and it is still uncertain if the users want to pay for the better quality picture, enhanced content and interactivity.

Several standards have emerged on the different continents, where the European DVB standard seems to be the most successful. Within these standards there are several substandards depending on the transmission methods: satellite, cable or terrestrial. The transmission methods have different advantages and limitations, and the TV companies are competing using different transmission methods, where the satellite companies and subsequently digital satellite TV has had a head start, since the DVB-S standard was created first, the competition is harder and the regulations less strict. But terrestrial and cable have more users and are expected to be the most important for the industry especially since most European countries have decided to build a terrestrial digital TV network. The focus on the open MHP platform for terrestrial digital TV also seems be an advantage for the further development and diffusion of digital TV.

The combination of the delay in the roll out of digital TV, the rapid technological development in and falling prices of optical fiber, and the demand for broadband Internet connections have made optical fibers direct to the home to become an real alternative transmission method for digital TV. There are however some problems in this transmission method, which is the demand for national coverage. It is also the limitation for cable transmission, that it is impossible to supply all households, which is important for the national license fee financed TV stations. The optical fiber will probably be more complementary to the terrestrial based digital TV, but it is also a substitute for some of the services that digital TV was supposed to provide. The problems are the limited speed in the return channel, the missing hard disk, IP over DVB and limited transmission capacity etc. The speed of the

interactive services is important since it could easily be a major turn-off factor for the user, this is especially important for the services that also can be found on the Internet e.g. why should the user search for a new home via the TV or use video-on-demand, when similar services can be accessed with a computer at a much higher speed.

In the period of uncertainty between two technological life cycles the barriers to enter an industry seems to be lower (Klepper and Simons 2000). Under the uncertainty of disruption it may prove next to impossible, not least for small countries, to navigate and react upon future threats. However for some technologies, where dependence of regulation and standardisation is outspoken, smallness may also contain a source for exploiting the threats and turn them to opportunities. When the future consumption structure, in this case digital TV, is unsettled, experiments with consumption patterns may prove to be an adequate way to reduce uncertainty and promote technological development. Even when taking into account that the search for appropriate solutions has some priority at the global level among the large multinational companies, although at present they seems to be waiting. But such social experimentation requires unique capabilities to combine public or private regulation, public R&D initiatives as well industrial efforts at a broader level. The experimentation in the case of TV2 Nord Digital could be a step in this direction, but since the industry is highly regulated the power of government is considerable. The experiment in North Denmark cannot create competitiveness for the local industry in itself, but can provide some guidelines for the companies, especially if the Danish government had decided on a full-scale implementation of digital TV. Since the two major TV stations in Denmark are public service channels financed at least partly by license fees, an ambitious plan for a fast transition from analog to digital TV could have created some interesting perspectives on the role of advanced demand and social experimentation. However the Danish government have lately decided upon a less ambitious plan, which could undermine the entire experiment in North Denmark, especially if they are not allowed to continue the transmission after the test period. Denmark is likely to have lost the opportunity to become first mover or even between the first, even though the diffusion of digital TV has been slow all over Europe. The new plan is not ambitious and has unfortunately some similarities with the Swedish approach. This raises a question of who will buy a set-top box, when the services and TV channels are few for the next many years? The potential opportunities created by being an advanced user seem to be replaced with a reluctant user following behind the lead users.

One of the main concerns is the price of the shift to terrestrial digital TV. The transmission network and parts of the broadcasting equipment have to be upgraded and more importantly, the users have to buy a set-top box. It is necessary for the users to purchase set-top boxes to convert the signals, but there are still technical problems with the set-top box regarding return channel, hard disk etc. has setback the interactive service that should attract users. Without interactivity or enhanced content many of the benefits for the users are missing and in combination with a long transition period it could result in an undesirable chicken-and-egg-situation with the users waiting for services, before buying the digital receivers and the broadcasters and regulatory waiting for customers before expanding the networks, and increasing the enhanced content and services. In countries with some degree of licence fee financed public service TV, the government will most likely secure that these TV stations will not be in a worse situation when broadcasting digital TV, which could result in a slow diffusion of digital TV. This seems to be the situation in Denmark.

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