Digital TV — a survey

Norsk Regnesentral
ANVENDT DATAFORSKNING

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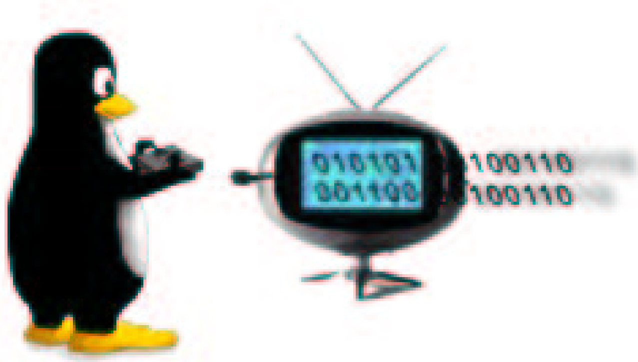
RAPPORT/REPORT



Report 988

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Sammendrag/Abstract:

NR researchers have looked into the possibilities for digital and interactive TV. Digital TV will give advantages for all involved parties, but results also in technical challenges. Issues like interactivity, return channel, new programme formats, etc. are discussed. There will also be integration between broadcasting and Internet technology, with enhanced possibilities for the user, producer, and service provider.

This report looks into the different techniques that enhance the television medium with interactivity. New services as the Electronic Programme Guide (EPG) will be available. A return channel by modem or cable will enable the TV set to access multimedia content and additional information, download software, and give possibilities for electronic commerce. The user will receive a set-top box for the TV set.

Standards and initiatives available within digital and interactive TV are presented. Many manufacturers with different techniques are on the marked with their products. A survey on some of the most promising techniques is given, including MPEG, DVB, NorDig, and ATVEF.

We also look at software available within the wider area of digital TV, and present a selection. In order to demonstrate some of the new aspects, demonstrator applications were developed, and we share experiences from these implementations with our audience.

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Preface

Background

This report is based on a previously published note by W. Leister, L. Aarhus, T. Karlsen and A. Kluge in 1999 [25]. Much has changed since then, and this document hopes to capture those updates. Recent developments have been both enabled and constrained by new regulations and new technology. The most important news since the 1999 version of this document is that the long-awaited MHP standard has been released and is being widely adopted.

This document, as well as its predecessor, is the result of projects at Norsk Regnesentral having the joint goal to obtain an overview over digital TV and to provide some indications about the consequences of this new technology. The material in this document is based on textbooks, WWW Internet sites, and material provided by manufacturers and organisations. Due to the pace of technology advancement, some standards or products mentioned in this report may already be obsolete at time of reading.

This digital TV project is part of the Channel S research program at Norsk Regnesentral in 2002; the thesis of Henrik Olsen at Ifi, Universitetet i Oslo (image based rendering and digital TV) [39] is being done in conjunction with this project. Other research projects within the Channel S program might also be of interest for the reader. These include work addressing open source distribution of multimedia, image encoding with wavelet technology, and multimedia multi-channel production[1].

Organisation of the document

Part I presents an overview of digital TV technology. It begins with clarifications about the distinctions between different kinds of digital and interactive television offers. Thereafter, it focuses upon individual topics such as roles in the value chain, transmission issues, program manifold, new services, interactivity and cost concerns. In Section 3, related multimedia initiatives, including the work of the ATVEF and MHEG initiatives, is presented.

Part II presents our practical experience with building a digital TV environment, along with information about the demonstrators which were implemented.

Part III addresses technical issues with a presentation of relevant topics in standards and existing technologies. First, we present the DVB-compliant architectures for digital TV in Section 6. Relevant parts of the MPEG standard are outlined in Section 7.

Part IV contains a software catalogue of programs used within the field of digital TV. This catalogue includes information about software for encoding and decoding; software for playing, recording and editing; server- and client-side software and more.

Since many new terms are introduced with this technology, a small glossary with explanations for terms within the field is provided in Part V. A section of references concludes the report.

Of specific note, the following topics are not discussed in this document:

- enhancements to analogue TV
- High Definition TV (HDTV)
- videotext (e.g., Text-TV, Teletext).

The reason for excluding these topics is that they are not of central interest with regard to the focus of project work.

[1]For more information, see http://www.nr.no/channelS/projectPlans/projectPlan2002.html.

Part I
What is Digital TV?

TV has more than fifty years of history, and most of the readers should have experience with the medium. Readers interested in historical aspects of TV are referred to a DVB feature article [42]. In recent years television has played a more important role in our everyday lives, for both entertainment and information. The television set has become both a family member, as well as a window on the world. The concept of television is still of a purely receptive nature: a few broadcasters send their content and many households passively receive it. However, the fact that many send SMS messages to the channel in these days show that users want interactivity.

TV broadcast services have been using analogue techniques both in production, distribution and presentation. Digital TV will bring integration between broadcasting and Internet technology, with enhanced possibilities for the user, producer, and service provider. In basic digital TV, the media streams will be digitally broadcast in the MPEG standard. Most satellite broadcasts are already operating digitally, while analogue transmissions are being switched off. Digital terrestrial broadcast networks are underway.

The DVB (Digital Video Broadcast) Forum has defined standards for transmission, API, and equipment. Additional services, such as the Electronic Programme Guide (EPG) will be available. A return channel may provide services like electronic commerce, games, and access to multimedia-material on demand. Since the user interface may be driven by a remote control instead of a keyboard, the dialogue patterns must be adapted to the new medium.

The use of digital techniques for TV enables the possibility for for more channels, as well as better video and auudio quality. The main issue will be the possibility for various forms of interaction. Finally, the introduction of digital TV will have an impact on the production process of the material presented.

Digital TV can be placed between broadcasting, WWW, and Multimedia techniques, as illustrated in Figure 1. The WWW as an interactive medium may melt together with the broadcast techniques in the Internet-enhanced analogue set-top boxes. Other techniques, such as Virtual Reality, and Multimedia will increase the scope of possibilities, including games. Using the possibilities of MPEG, digital TV can provide us with consuming TV content, interactive TV, multimedia, and information terminal functionality. It is the combination of these techniques which opens up new possibilities.

Several publications have been made recently that present a picture of the future in an information society, including visions of digital TV [35, 18]. In these publications TV is presented as one integrated part in an information-network rather than a separate phenomenon. While these publications approach the topic from the computing perspective, the broadcasters might draw another picture [7]. It is likely that a mixture of both views will describe the phenomenon of TV of the future.

While the areas covered in this report are rather wide, we cannot expect that the reader is familiar with these technologies. However, knowledge of Internet and Web technologies are required

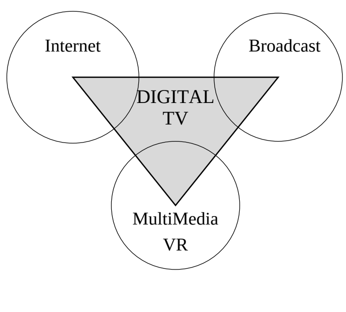

Figure 1: Digital TV will combine applications from the Internet, broadcast technology and multimedia

(see `http://www.ietf.org` and `http://www.w3c.org`). The reader should have a basic understanding of computer science in general; for certain sections, a basic understanding of operating systems is also required.

1 Characteristics of Television: Today and Tomorrow

To receive digital television, end-users will connect to their TV set a **set-top box** or, alternatively, some kind of computer with additional digital TV features. A set-top box is a device which enables the owner of analogue TV-sets to receive digital TV signals, analogous to the way cable decoders enable users to receive cable programs which have been purposefully scrambled. For Digital TV, the signals are received and processed digitally in a set-top box (or equivalently-enabled DTV computing device). Enhanced and interactive services are possible with more advanced hardware and software in the set-top boxes, as specified within the Media Home Platform (MHP) standard[2].

The definition of the DVB set top box, and the definition of the MHP as an API are the most important steps towards a more general use of the digital TV technology. Digital TV profiles defined by the MHP standard are: (1) enhanced broadcast profile, and (2) interactive broadcast profile, which characterize the new possibilities. MHP profiles are discussed in Section 6.2.

In our previous report [25], we extended a classification on digital TV profiles by Brandrud [7]. This extended classification, now adjusted so as to be in accordance with DVB terminology definitions, includes the profiles below:

1. **Enhanced analogue TV** gives the possibility for Web browsing, email functionality, information retrieval, electronic commerce, and to some extent access to smart house functionality. Analogue broadcast TV will disappear in the near future however, due to governmental regulations as well as technical and commercial reasons[3].
2. **Basic Digital TV:** The signals from the broadcaster are coded digitally, usually with the MPEG-TS format. The digital set-top box converts the digital signal to the analogue TV signal. Additional functionality as the access to an EPG (electronic programme guide) is provided.
3. **Enhanced broadcast profile / Advanced Digital TV** needs additional processing power and memory in the set-top box for advanced applications. This might include use of the carousel method used to download programs.
4. **Interactive broadcast profile / Internet Enhanced Digital TV** provides the consumer with a return channel (usually using modem or cable technology). This can be used to achieve a channel to the providers, and open up for Web browsing, email functionality, information retrieval, electronic commerce, etc.

1.1 Roles

In the following, we discuss different primary roles in the value chain for television, from content creation to consumption. The roles described in this review are relevant to both television in its current form as well as its digital and interactive forms.

In order to help describe changes in roles as television becomes digitally-based, we begin by naming just a few of the tasks/actions in the value chain which can be be performed or supported digitally:

- Production: programs and program content can be recorded, edited and assembled in digital form.
- Content: digital content can be dynamically "personalized" and distributed to individual users.
- Transmission: content can be transmitted and distributed digitally using standards such as MPEG-TS, MPEG-2, and DVB. In addition, the transmission channel can simultaneously carry several program channels, data, additional content, etc.

[2]There are a number of standards used to specify different aspects of digital television; MHP is just one of them. The standardisation in Europe within digital TV is mainly driven by the DVB group, while the development in North America is driven mainly by ATVEF [51].

[3]Digital TV makes better use of the available frequency bands, and allows several channels with the same quality on one analogue channel. Additionally, the new possibilities for interaction and applications will accelerate a shift towards digital technology. For the providers, exploitation of this technology opens new opportunities within program production, archiving, program formats/characteristics, etc.

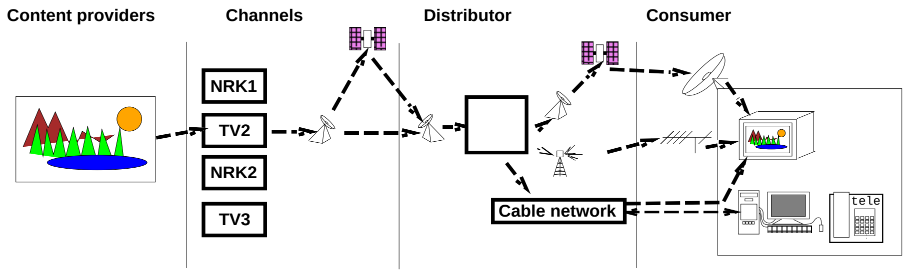

Figure 2: Different roles within the Television Media

- Feedback: return channels which use communication technologies other than "pure" digital TV (e.g., PSTN, SMS) will be integrated, from an application perspective, within the overall digital TV concept.
- Interaction: user interaction with the television or set-top box usually transpires via remote control; this device transmits digital information over an infrared carrier. For digital television, standard APIs have been specified for enabling new forms of interactivity and interactive applications (e.g., the EPG, games, etc.).

Traditionally the television broadcast value chain consists of four roles[4] which is presented by S. Andersen [2]. We illustrate these roles in Figure 2. The roles include:

- Content provider
- Channel operator
- Distributor
- Information consumer

There are also roles beyond this value chain. The roles which have an impact on the development of digital TV include also:

- Standardization bodies
- Hardware manufacturer
- Software manufacturer

The **information consumer** is interested in getting high quality information and entertainment for decent costs. He or she will be able to make several choices with respect to technology, quality of the equipment, degree of interactivity, context of use, etc. The consumer is also dependent of the different offers from the providers within his location area. Economical aspects are an important issue, especially the willingness to pay for a service.

The role of the **distributor** is to carry the signals from the channel operators to the consumers. The tasks reach from maintenance of the transmission equipment to allocation of the bandwidth necessary for transmission. The migration to digitally operated equipment will increase the bandwidth, and reduce the operating costs. Hence, the distributors will have a strong motive to migrate from analogue to digital TV techniques.

The role of the **channel operator** is to compose one or more channels. Each channel consists of many programmes, transferred sequentially. Different channels have different profiles, both regarding content and advertisements. Channel operators get their content from content providers. The consumer's interactivity consists of choosing the channel that is closest to his or her needs. Until recently the channel operator was the most visible part within the TV world. As an example, NRK1 or TV2 are channel operators in Norway that most of the people recognise.

The **content provider** produces the content for the channel. Content providers may be organised as an independent company, or a department within the channel operator's organisation. Today, the content providers may use digital resources to produce the programs, independently

[4] In a paper from Microsoft [31] the digital broadcast infrastructure is divided into Production – Broadcasting – Viewing. This view neglects the role of the TV channels as a part of the process, which may be a hint on the underlying business model.

from how the consumer receives the signal. Still, content providers typically produce content to be used in a broadcast context, which implies little or no use of interactivity. Interactivity in the traditional setting (i.e. feedback to the provider) is used by other media like email, phone, fax or even letters or postcards. Since SMS messages were discovered as a revenue-producing mechanism within a business model, many providers have started to implement services that use this rather new possibility.

In the traditional TV world only major operators have been engaged, mainly due to high costs for infrastructure and compliance requirements demanded by governmental regulations. In many cases, one operator filled several roles at the same time. This may be illustrated by NRK[5] which initially acted as content provider, television channel and signal distributor. A significant part of the technology in use was developed by the broadcasters themselves, especially the production technology.

When digital TV was first introduced, services were based on alternative, proprietary standards, a situation which made it virtually impossible for content providers to compete solely on content. As a result, competition within the digital TV market began to become vertically organized (i.e., the choice of technology controls the offer to the user). Since the introduction of new and open standards for digital TV equipment and software, horizontally-organized competition has begun to evolve. In a horizontally-organized market, hardware manufacturers, software manufacturers, content providers, and other actors can compete on a equal basis. Introduction of this new technology will have consequences for other parties, such as advertisers and re-sellers. If they are clever, they should already be planning their own agendas with respect to the expected roll-out of digital TV.

1.2 Distribution and Transmission

Digital TV is mainly based on a broadcast paradigm. This implies large bandwidth downstream (e.g., terrestrial, satellite, cable), while upstream user-unique data typically requires less bandwith. Upstream data may also be transported using a transmission carrier different than the one used for downstream data (e.g., PSTN, ISDN, xDSL, or cable modem). Digital TV is a typical application for asymmetric networking patterns.

There are several different ways to receive TV and radio signals. The most common alternatives illustrated in Figure 3 include transmission in the following modes:

- terrestrial
- cable
- satellite and parabolic antenna
- individual broadband networks (xDSL, IP-zones, LAN, wireless LAN, ...)

DVB has defined several standards both for broadcast and the return channel based on various technologies. It is an important issue that these technologies can be combined with each other.

All these transmission modes have in common that the customer's equipment is rather cheap and well suited for mass production. However, for the distributor these techniques have different values with respect to infrastructure, bandwidth, maintenance, costs, etc. This is summarized in Box 1.

For example, terrestrial networks are traditionally used by broadcasters, e.g., by the well-known Norwegian channels NRK1 and TV2. The signals are distributed almost to all parts of the country, but the networks are very expensive to build and maintain due to big investments into infrastructure in the form of a network of emitters and transmitters. In addition, bandwidth and number of channels is limited, as long as driven with analogue technology.

A cable network brings the television signals to the consumers while it also provides a permanent broadband return channel at the same time. Due to high costs for building and maintaining the cable network, it is only suited for areas with high population density. The cable operators may also provide pay channels and other services to the consumers. Since 1996 cable operators provide Internet access[6] through the cable network.

[5] Norsk Rikskringkasting NRK is the public service broadcaster in Norway.
[6] This is valid for Norway, and might vary for other countries.

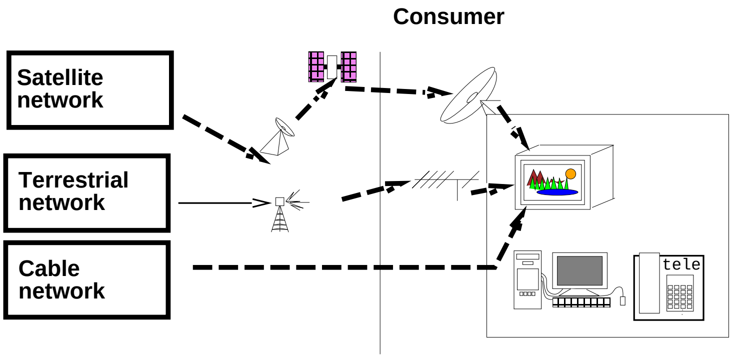

Figure 3: Alternative broadcast distribution methods for digital TV. Individual distribution via broadband networks comes in addition.

- **Terrestrial**
  - Expensive to build and maintain (network of transmitters)
  - Available in most populated areas in Norway
  - Low capacity, few channels
  - Inexpensive consumer equipment (antennas)
- **Cable**
  - Expensive to build and maintain (cable)
  - Restricted to areas with high population
  - High capacity, many channels
  - Inexpensive consumer equipment (no antennas)
- **Satellite**
  - Expensive to build and maintain (satellites)
  - No terrestrial infrastructure (e.g., cable, transmitters) necessary
  - Available in most areas in Norway.
  - High capacity, many channels
  - Inexpensive consumer equipment (parabola dishes)

Box 1: Characterisation of broadcast transmission modes

Satellite signals can be received in most places. However, there are some areas that cannot receive the signals, e.g., the fjord areas of Norway[7]. Though there is no need for a terrestrial infrastructure, huge costs in maintaining the satellite network can occur. Satellite transmission was the first mode that was used for digital TV transmission.

Other possible solutions for transmission include: Satellite Master Antenna Television system (SMATV), community antenna TV (CATV), microwave distribution service (MDS). These are used in special environments, and are often more economical for the single user.

The discussion whether to use broadcasting or point-to-point transfer is important from a perspective of seamlessness. That is, neither the content providers, producers, application developers nor users should have to concern themselves as to whether the applications, content and user data are transported using broadcast or point-to-point mechanisms. Digital TV techniques will provide us with a mixture of broadcast material and individual information[8] both up- and downstream. To achieve seamlessness within constraints such as complexity, economy, flexibility and robustness, a balance must be found between the different data transport mechanisms, their implementations and their use.

[7]This is due to geographical reasons. The high mountains and narrow valleys in the fjord areas of Norway make that the receivers are in the shadow of these mountains.

[8]Personal or confidential information can be broadcast using a PKI solution (see e.g., [21]).

The DVB Forum has defined several technologies for the return channel. These technologies include:

- DVB-NIP (Network Independent Protocols)
- DVB-IP (PSTN and ISDN)
- DVB-IC (DAVIC cable modem adjusted)
- DVB-ID (wireless, DECT)
- DVB-IM (LMDS, Local Multipoint Distribution System)

Box 2: Return channel definitions by DVB (not all alternatives listed)

Situations favourable for broadcast methods include mobility situations, and sending the same material to many recipients at the same time. This includes broadcasting news, bulletins, software upgrades for set-top boxes, bulk transfer of multimedia material for later use. For broadcasting the return channel is usually on a separate medium, and probably only available with low bandwidth. However, for unpredictable transfers, individual and interactive transfers of high bandwidth point-to-point connections are preferable.

1.3 Return Channel

To achieve interactivity back to the provider we need a return channel. All techniques available for IP-traffic are suitable for the return channel. Techniques for implementing the return channel may be based on:

- **terrestrial networks:** PSTN, ISDN, xDSL, etc.
- **cable**
- **high bandwidth networks:** Ethernet, ATM, xDSL, etc.
- **satellite**
- **mobile carriers:** GSM, SMS, GPRS, UMTS, etc.

The various DVB Return Channel specifications have been published by ETSI. These include DVB-RCC (Cable) and DVB-RCT (PSTN or ISDN). These are complemented by DVB-NIP (Network Independent Protocols), based on MPEG-2 DSM-CC. DVB-NIP allows session control and protocol tunnelling in MPEG-2 Transport Stream packets. The work within DVB Forum is now concentrating on finding suitable technical solutions for terrestrial systems, satellite master antenna television systems (SMATV), Local Multipoint Distribution Systems (LMDS, microwave) and Digitally Enhanced Cordless Telecommunications (DECT). Initiatives for return channels within the DVB Forum are outlined in Box 2.

1.4 Bandwidth and Program-manifold

For standard 6.7 or 8 MHz TV channels, the DVB standard (see Section 2) offers a data throughput potential of between 6 Mbit/s and 38 Mbit/s depending on whether only a part of the channel or the full channel or transponder is used. With MPEG-2 TS (see Section 7) several programmes can be multiplexed to one media stream. In short, digital TV techniques increase the number of channels that can be transported on one TV channel by at least a factor of six, depending on the bandwidth needs of the media streams.

While a radio service consists of a single audio elementary stream, the traditional television broadcast is made up of three elementary streams: coded video, coded stereo audio, and Teletext data. Future television broadcasts will have many more elementary streams, e.g., additional video streams carrying the same picture at alternative resolutions, several camera views, several audio channels, or Teletext in different languages.

Digital traffic with the possibility of auto-correction is more robust with respect to disturbances, thus the perceptual quality of digitally transferred media will also be improved. More services and possibilities will also be available for the user. By including application programs within the media stream, high-level components and multimedia material can be delivered which provide the user with possibilities for increased interactivity.

1.5 Navigator

The navigator is used to provide the top-level navigational interface for digiatl TV users. It is usually part of the firmware within the set-top box. The navigator is used for controlling the most of the set-top box functions. This might selection of programs, switching applications, accessing stored content, controlling the Personal Video Recorder (PVR), accessing the Electronic Programme Guide, etc.

1.6 Electronic Programme Guide

The Electronic Programme Guide (EPG) is a navigation system for the consumer which allows the user to browse through detailed information about the contents of programmes and services, along with their respective events. The EPG also comprises a user interface which can be provided by different parties (e.g., broadcasters, transport providers) to present a group of services, usually called a bouquet.[9]

The EPG consists of two parts: the information itself and an application program to present the information. The information presented by the EPG is partially based on service information (SI) data provided with the incoming MPEG stream. The application presenting the EPG content could come with additional functionality in order to retrieve other information (e.g., smart house functionality) and may give the possibility for advertising. The functionality and look and feel of the EPG reflect the editorial freedom of each EPG provider. Therefore, the EPG cannot be standardised, but its requirements must be supported by the API of the set-top box.

The presentation application is built upon the API of the digital TV set-top box, e.g., MHP. The EPG application is locally installed in the set-top box. It may be (1) pre-installed by the set-top box manufacturer, (2) provided by the service provider (e.g., as a smart card within the Common Interface), (3) installed locally by the customer, or (4) downloaded through the media stream.

The information structures in the EPG are based on service information data. It is desirable that the API system and the information structure definitions should be decoupled as much as possible. It should be possible to make use of the capabilities of user terminal devices enabling an EPG application to serve low- and high-end user requirements.

For the user the EPG is a tool for navigating / browsing through the program jungle. Through the use of personal profiles, it may offer other functionality as well. In addition, it may provide certain services, such as the possibility to order programmes, along with integration with the Web, IRC, News, etc.

It is interesting to note that according to Sedlmeyer [49], ARD's[10] EPG requires about 4.5 Mbit/s of bandwidth, including applications and multimedia material. This is more than 10% of the bandwidth of one transponder. Usually this is more than one audio- or video-component of a TV channel. The numbers show also that ca. 90% of the bandwidth needed for the EPG is used for the transfer of images and multimedia material, while application code uses about 10% of the bandwidth.

1.7 Interactivity

Many of today's TV companies still restrict their vision within the broadcasting paradigm. Offering viewer interaction is something new, with respect to both technology, organisation, journalism, and programme creation. Within the DVB framework, interaction was the last issue which received consideration; this may be due to the inherent complexity of interactivity in any context, as well as its particular complexity with respect to the technological and commercial possibilities afforded by digital TV. Hence, it is unlikely that broadcasters should be innovators within this area. It is more likely that people from marketing-related companies (e.g., advertisement, sales) will be first out with service concepts and solutions. Services which have been a success in the past (e.g., Internet services within banking or electronic commerce) will likely be the first examples.

[9] A discussion came up in 1999 about who should own the EPG. While this discussion was not quite understandable from a technical point of view, the providers feared for an impact on marked shares.

[10] Allgemeine Rundfunkanstalten Deutschlands, German public service provider.

- **Local interaction** (i.e., interaction with applications or content which is resident on the set-top box or has been downloaded in advance and stored locally)
  - Videotext
  - Electronic Programme Guide (EPG)
  - Applets, games and applications
  - Viewing/interacting with other multimedia material (e.g., web pages, hyperlinked audio-video clips, etc.)
  - Smart Home applications (e.g., controlling house installations with the TV set)
- **Interaction with information over a network**
  - Electronic commerce, advertisements in program content (e.g., ordering products)
  - On-Demand Access to films, music, archives, etc.
  - Access to the Web and Internet
  - Electronic mail
- **Real time contributions while the programme is ongoing**
  - Voting
  - Response to quiz programs
  - Auctions
- **Customisation**
  - Personal profiling, with choice of materials
  - "Be your own director." Possibilities to choose camera, slow motion, repetition-on-demand, screen layout, etc.

Box 3: Categories for interactivity, along with examples of applications

Different forms of interaction are possible in connection with TV. We offer a classification with respect to technology and interaction type in Box 3. In contrast to categories of interaction, one can also consider a classification for interactive applications, based upon our judgements[11] about the expected kinds of digital TV applications to appear:

- Enhanced broadcasting with local interactivity
- Interactive broadcasting using a return channel
- On-Demand services, e.g., Internet access.

While the return channel is the most distinct way of interaction in digital TV, we can identify other forms as well. Besides changing the TV channel (which is the only possible interaction in today's TV usage) the EPG and the built in navigator will offer access to service information data provided with the media stream. Applications can be downloaded from the media stream, stored locally, and be used. This includes games and other services that could be provided by the broadcasters. Access to additional multi media material (e.g., Web pages) that comes with the media stream could be provided as well as ordinary Internet-functionality. It is still unclear who will be the provider for the look-and-feel for the different functionalities.

When using an interactive TV service, the long waiting periods required to set up streams should be avoided; if they can't be, these "gaps" should be used to show other material. As a medium, TV implies that a service must "play" in some way, despite an eventual lack of user interaction. In order to continue a service when the user switches between channels, the state of a program must be kept. Interaction features such as stopping a service are only possible when changing the TV channel, or switching the box off.

[11]These judgements are based on technology roll-out as well as realizable short- and medium-term business plans for broadcasters.

1.8 Home Environment and the Remote Control

The digital TV will be mainly operated in a home environment, which introduces special needs with respect to the user interface. The long distance between screen and user (approx. 3–5m) and the home environment make it difficult to use an ordinary keyboard. Instead the user might operate the equipment with the help of a remote control. The user must be assumed to be an average person, with no special knowledge in computing. These demands set challenges to user interface design. Small letters, overfilled information areas, flashing animations, and use of too many colours can easily create chaos and illegibility on the screen.

Regarding the design of the remote control the DVB has defined recommendations (see Section 6.6). DVB specifies which buttons on the remote control are mandatory, like the four menu cursor directions, "home", "quit", "OK", four colour buttons, and the numeric buttons. The navigation services, the EPG, and other services have to be implemented suitable for this kind of remote control. The use of a remote control makes fine grain positioning of a graphics cursor difficult and ergonomically unsuitable.

Each STB producer can choose to add other functionality. This might include the use of PDAs[12] or additional small keyboards as in the Nokia Mediaterminal. We also observe that the user interaction pattern has changed with the venue of SMS services, and this can fact could possibly be later exploited with respect to remote control design, as well as overall interface design.

1.9 New Services

For the user, the new possibilities and interactivity offered by digital TV technology allow new, more diversified services than ordinary TV. Examples may include on-demand information retrieval, news services, weather forecast, etc. Services could track and adapt to a user's viewing and interaction patterns, and provide tailored information for certain areas or subjects.

Digital TV allows for downloading of applications and content which can be stored and run/displayed on the set-top box alone (i.e., as if it were a stand-alone device). Such material can be downloaded from a data carousel (see Section 7.4) or transparently delivered together with some other media/programme within a stream. These applications include the possibilities for games, single-player as well as interactive with other participants[13]. The download facility can also be used to download media streams, order films (Near Video on Demand, NVoD), additional information (Web pages) etc. The material can be viewed, retrieved, searched, and processed locally on the set-top box. Also download of multi-media material and applications in times of low traffic is possible. Similar to enhanced analogue TV Internet and Web enhancements will be possible including Web access, Usenet News, and email functionality.

Other new services, directed more toward the TV as such, include the delivery of several media streams for one programme and letting the user be her own producer. This could include several video or audio streams which the user can combine to her own preferences. Sports arrangements could be sent from several camera positions, or with several commentators or languages. Also post-processing of images, such as arrangement of several images on the screen could be possible. Additionally, temporary local storage on the set-top box would allow to play back some scenes, capture still images, provide slow-motion etc. Locally-stored application programs could give the possibility to help support this kind of process for the user, hopefully providing an improved user experience. Using attached meta-data applications could help sort out important events for guiding the user.

With a return channel, services such as interactive story-boarding can be created. In these applications, it is the community of users who decide how a story continues, or what part of a soap opera the community of users would focus. This programme format has been discussed earlier

[12] There are implementations of remote control functionality for the Palm Pilot.

[13] This might be a step to form virtual communities. The social aspects could have consequences in the same way as those deriving from the introduction of the Internet. Already today, channel providers and advertisers try to create communities around products. Broadcasters could try to create communities based on geographical aspects, or on themes like soap operas. It is not likely that we will experience changes in sociological patterns in connection with digital TV in the future. We refrain here from speculating more about such consequences, however.

(cf. [6]). Programme makers will also devise other new programme formats, given the range of possibilities offered by the technology.

User access to archives and databases, automatic classification, and digitally generated animations are other possibilities which can be added to the set of conceivable services for digital TV.

1.10 Cost issues

Cost is an issue for all actors within the value chain for digital TV.

There are other costs related to content preparation and production. First of all, the range of different types of multimedia material is much broader. To prepare the delivery of parallel media streams, software and background material, new processes for production of TV material will have to be established. Access to archives with search capabilities will create totally new activities (and costs) within broadcasters' organisations. In particular, digitising and archiving existing material is a laborious task.

Furthermore, the content provider is interested in distributing and selling the content to as broad a public as possible. This might include TV, Internet, and public areas as airports, railroad stations, and malls. It would be an advantage for the providers to have the differentiation between these different channels as late as possible, especially in order to save costs in the production process.

For distributors, programmes can be cheaper to distribute when broadcast digitally. The reason is mostly that one satellite can be used to distribute more channels at the same time. Frequencies are a limited resource and the TV distribution competes with other communication services (radio, telephone, Internet traffic) that have increased needs. Therefore it is economical to use the possibilities in the digital techniques.

Still, the cost structure of networks remains important to distributors. xDSL as a broadband technique for delivery of individual multimedia stream has first been offered in the form of a flat rate subscription. However, for mass data this does not scale in a cost efficient way, and recent developments have shown that the providers may not be able to cover their costs effectively in this way. Thus, per-use, time-based or volume-based pricing structure is likely to be (re-)introduced.

This kind of cost-transfer by distributors directly impacts users. In order to soften this impact, it may be possible to subsidize or "give away" set-top boxes to the consumer, as some form of incentive. Clearly, consumers cannot use digital television unless they have some form of set-top box, so this approach may have an extra advantage with respect to market penetration.

2 Standards for Digital TV

This section is intended to give an overview of the current actors, as well as open and proprietary standards and implementations within digital TV. Of the open international standardization bodies relevant to digital TV, some of the most important are the European Broadcasting Union (EBU), the International Telecommunications Union (ITU) and the European Telecommunications Standards Institute (ETSI). Perhaps the most relevant standards here are Digital Video Broadcasting (DVB), arising from the DVB Project within ETSI and Multimedia Home Platform, arising from work within the DVB Project.

In the Nordic region, the most important digital TV organization is NorDig. NorDig follows the DVB recommendations and adds technical details specific for the Northern countries. In America, there is no common standard aside from the transmission issues, which are standardized by the Advanced TV Enhancement Forum (ATVEF).

With regard to the discussion here about implementations, the presentation focusses upon the user-side endpoint of a digital TV system, i.e., the set-top box.

The user-side endpoint of a digital TV system can be characterised by the following three subsystems:

- the IRD (Integrated Receiver-Decoder) unit,
- the API (Application Programmer Interface), and
- the CA system (Conditional Access system).

The specifications of most IRD units follows the relevant DVB/MPEG recommendations, but the CA systems and APIs are different and incompatible between most platforms. There is an incompatibility between the IRD for cable, satellite, and terrestrial distribution, specifically in regard to the tuner. In contrast, the operating system for set top boxes is not an issue thus far, since it is hidden to most of the developers and viewers.

The hardware of the DVB-compliant set-top boxes (also denoted as IRD unit) consists of the components which together provide presentation of the content of an MPEG transport stream. This includes tuner, CA module, demultiplexer, and decoder for delivery of digital TV programmes. Other parts include the main board computer (including graphics processor and CPU), smart card reader, remote control, and a network connection. Figure 4 gives an overview of the architecture of the IRD unit compliant with the DVB recommendations.

The API is a middleware layer to access the functionality of a digital TV set-top box without exact knowledge of the hardware specifications. The API controls all features in the set-top box, e.g., graphics functions, user interface, and audio/video services. The range of APIs for digital TV includes libraries of C calls, Java libraries, HTML-based systems, and architectures like MHEG. MHP integrates many of these concepts.

Before MHP was introduced the following API platforms were already established in the European market. The systems in the list below are characterized by IRD-unit/API/CA-system:

- **Eurobox/OpenTV/Viaccess** used by the ECCA group. Introduced by Telia and Tele Danmark in the Nordic markets.

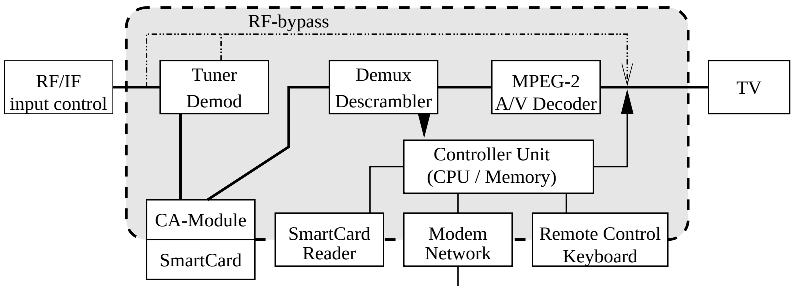

Figure 4: Hardware components of digital TV (simplified)

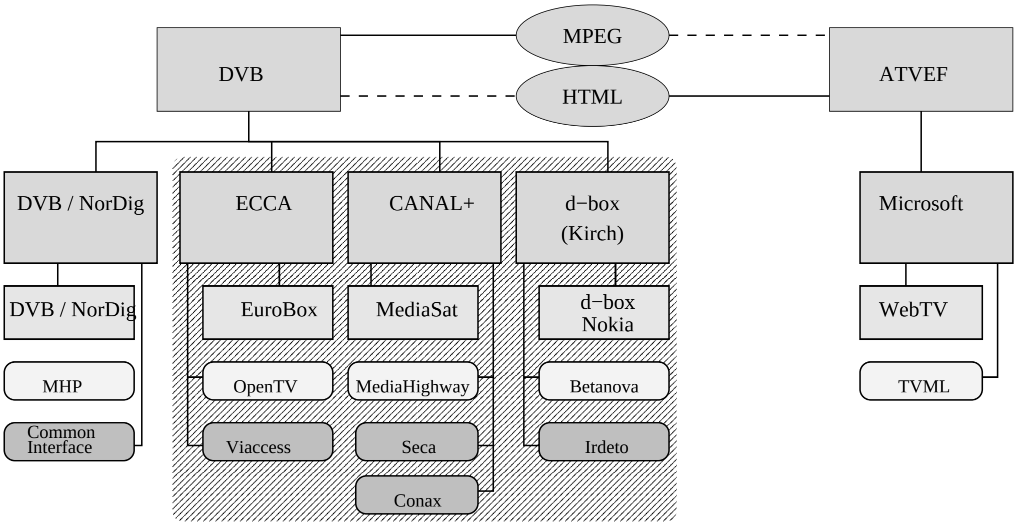

Figure 5: Overview on standards and initiatives in digital TV. The figure shows the initiatives with their respective IRD, API, and CA system in the columns. The hatched area shows the standards that are likely to be replaced by the MHP platform, or used as plugins within MHP.

- **MediaSat/MediaHighway/Conax** is a standard by Canal+. Established by Canal Digital Nordic for the Nordic markets.
- **d-box/Betanova/Irdeto** deployed by Beta Research, an enterprise within the Kirch group; mostly used in Germany.

Things are different in the American market, since the ATVEF only standardizes on transmission issues. A book on digital TV [51] is more profound on this subject. In that market, we found:

- **webTV/TVML/**– is an initiative by Microsoft, using the ATVEF standards.

In the following, we present organisations and technical standards which play major roles within digital TV. In Figure 5 we present an overview of how these different actors and standards are related to each other. The two basic initiatives are the DVB and the ATVEF, which base their technologies around MPEG and HTML, respectively (as depicted in the figure). The next row in the figure shows the name of an initiative or manufacturer which specified a technology. The technologies follow the specification of an IRD unit (middle gray), an API (light gray), and a CA system (dark gray). Some initiatives implement several different APIs or CA systems on the same IRD unit, when using DVB compliant equipment.

2.1 DVB Forum

The Digital Video Broadcasting Project (DVB) involves broadcasters, manufacturers, network operators and regulatory bodies for the development of standards for digital TV. It includes over 220 organisations in over 30 countries worldwide. The norwegian memebers of DVB forum include: Samferdselsdepartementet, Kulturdepartementet, Post- og Teletilsynet, Statens Mediaforvaltning, Norkring, NRK, TV2 Norsk Kabel TV forbund, Telenor, Satellite Service, Telenor Plus, Tandberg Televisjon, TV-Norge, TV3, and Norsk Forbund for Lokal-TV.

DVB-compliant digital broadcasting and reception equipment is available on the market, and numerous broadcast services are using the DVB standards worldwide for the delivery of digital TV, multichannel sound, and multimedia data. The DVB Project has generated international standards for all programme delivery media and transmission systems. Besides the hardware specifications (see Section 6) the DVB is now working on the Multimedia Home Platform (MHP) (see

Section 6.2), which is an API standard within digital TV. Currently the MHP standard 1.0.1 and 1.1 are available. MHP standardizes the API and a framework, including additions like the use of plug-ins, HTML, and the Internet in three profiles. DVB has also suggested architectures for conditional access (see Section 6.7). More information on the activities of the DVB project can be found at `http://www.dvb.org/`.

2.2 NorDig

NorDig is a cooperative organisation of the Nordic public service broadcasters and Nordic telecom companies with the goal to establish common specifications for digital television in the Nordic countries. The basic hardware and software specifications (NorDig I HW [37], NorDig II HW/SW [38]) are compliant with the DVB and MPEG specifications. NorDig-1 defines a user terminal (IRD), incl. all low and high functionality necessary in order to operate it. NorDig-II updates these specifications, and additionally supports several levels of interactive services and applications defined by the DVB MHP Interactive Broadcast Profile.

The Common Interface, the loader mechanism and memory expansion options are of major concern within the specifications. As there are already several CA systems introduced in the Nordic market, it is considered difficult to achieve the definition of one single standard. However, the Common Interface provides a solution for interoperability. NorDig tries to standardise on one single software platform for applications (e.g., EPG, PPV, NVoD, information and transaction services), for which the MHP platform has been chosen. The web pages of NorDig can be found on `http://www.svt.se/nordig/`.

NorDig supports horizontal competition in the market, i.e., competition on content rather than competition on technical platform. Therefore, NorDig has specified a common hardware platform in the different transmission medias, satellite, cable and terrestrial networks, and is comitted to a migration from today's closed proprietary systems to the MHP platform. This includes the avoidance of technical hindrances for the viewers, a short transition period, and the availability of smart cards for the CA modules.

2.3 EBU

The European Broadcasting Union (EBU) is an association of national broadcasters. EBU was founded in 1950, and replaces the IBU (International Broadcasting Union) from 1925. Besides negotiating broadcasting rights, the Eurovision and Euroradio networks, EBU also works offers operational, legal, technical, and strategic services to its members. EBU has participated in RDS (radio data system), DAB (digital audio broadcasting), DVB (digital television), HDTV (high definition TV), and others. Projects include broadcast systems, network systems, and production systems for television in general.

2.4 CANAL+

CANAL+ is a major broadcaster based in France and Benelux, which has developed the MediaSat digital set-top box. Besides digital TV it can be used for software downloading, bank card payment, Internet access, and home banking. The set-top boxes for CANAL+ follow the recommendations of the DVB. CANAL+ introduced its own CA system (Seca), encryption system (MediaGuard) and API (MediaHighway) for set-top boxes.

In compliance with DVB standards, the digital system is open to unscrambled channels. It can also carry other operators' digital services using the SimulCrypt system (see Section 6.7). Using the MediaSat terminal the services from CANAL+, Canalsatellite and ABSat can be accessed. A smart card allows subscribers to access up to 15 different digital television packages, each broadcasting 64 programming and service options. Digital service operators can enter the open system, and manage their customer bases and products independently. The MediaHighway API is available for broadcasters using licenses from CANAL+. The CANAL+ platform is supported by Canal Digital Nordic in the Nordic countries.

2.5 ECCA Eurobox

The European Cable Communications Association (ECCA) groups European cable operators to promote and represent their interests at a European level. ECCA succeeded the Alliance Internationale de la Distribution par câble in 1993. By initiative of ECCA, a common specification for cable set-top box following DVB system recommendations, was decided by Casema (NL), Tele Danmark Kabel-TV (DK), Mediakabel (NL), Telia InfoMedia TeleVision (S), Cablelink (IRL), Deutsche Telekom (D), France Telecom Câble (F) and Lyonnaise Câble (F). Cable operators agreed to use the same digital cable set-top boxes, including CA system and API, on their cable networks. The specification for the Eurobox describes both hard- and software aspects [14]. Viaccess was selected as the common Conditional Access system and OpenTV as API. Eurobox has the support of the following operators: Deutsche Telekom, France Telecom, Telia, Tele Danmark, Casema, and Mediakabel. For technical details details see Section 6.4.

2.6 d-Box

The d-Box is designed as a DVB-compatible set-top box for the use in the German market by the Kirch-Group. While the first boxes are manufactured by Nokia exclusively, the standard has now been opened up. The original API and software, Betanova, comes from Beta Research, a subsidiary of the Kirch group. The d-box seems mainly to be used as a decoder box for pay-TV. The d-Box is technically nearly identical to the Nokia MediaMaster. The first d-Boxes used *Irdeto* as the CA standard. However, after the introduction of the Common Standard by DVB, also other CA systems can be used.

The d-box I uses betanova 1.3 software. It can show information to the current program, and control a VCR. At a later stage the internal modem (2400 baud!) will be activated for web surfing and home banking. The d-box I has a 68340 16 MHz processor with 1 MB Flash RAM, and a MPEG-2 video decoder up to 15 MBits/s. The d-box I is available cable and satellite reception.[14]

The d-box II uses a Motorola PPC 823 Processor at 66 MHz with 8 MB Flash and 32 MB SDRAM. It also contains V90 modem and Ethernet connections. The software betanova 2.xx is built upon Java, and is prepared for MHP.

2.7 Conax

Conax-CAS3 is a conditional access system for digital video broadcasting, developed by Telenor Conax. The system is compliant with DVB/MPEG-2 standards and incorporates a Common Interface compliant PCMCIA card for high speed decryption of the digital services. Conax-CAS3 supports conditional access using subscription for a limited time period, booked pay-per-view, token-per-view, and membership. Telenor Conax has also developed the Eurocrypt S/S2 CA system for analogue TV (D2-MAC), and CA systems for information distributed via Internet. Conax is used by CanalDigital Nordic. More information on the company is available on `http://www.conax.com/`.

2.8 MHP

MHP is the Multimedia Home Platform defined by DVB. Version MHP 1.0.1 and MHP 1.1 are current, while MHP 2.0 is under preparation. The MHP comprises of the definition of an API, an architecture, and description of its elements. The API is based on Java (DVB-J). Transport protocols, HTML (DVB-HTML), plugins, content formats, graphics reference, and security model are also part of the MHP specification. For the technical details we refer to Section 6.2.

2.9 OST

Open Standards Terminal (OST) is an open source initiative from NOKIA to implement the MHP platform. It is based on Linux, and other open-source projects like Xfree86 and Mozilla. Additionally the OST platform adds support for native Linux applications (e.g., games), digital video recording, full IP access, support for all web standards,

[14] The specification of the d-box I seems to be quite out of date. However, these characteristics are typical for set-top boxes from the time before the MHP standard was released.

legacy iTV standards, and extension to new application and content standards. The platform consists of the kernel modules from LinuxTV (developed by convergence.de). The platform also includes a Java Runtime Environment. For more information on technical details see Section 6.3. The platform itself contains no user interface or interaction model, and this so-called navigator must be provided elsewhere.[15]

The OST platform supports different kinds of so called Application Environments, i.e., a framework or middleware in which certain types of applications may be executed. At present, application environments exist for Linux, Mozilla, and MHP applications. Several applications of different kinds can be concurrently active.

2.10 OpenTV

OpenTV develops software for interactive television, and delivers API and programming environments for set-top boxes. The company was started in 1994 by Thomson Multimedia and Sun Microsystems, but is operating independently today. Besides the API for set-top boxes, authoring and converting tools and server products for transforming web contents to digital TV streams are available. More information on the company is available on `http://www.opentv.com/`, where the reader also can find a reference manual on the OpenTV programming interface. OpenTV is used in the ECCA Eurobox. See also Section 6.5.

2.11 JavaTV

JavaTV is a proposal for an API for digital TV platforms by SUN. The JavaTV API addresses the delivery of interactive content to consumers via cable set-top boxes, satellite receivers, digital televisions, and HDTV. The JavaTV API provides an independent software platform to access the hardware features that are unique to televisions, such as the controls for channel changing and on-screen graphics, while maintaining portability across operating systems and microprocessors. The JavaTV API also addresses other functions such as audio/video streaming, e-commerce, conditional access and smart card support. More information on the state of JavaTV can be found on `http://java.sun.com/`.

2.12 ATVEF

ATVEF (Advanced Television Enhancement Forum, `http://www.atvef.com/`) is a forum of organisations, consumer electronic providers, content creators, and broadcasters formed to specify a public standard for delivering interactive television to a variety of set-top and PC based receivers. ATVEF is both the name of the group and a specification for integrating digital television with web technologies. The ATVEF specification 1.0 [3] is built on extensions to HTML, known as TVML, ECMA scripts, and triggers. It also defines UHTTP as a protocol to transport web content on a simplex transport channel (e.g., VBI, MPEG-TS). The ATVEF specification is used in WebTV. Technical details on the standard can be found in Section 3.1.

Recent developments at Microsoft within the area of digital TV are shown in a note [30]. This technology is mainly based on the ATVEF standards and Web technologies.

2.13 Nokia, Mediamaster and Mediaterminal

Nokia is a Finland-based manufacturer of communication equipment. They were involved in the development of the d-box. Nokia also manufactures the Mediamaster digital TV set-top box, which implements the DVB and MPEG-2 transmission standards. It uses the PSTN as return channel, and supports the Common Interface CA module. However, the remote control is different to the other specifications (e.g., colour buttons are missing, see Figure 14). See also `http://www.nokia.com/multimedia/`

The NOKIA Mediaterminal 510S implements the MHP based on the OST platform. It uses a proprietary navigator called NaviBars. The set-tob box is based on a Intel-based PC at about 500 MHz, and uses LinuxTV as platform. ...

[15] The NOKIA mediaterminal 510S is based on MHP, and uses the proprietary navigator *NaviBars*.

2.14 Philips

Philips broadcast division is involved in digital TV by manufacturing set-top boxes, which were delivered with the British channels ONDigital and SkyDigital at the end of 1998. Philips is also involved in the development of DVB- and MPEG-compliant systems, as well as the CA-system Cryptoworks. Other activities include systems implementing multimedia standards such as DAVIC or MHEG.
Production equipment has been developed, e.g., an MPEG-TS stream-cutter, that makes it possible to insert advertisements and other locally produced material, without decoding the single media streams. More information on the activities can be found at `http://www.broadcast.philips.com/`

2.15 Force

Force develops and manufactures digital set-top boxes for satellite, cable and broadband applications for the consumer market. More information on the activities can be found at `http://www.force.tv/`

2.16 Summary Remarks

As the first standards in digital TV began to appear, a number of actors began constructing various kinds of (semi-)proprietary digital TV systems and solution components. Without comprehensive standards and/or available components to choose from, however, the production of large-scale digital TV systems requires large investments in developments and maintenance. Furthermore, makers of proprietary systems take a substantial risk in that their technology base may not be easy to integrate with systems based upon international standards, when such standards finally do become agreed upon.

Today, a number of solutions are available. These include proprietary systems and components, as well as those based upon open and de facto standards; most of the implementations seem to follow the DVB (Digital Video Broadcasting) recommendations. We see that with the arrival of MHP, there is also a tendency for manufacturers of proprietary systems to migrate towards that standard. The MHP standard allows plugins in version 1.1, which makes it possible to still use the old APIs while the plugin provides compatibility. For manufacturers, an MHP plugin-based approach offers a cost-effective way to integrate proprietary systems.

3 Related Multimedia Standards and Organisations

Besides the DVB- and MPEG-compliant standards and initiatives there are other competing ones. The ATVEF specification uses extensions of HTML, triggers and UHTTP. Also other multimedia standards are involved in the development of digital TV. DAVIC, MHEG and SMIL are alternative candidates for techniques within digital TV. DAB is a framework for digital audio broadcasting.

3.1 ATVEF

The ATVEF (Advanced Television Enhancement Forum) is one of the primary organizations shaping interactive television in the United States. Version 1.0 of the ATVEF specification is comprised of television enhancements from three related data sources: announcements (delivered via SDP), content (delivered via UHTTP), and triggers (delivered via the trigger protocol over UDP). The specification of the content types available is based on web standards and extensions of HTML 4.0, CSS1, ECMA Script (i.e. JavaScript 1.1), DOM0. For embedding TV in Web pages a `tv:` URL scheme is defined, that can be used at various places within a HTML document. Announcements are used to inform users of currently available programs.

Addresses and ports for IP multicast streams, resource transfer and triggers are announced using SDP announcements (RFC 2327). Triggers are specified by the EIA-746A recommendation of the Electronic Industry Alliance (`http://www.eia.org`). The data types are usually transported by a data text service with the transport stream, e.g., IPVBI (see [52]) or MPEG-TS. However, ATVEF does not specify how content or triggers are transported.

A general overview over ATVEF and digital TV in America can be found in [51].

3.2 Enhanced Analogue TV

As an intermediate step, enhanced analogue TV has been developed. This approach requires that the user installs a *set-top box*, which receives an analogue TV channel, and a number of digital signals from a distributor, interprets the content, and presents it on a TV screen. The enhanced TV set-top boxes comprise of TV functionality enhanced by Web browsing facilities, email functionality, local information access, EPG, and additional information to the current program. Smart house concepts or controlling the VCR are additional possibilities.

The return channel is essential for the most forms of interaction. Often PSTN (Public Switched Telephone Network) with modems, ISDN (Integrated Services Digital Network), xDSL (e.g., ADSL), or cable modems are used.

Enhanced analogue TV has not been a success in Europe in general. Several European providers and manufacturers of equipment went out of business (including the Norwegian based PCTVNet). There may be various reasons for this, though it seems the cost of the set top box did not give enough value for the customer.

3.3 WebTV

WebTV provides the user with enhanced TV, along with additional web-based information accessible via the remote control (`http://www.webtv.com/`). The WebTV Classic and the more advanced WebTV Plus set-top boxes depend on a service from a provider on a subscription basis. WebTV is owned by Microsoft. For further reading we refer to a Microsoft document [30].
Internet information access is achieved via modem, and a version for cable TV is planned. Support for several satellite receivers (mainly US-based) is available. Standard printers can be connected to the WebTV set-top box. Web access is enhanced by crossover links during TV-programs that are implemented using TVML. WebTV also supports WebPIP (picture-in-picture facility). The concept supports online email accounts. Additionally, local TV listings are available (EPG-functionality). These enable the possibility for VCR programming / recording. A smart card concept with access to the WebTV account, enables for electronic commerce. SSL (Secure Socket Layer) is implemented to offer secure online banking and other forms of electronic commerce to subscribers.

3.4 Triggers

Triggers are real-time events, broadcast within IP multicast packets, delivered to the address and port defined in an SDP announcement. Triggers typically include a URL, a human-readable name, an expiration date, and a script. If the URL matches the current top-level page and the expiration date has not been reached, the script is executed on that page through the trigger object. Triggers are text-based on the basic format of the EIA-746A standard. Only the URL value is required in a trigger. An example of a trigger could be

```
<http://fooey.com/>[name:Find Out More][script:shownews()]
```

Triggers may be delivered by a broadcast mechanism (broadcast data triggers), or within an IP packet stream. It is assumed that when the user tunes to a TV channel, the receiver automatically locates and delivers the broadcast data triggers associated with the TV broadcast. However, the specifications of a transport mechanism is beyond the scope of the ATVEF specification.

A single video program may contain both IP and broadcast data triggers simultaneously. This is advantageous in order to target both IP based receivers and broadcast-only receivers. Support for broadcast data triggers is optional.

In order to avoid repeated or unrelated execution of scripts, triggers are used with the following mechanism: When a broadcast data trigger is encountered, its URL is compared to the URL of the current page. If the URLs match but there is no script, the trigger is assumed to be a retransmission of the current page, and should be ignored. If the URLs do not match and the trigger contains a name, the trigger should be offered to the viewer. However, if the URLs do not match, and there is no name, the trigger should be ignored by the receiver.

3.5 UHTTP

The Unidirectional Hypertext Transfer Protocol (UHTTP) is a simple, robust, one-way resource transfer protocol that is designed to deliver resource data in a one-way broadcast only environment. UHTTP is appropriate for one-way IP multicast over IPVBI, MPEG-TS, or other unidirectional transport systems. Resources sent using the UHTTP protocol are divided into a set of packets, and encapsulated in UDP packets. Each packet contains enough header information to enable the receiver to begin capturing the resource data at any time during the broadcast. The header contains an identifier in form of a GUID that uniquely identifies the resource or resource package. Additional information enables the receiver to place the data following the header in the appropriate location within the resource, and indicates how long the receiver should continue to listen for additional data. The protocol also includes a forward error correcting mechanism using an XOR algorithm, and the ability to gather resource segments over multiple retransmissions to correct for missing packets.

A resource can be sent via UHTTP using the same globally unique ResourceID. The header information allows the resource transfer service to receive segments out of order or multiple times. If the resource is sent repeatedly, the receiving service can fill in missing ranges using these retransmissions.

The protocol provides the inclusion of (optional) HTTP style headers preceding the resource data for describing the content type of the resource (MIME) and content location in the form of a URL. The header may also be used to describe groups of resources using a multipart construction (MIME-type multipart/related). Also other meta information, including date stamping and expiration dates, may be used.

HTTP headers are required for resources intended to be interpreted as web content. Content that is not available on demand needs to have a local name for each resource. This is necessary in order to support cross-references within the content, for use in hyperlinks or to embed one piece of content within another. Browsers with an Internet connection may also use that connection to retrieve web content, which is provided by broadcasters as an alternate form of resource delivery. Receivers will decode the headers and data and store them in a local cache system. The use of Content-Location headers with UHTTP style URLs is intended to mirror resource delivery to a local cache without requiring that the data be available on the web.

3.6 DAVIC

The Digital Audio-Visual Council (DAVIC) is a non-profit industry consortium exploring the potential of digital technologies applied to audio and video services. DAVIC has adopted standards and specifications from several standardisation bodies which include MHEG, DSM-CC from MPEG, and OMG (since the DSM-CC architecture uses CORBA). The first set of specifications (DAVIC 1.0) concentrated on TV distribution, NVoD, and VoD. In later versions the Internet technology is integrated.

3.7 MHEG

MHEG is an acronym for Multimedia and Hypermedia information coding Expert Group, that is WG12 of the ISO. The standards on coded representation of multimedia hypermedia information objects are published as an international standard in ISO/IEC 13522. Currently the standard includes the following parts:

Part 1: MHEG Object Representation Base Notation (ASN.1)

Part 3: MHEG Script Interchange Representation

Part 4: MHEG Registration Procedure

Part 5: Support for Base Level Interactive Applications

Part 6: Support for Enhanced Interactive Applications

Part 7: Conformance Testing for MHEG-5

The MHEG-5 standard (aka MHEG Part 5) was developed to support the distribution of interactive multimedia applications in a client/server architecture across platforms of different types and brands. It supports (broadcast and interactive) digital TV applications within home shopping, multimedia information retrieval, and near video on demand. MHEG-5 has been one of the candidates for the API standard of digital TV set-top boxes. MHEG-5 has been used within digital TV in the UK profile DVB DTT service. An overview of MHEG-5 can be found in [23]. The MHEG standard is rather complex, and still under development.

MHEG-5 defines syntax and semantics of a set of object classes that can be used for application interchange. The applications consist mainly of declarative code, but provisions for calling procedural code have been included. MHEG-6 provides an API for MHEG-5, which consists of a Java Virtual Machine specification for handling Byte Code for the MHEG programming objects; and an Applet Class specification for WWW application compatibility.

In MHEG the developed applications reside on a server, and as portions of the application are needed, they will be downloaded to the client. In a broadcasting environment, this download mechanism could rely on cyclic re-broadcasting of all portions of the application. The client needs a runtime system that interprets the application parts, presents the application to the user, and handles the local interaction with the user. An MHEG engine has the ability to display visual objects in a rectangular coordinate system with a fixed size, and to play audible objects.

An MHEG-5 application is made up of scenes and objects that are common to all scenes. A scene contains a group of objects, representing information (graphics, sound, video, etc.) along with localised behaviour based on events firing (e.g., a button is pushed to activate sound). At most one scene is active at any one time. Navigation in an application is performed by transitioning between scenes. A user input device (e.g., remote control, or game controller) can be used with the runtime system to allow interaction with the applications.

The MHEG-5 specification does not prescribe any specific formats for the encoding of content. As an example a video object can be encoded as MPEG. Content encoding schemes are defined by the MHEG group in order to achieve interoperability. This encoding is an instance of ASN.1, using the Basic Encoding Rules (BER).

3.8 SMIL

SMIL (Synchronised Multimedia Integration Language) is being developed by the SYMM (Synchronised Multimedia) Working Group within the World Wide Web Consortium (W3C), and includes representatives from the CD-ROM, interactive television, Web, and audio/video streaming industries. CWI (Centre for Mathematics and Computer Science, The Netherlands) and NIST (National Institute of Standards and Technology, USA) play key roles in the development. The first public draft of SMIL (pronounced "smile") was released in November, 1997.

SMIL is designed to define and synchronise multimedia elements (video, sound, still images) for Web presentation and interaction. SMIL coordinates the timing of separately created multiple movies, still images, and sound. This facility may be used in TV programs such as newscasts or training programs where many multimedia components are employed.

Each media object is accessed with a unique Uniform Resource Locater (URL) which allows presentations to be made of objects arriving from more than one place, and that objects can easily be reused in multiple presentations. Media objects can be stored in multiple versions, for example to provide users with different bandwidth demands, or to support multiple language versions of sound tracks.

A presentation can be described using only three elements of the Extensible Markup Language (XML). It's intended that SMIL will be usable by anyone who can use HTML. Therefore it is also possible to author a media presentation using a text editor. More information on SMIL, definition, implementations, and references can be found at `http://www.cwi.nl/SMIL/`.

3.9 RTSP

RTSP (Real-Time Streaming Protocol) is a protocol developed by RealNetworks, Netscape Communications and Colombia University to control realtime multimedia streams. The protocol is based on the experiences RealNetworks got from RealAudio and Netscape got from LiveMedia. RTSP is a client-server multimedia presentations protocol which enables delivery of multimedia streams over IP networks. It is a kind of remote-control for audio- and video streams and has functionality for playing, pausing and positioning. The data source is either a real time source or stored media. RTSP is used by Netscape, Apple, IBM, SGI, VXtreme and SUN among others. RTSP is a proposed standard in RFC 2326 [48].

RTSP is based on HTTP version 1.1. It functions in much the same way by first establishing a connection between two machines: the client and the server. The client will then request a presentation from the server and a new session will be created to send the requested data. One reason to base RTSP on HTTP is that RTSP will gain from further development of HTTP; another reason is that HTTP is well-known and used everywhere.

RTSP differs from HTTP in several ways. HTTP is a stateless protocol while RTSP maintains a state for each session in order to relate incoming requests to existing sessions. HTTP is an asymmetric protocol where the client sends requests and the server responds. In RTSP the requests can go both ways, i.e., the server can send requests to the client.

3.10 HAVi

The Home Audio / Video Interoperability (HAVi) Organisation provides a home networking software specification for seamless interoperability among home entertainment products. HAVi also is the name of a standard specification for networking digital AV appliances, a technology which will allow digital, consumer electronics and household appliances to communicate with each other within the home. The founding members of HAVi are: Grundig AG, Hitachi Ltd., Matsushita Electric Industrial Co. (Panasonic), Royal Philips Electronics, Sharp Corporation, Sony Corporation, Thomson Multimedia, and Toshiba Corporation.

The HAVi specification has been designed to meet the particular demands of digital audio and video. It defines an operating-system-neutral middleware which manages multi-directional AV streams, event schedules, and registries; it also provides APIs for the creation of a new generation of software applications.

The HAVi Organisation promotes interconnecting standards such as Jini, Universal Plug and Play (UPnP). It also promotes high-bandwidth technologies for transmitting multiple AV streams, using the underlying IEEE-1394 digital interface (i.e. iLINK or FireWire). The HAVi specification defines a set of APIs and middleware capable of automatically detecting devices on the network, coordinating the functions of various devices, installing applications and user interface software on each appliance, and ensuring interoperability among multiple brands of devices.

Typical examples of AV content could be audio or video produced by HAVi-enabled consumer devices: digital video recorders, digital cameras, CD's, MD's, or digital broadcasts received by a set-top box. With the growing importance of the Internet as a source of AV content, HAVi also addresses data such as HTML or images which can be retrieved from the Internet.

HAVi devices are capable of controlling other HAVi devices over the HAVi network. Typical HAVi devices are digital audio and video products such as cable modems, set-top boxes, digital TVs, Internet-enabled TVs, intelligent storage devices for AV content, video phones and Internet-phones.

HAVi's GUI definitions are of particular importance to MHP. Two of the Java packages within the DVB MHP API originate from HAVi. These packages contain several dozen Java classes and interfaces related to user-interface and event programming.

4 DAB – Digital Audio Broadcasting

In 1987 the EU project EUREKA 147 developed a digital radio broadcasting system, which became DAB (Digital Audio Broadcasting). DAB is a reliable multi-service digital broadcasting system for reception by mobile, portable and fixed receivers with a simple, non-directional antenna.

In 1993 the DAB standard has been defined by ETSI. Before, IRT (Institut für Rundfunktechnik) and BR (Bavarian Broadcasting Corporation) carried out tests and feasibility studies from ca. 1980. While the project technically has been a success, the number of listeners has been modest. This is mostly due to costs of the receiver unit, and the fact that the mass market is rather conservative (no sudden changes). For more information on DAB see `http://worlddab.org` and `http://www.eurekadab.org`. The documents are available from ETSI (`http://www.etsi.org`). For a technical overview we recommend a document available on the Web [1].

Current analog FM radio broadcasting system in the VHF band have reached the limits of technical improvement. It cannot satisfy the demands of the future, which include requirements for sound quality, number of channels, portable receivers, and quality impairment due to multipath propagation or signal fading.

Besides coding and transmission of audio, the developers of DAB wanted to provide additional services, like EPG, traffic information, control signals, systems, program identification, radio text information, data transmission to closed user groups, etc.

DAB provides a dynamic range control (DRC) system. A dynamic range control signal is added with the program, so that listeners can select the sound dynamics they wish (e.g., for home or car environment)

The main issue of DAB is a error-free signal transmission with better audio quality and minimum use of bandwidth transparent radio channel. In the future, there should be possibility to include multichannel surround sound or freely assignable data transmission. DVB is designed for unrestricted mobile, portable, and stationary reception, as well as for high transmission capacity.

Coding

DAB uses MPEG 1/2 Audio Layer II as coding format. Source coding is needed to prevent large bandwidth requirement. MUSICAM (Masking pattern adapted Universal Subband Integrated Coding And Multiplexing, MPEG 2 Audio Layer II) and ASPEC (Adaptive Spectral Perceptual Entropy Coding) have been candidates, and MUSICAM was selected. Using psychoacoustics MUSICAM can reduce the audio bit stream bandwidth from 1411 kbit/s (CD quality) to 192 kbit/s. Further data reduction can be achieved by dividing the audio frequency range into signal bands and processing each band separately. Future development of DAB will include transformation coding, which is part of the ASPEC proposal.

The DAB proposal is designed in a such way, that the bit stream of a stereo signal consists of 32 kbit/s blocks ($n \times 32$ kbit/s). Other characteristics include a frequency range up to 20 kHz; 48 kHz sampling rate; 18-bit resolution; 4 audio modes: mono, stereo, dual channel, and joint stereo; bit rates from 32 kbit/s mono to 384 kbit/s stereophonic programme; audio frame 24 ms corresponding 1152 PCM audio samples, digital I/O conformant AES/EBU standard; and 2 kbit/s (bytes of data per frame) for Program Associated Data (PAD)

Transmission system

The DAB transmission signal carries a multiplex of several digital services simultaneously. Its overall bandwidth is 1.536 MHz, providing a useful bit-rate capacity of approximately 1.5 Mbit/s.

A radio signal is normally distorted by physical conditions and multipath propagation. Interferences can be avoided by using a broadband transmission system called COFDM (Coded Orthogonal Frequency Division Multiplex). COFDM with error detection and correction provides a digital transparent channel allowing transmission of a stereo program or any other data. Programmes are divided into a total of 1536 carrier frequencies with a bandwidth of 1.5 Mhz. The transmission system includes the use of error detection and error correction.

A specific part of the multiplex contains information on how the multiplex is actually configured. It may also carry information about the services themselves, and the links between different services. In particular, the following principal features have been specified:

- Flexible audio bit-rate from 8 kbit/s to 384 kbit/s.
- Data services.
- Programme Associated Data (PAD), embedded in the audio bitstream for data transmitted together with the audio programme (e.g., lyrics, phone-in telephone numbers). The amount of PAD is adjustable (min. 667 bit/s) at the expense of capacity for the coded audio signal within the chosen audio bit-rate.
- Conditional access (CA), applicable to each individual service or packet. Specific subscriber management is not part of the DAB specification.
- Service Information (SI), used for operation and control of receivers and to provide information for programme selection to the user. SI also establishes links between different services in the multiplex or to other services.

Techical specifications

The DAB signal is sent as a suite of OFDM symbols which form together a frame. Each frame contains OFDM symbols of these three transmission channels:

- Synchronisation Channel;
- Information Channel (FIC);
- Main Service Channel (MSC);

In DAB each service signal is coded individually at source level, error protected and time interleaved in the channel coder. Then the services are multiplexed in the Main Service Channel (MSC). The multiplexer output is combined with Multiplex Control and Service Information, which travel in the Fast Information Channel (FIC), to form the transmission frames in the Transmission Multiplexer. Finally, OFDM is applied to shape the DAB signal which consists of a large number of carriers. The signal is then transposed to the approporiate radio frequency band, amplified and transmitted.

Each audio programme contains Programme Associated Data (PAD) with a variable capacity from 667 bit/s up to 65 kbit/s which is used to convey information together with the sound programme. The PAD Channel is incorporated at the end of the DAB/ISO audio frame.

Independent Data services: In addition to PAD, general data may be transmitted as a separate service. This may be either in the form of a continuous stream segmented into 24 ms logical frames with a data rate of $n \times 8$ kbit/s or in packet mode. A third way to carry Independent Data Services is as a part of the FIC.

Essential items of SI that are used for programme selection are carried in the FIC. Information that is required immediately when switching on a receiver mayu be carried separately as a general data service (Auxilliary Information Channel).

Together with the data services, DAB can provide multimedia radio. The DAB based multimedia services rely on files containing relevant data for the selected services together with additional information to allow for data presentation and classification. Each item is called a Multimedia Object, which is managed by the Multimedia Object Transfer protocol (MOT). Multimedia services can contain images (JPEG), text, hypertext (HTML), data, and even video streams (MPEG).

Part II
Building a digital TV platform

NR has been involved in building digital TV platforms in the frame of other projects. Especially we mention the **MIT** project, where the major part was an interface study for the Norwegian channel TV2 [26]. In the EU project **Madison** `http://www.archetypon.gr/madison` a virtual world was implemented on a set-top box using the MPEG-4 standard. The current work focuses on developing applications using the DVB standards and MHP.

Besides getting an overview on digital TV, one goal of the current project is to get practical experience. Therefore some selected parts of the digital TV value chain were chosen to be implemented as a prototype.

5 Practical work and building an environment

In order to build an applications for digital TV the following parts have to be in place:

1. Assembling the stream into MPEG-TS format. This includes multiplexing the audio-video-data-SI stream. In addition, data have to be included with the DVB data services, e.g., an object carousel which might contain both data and xlets.
2. Transporting the stream over a network, e.g., with the RTP protocol. Alternatively, real digital TV signals could be used. However, this would require a play-out system for delivery of MHP services, which we cannot afford within the frame of this project.[16]
3. Receiving and unpacking the MPEG-TS stream. This includes forwarding the data to the appropriate decoder, or placing the objects from a carousel to the correct location.
4. Using the data from the DVB network in an application. We implemented applications as Xlets that can access data and present the content using MHP functionality.

Most of the necessary functionality is already implemented in several software packages (see Section 8). There are several solutions on how to implement a demonstrator. We have to decide which aspects of digital TV we want to demonstrate, and the technology used. The following matrix shows examples for such choices:

	fancy	half fancy	simple
real	use professional authoring tools	use IRT reference implementation	use MHP header files to compile, run on mediaterminal
half real	java applet, some digital TV aspects		Java applet + some digital TV aspects, e.g., transport stream
fake	Java applet	Java applet	Java applet, DVB HTML

5.1 Transmission of MPEG-2 TS over IP

Assembling the stream. How to pack and unpack data from a DVB network and MPEG-TS is described in the MPEG-2 standard, and the DVB standardisation documents. For assembling the stream the following software packages from our software catalogue give contributions:

- The MSYS toolkit (see Section 8.2.4), and our extensions provide functionality to assemble MPEG-TS streams
- The packages `mpegtools` (see Section 8.2.1), and `mplex` of `mjpegtools` (see Section 8.2.3) provide functionality to pack and unpack.

[16]Several solutions are available; e.g., the Cardinal Playout Compact at `http://www.cardinal.fi`, the Unisoft TSPlayer at `http://www.unisoft.com`, the Alticast iTV Synchronisation System at `www.alticast.com`, and others.

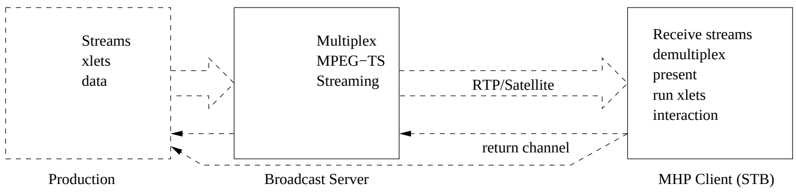

Figure 6: Schematic drawing of the applications

- DTV (see Section 8.8.2) and VDR (see Section 8.3.3) implement the reverse operation (i.e., unpack DVB streams).

Encapsulation of MPEG TS using the RTP protocol. The MPEG-TS can be encapsulated in the RTP protocol when transported over IP networks. The technical details on the RTP protocol and encapsulation is given in Section 7.6. The relevant RFCs include RFCs 1889, 1890, 2038 and 2250 [47, 20]. Depending on the requirements we can implement unicast or multicast streams:

Unicast: We implemented the application `dvb-udp` which implements some aspects of RFC 2250-2 for POSIX.1 platforms, using the API of `librtp` (see Section 8.8.4).

Multicast: The application `Dvbstream` from LinuxSTB (see Section 8.8.3) is capable of broadcasting a DVB transport stream or a DVB program stream over a LAN using the RTP protocol. For transport of the MPEG-TS packets we use the RTP protocol encapsulation (see Section 7.6) implemented in the dvbstream package (see Section 8.8.3). See also the `librtp` package (Section 8.8.4) for a library that handles RTP and RTCP.

Receiving and unpacking. When receiving a DVB conformant signal, the OST extensions of the Linux kernel (LinuxTV) handle receiving and unpacking the stream within kernel modules. We had planned to receive the MPEG-2 TS from RTP, and insert the packets into the kernel. However, in our experiments with the Nokia Mediaterminal we did not succeed to do so.

We also experienced the problem that the RTP packages could not be received by UDP, which possibly is caused by the packet filter. However, we were advised not to change the networking setup of the Mediaterminal, as this could lead to an unusable set-top box. Therefore the transfer of the packages was performed using a connection oriented protocol (TCP), and connect from the Mediaterminal to the server in order to avoid problems with the firewall.

Therefore, the MPEG-TS packets were received by the Mediaterminal from a TCP connection (initiated by the Mediaterminal). Te application then forwarded the content as RTP packets via UDP to the MHP application, thus preserving as many characteristics of a digital TV stream as possible without the need of a play-out system.

Xlets and MHP. An empty implementation of MHP functions in xlets is available from DVB (DVB CD 4.1). This collection of calls can be used to learn about the MHP API, but not for an implementation.

The Nokia Mediaterminal 510S contains the binaries of a an MHP implementation. In order to implement xlets, these have to be compiled using the API from the DVB CD.

Alternatively, professional implementations can be used. A license for the reference implementation from IRT `http://www.irt.de` is available at ca. 25000NKr. Implementations using a graphical user interface are available, e.g., the MHP authoring tool by Cardinal `www.cardinal.fi`.

5.2 Building the Chatroom Application

The idea behind the Chatroom application was inspired by the fact that many viewers these days use chat pages for interactivity and send SMS messages to TV providers. However this way of TV viewers' interaction has several disadvantages like, for example the messages are shown as they arrive and cannot be stored for viewing later, there is no division for different chat rooms and all of the messages are exposed on the screen disregarding of interests. Here we suggest a chatroom application that implements a service, where the TV viewers can send messages to a chatroom using a return channel. These messages can be presented to all viewers[17].

Using DTV techniques available in MHP the users can customise messages, e.g., by choosing chat rooms, subjects, have influence on placement and layout on the screen, etc. The user can prepare a message by interacting with the set top box using a remote control unit and send this message to a TV chat server through a return channel.

This chatroom application implements a client/server architecture. The TV chat **server** module provides the following functionality:

- receive the messages from MPEG stream and unpack them;
- store the messages in a local storage if necessary;
- package the messages appropriately and broadcast them via the DVB stream to the set-top boxes using data encapsulation in MPEG sections, data carousel, or object carousel.

The client-side module resides in the top-set box. It implements an xlet interface and provides the following functionality:

- The xlet accesses the data in the DVB stream, and presents the messages to the viewer according to the current user profile.
- The viewer can tailor this profile according to his/her preferences, e.g., change subject, go to another chat room, change profile, save profile, etc. The set-top box can store all recent messages, build up a history, etc.
- The xlet that reads the user's profile and presents the messages to the users.[18]
- The xlet also acts as an input channel for new messages to the server.

To prove the concept we have developed an xlet application, which resides in a Nokia Mediaterminal. The messages arrive at the xlet via an UDP connection. These messages are displayed on the TV screen, and stored in the Mediaterminal. The user can type his/her own message on the screen and send it to the chat. As the chat application is run in the background of TV programs its implementation is very sensitive to how the user interfaces appear on the TV screen. This problem requires addition research and is not included within the scope of this project.

The Mediaterminal implements the PersonalJava Application Environment. As widget class the `java.awt` package must be used, which is considered as obsolent components toolkit in the Java development literature. In order to get better graphical appearance of the widgets and its contents, namely to provide transparency of the interface elements the `org.davic.awt` package was used in addition. However it is hard to implement professionally looking interfaces with these means.

5.3 Building the IBR Application

For a visually more advanced application we employ IBR methods in order to provide dynamic views from virtual moving cameras for preprocessed TV scenes. Our application was implemented using a view interpolation method as described by Chen and Williams [8]; see also [53, 28].[19] This application can be seen as a possible extensions to television in the future, as a step towards 3D-television. See also a paper from IBC 2002 [16] where a similar project is performed by others.

This study is intended (1) as a feasibility study, to see whether hardware, software and technology within digital TV are ready for non-trivial applications; (2) to identify what kinds of applications are feasible; and (3) which potential extensions of APIs could be useful.

[17] The format is alike the TV shows where the viewers send SMS messages that are scrolled on the screen.

[18] Whether the xlet is sent via the DVB stream, or is installed manually, is not the primary issue here. This functionality is part of the digital TV framework.

[19] The purpose of this work is not to present or implement a new IBR method. The IBR method used is well-known and too simple for a real-world application. Therefore, the resulting images are of lower quality and contain artifacts, as shown in [53]. The intention of this work is to see whether the use of an IBR method is feasible in a digital TV context.

In our work we developed a Java application [39] that displays the image-information while it allows the viewer to change the viewpoint. After the image-information arrives at the set-top box from a DVB stream the viewer can walk around in the "living" scene.

We need the following applications in order to implement the demonstrator:

- A sequence of frames, each consisting of a colour image in RGB, a depth image, and a set of camera position parameters.
- These images are streamed in a DVB stream using MPEG sections.
- The client program accesses these files, and presents the result of the rendering process to the viewer.
- The user can interact with the application using the remote control.

The original Java program performed this specification. It had to be changed in order to be implemented as an xlet. The following steps were necessary:

- The original Java program uses the AWT widget set. Also MHP uses the AWT widget set. Therefore, no greater changes have been necessary in order to implement the xlet.
- Interaction had to be changed to follow the DVB API.

In our view interpolation method we use depth maps in order to create coloured reliefs in space, which can be viewed from other positions. We have also experimented with disparity maps. Depth maps could be provided by e.g., a camera with special depth sensors; such products are available (see e.g., 3DV (`http://www.3dsystems.com`). For our experiments we use the output of a raytracer.

After the content has arrived on the STB, the image for another viewpoint is rendered from one or several sources and presented to the viewer. Note that the rendering process has to be done for each frame, thus the rendering algorithm limits the achievable frame rate.

The input of the view interpolation method is a raster image, a depth image, and information about the camera parameters; this information together with the images must be transmitted in the DVB stream. Data are encoded into the MPEG-TS, which can be done in several ways. For images the MPEG standard offers compression using the DCT method; see [33].

Image size on TV is normally 780×576 pixels for the PAL standard. Our test images were of the size 200×130 in order to get a suitable frame rate on the PC for our study. In our experiments, we could achieve a frame rate of up to 20 frames per second on a PC (ca. 800 MHz), while the Mediaterminal only reached 1 frame per second (which is far too low). However, the development of faster processors, and better MHP implementations makes us believe that we could reach the necessary frame rate in the near future.

We are aware that the choice of the programming language Java might not be optimal with respect to processing time. However, the digital TV platform makes it necessary to use DVB Java, and one intention of this report is to make conclusions about whether it is possible to use DVB Java for non-trivial functionality (i.e. more than handling menus on the screen).

Visual distortions in the reconstructed image are caused by the algorithm. These problems can be eliminated as outlined by Chen and Williams [53]. We also performed tests on how the quality of the resulting images is influenced by different compression algorithms. Results and examples are shown elsewhere [39, 28].

For transmission the MPEG standard defines the DCT method as a compression method, in order to increase bandwidth. The DCT method is lossy, and therefore has a visible impact on the image quality. The compression of the raster image reduces colour quality in the same manner as MPEG or JPEG does. Compression of the depth map results in a geometrical distortion; therefore the reconstructed image is visibly reduced in quality. However the problems are moderate.

More suitable library functions of the MHP libraries could accelerate the rendering, but MHP is not optimised for 3D graphics at all. Future work could include to identify operations for the API of MHP in order to make MHP suitable for visually advanced applications.

Our prototype shows that it is feasible to implement advanced graphical interactive applications for digital TV in the near future. However, the study showed that improvements are necessary in order to reach the market. Using faster hardware and MHP implementations would increase the frame rate of the IBR application. It would also be necessary to improve the API of MHP in order to implement often used complex graphics calls directly in lower level (e.g., C or C++) or even on calls to the graphics cards (as done in gaming machines).

5.4 Bootstrapping OST

In order to avoid dependencies with a specific implementation (e.g., the Nokia Mediaterminal) we used a DVB card and tried to install the most important parts of OST on a Linux PC (in late summer 2002). We installed Debian GNU/Linux 3.0 with the Linux 2.4.18 kernel. The Debian packages `libglib1.2-dev`, `autoconf`, `automake`, and `libtool` were installed.

The latest CVS version of the OST SDK was taken from `cvs.ostdev.net`. We observed that several header files were missing. At this point we did not proceed with the experiment, and waited for a newer version of OST to arrive. In late autumn 2002 newer versions were available. However, we did not continue this work due to lack of funding.

In order to ease the work for further experimentation we describe shortly how checkout from the CVS base and bootstrapping works. For downloading and installing OST the following procedure was used. First the source must be retrieved from `cvs.ostdev.net`:

```
cvs -d :pserver:guest@cvs.ostdev.net:/cvs co login [ENTER twice]
cvs -d :pserver:guest@cvs.ostdev.net:/cvs co sdk
```

We “bootstrapped” the source tree inside `sdk`:

```
cd sdk/
sh bootstrap
./configure --prefix=/opt/OST
```

5.5 Building Xlets with Cardinal Studio

An Xlet implements the Xlet interface in the Sun JavaTV API. Cardinal Studio (see `http://www.cardinal.fi`) is a proprietary package for building MHP compliant Xlet-based applications for Digital TV. The package shows to be useful for rapid design and code-generation for UIs, but seems to have little support for adding events.

We obtained the 30 days demo version of Cardinal, and installed it on a computer running the Windows operating system. The software is Java based. The Cardinal User Guide and SDK Manual provide some insight on how to operate the software. We successfully built and compiled a simple Hello World type application that ran on the Nokia Media Terminal when it was installed as a jar archive. We also were able to implement remote control events. However, it showed, that the Mediaterminal had a non-standard behavior, which later was confirmed by Cardinal.

Part III

Digital TV — Technical Specifications

In this part we introduce the technical details of digital TV. We cover architectural issues of DVB-compliant digital TV, including the NorDig specification (which is an example for a DVB-compliant platform). This includes both hardware and the API. Then, we introduce the Multimedia Home Platform (MHP) by DVB. We present some aspects of remote controls, CA, and OS for DVB-compliant architectures, where the descriptions are publically available. We also present the MHP platform "Open Standard Terminal" (OST).

The parts of the MPEG standard important to digital TV are presented more profoundly. Even if some technical details seem quite low-level, it helps to get an understanding on the underlying principles, and to elaborate the not so obvious possibilities for these technical solutions. A short (and possibly incomplete) overview of some related standards and organisations, as well as the competing technology from the ATVEF forum will conclude this part.

6 DVB-compliant Digital TV

In this section we present the concepts for currently available set-top boxes. As this overview is dependent on information available to the public, we are only able to present features, hard- and software that follow published standards. We present the ECCA Eurobox to enable a comparison with the NorDig standard, which both follow the DVB recommendations. The OpenTV is used on the Eurobox, and the specification of the API is available to the public. Remote controls, CA systems and operating systems for set-top boxes are also discussed here.

6.1 Digital TV Hardware – NorDig I

The digital TV hardware is defined by DVB. In the Nordic countries, NorDig has adapted these specifications with some adaptations. We use the NorDig I and II specifications in order to show the hardware.

NorDig I [37] is a specification of a Digital Integrated Receiver Decoder (IRD) for use in cable, satellite and terrestrial networks. An IRD implements the digital TV services by a combination of hardware and software solutions. Part A of the NorDig specification describes the hardware specifications, that are conform to the DVB standard. A set-top box is the implementation of an IRD. Therefore this short overview also denotes the propositions of the DVB on hardware for digital TV.

The IRD includes a bootloader as firmware for upgrade of resident system- and application-software. The IRD is provided with an installed cable, satellite or terrestrial tuner and demodulator, a Common Interface, a Smart Card Interface (reader), an input for a separate transport stream, and an interface for the interaction channel. The Transport Stream (TS) input can be connected to an external Tuner and Demodulator module (cable, satellite or terrestrial). The user accesses the services from all the tuners by means of the remote control. A detailed overview on the functionality of the IRD hardware and firmware is given in Figure 7. It contains the following parts:

Tuner/demodulator. The tuner/demodulator performs channel (frequency) selection, demodulation and error correction of the incoming MPEG-2 signal. The output is an MPEG-2 transport stream which is fed to the demultiplexer via the external plug-in conditional access (CA) module. Also an external Tuner/Demodulator for cable, satellite or terrestrial, or other equipment can be connected to the IRD's TS input.

Demultiplexer. The demultiplexer synchronises with the transport stream coming from the tuner/demodulator or from the CA module, and selects the appropriate system, audio, video and private data elementary streams according to the service selections made by the user. It also contains circuits for unscrambling of services subject to conditional access data in the smart card.

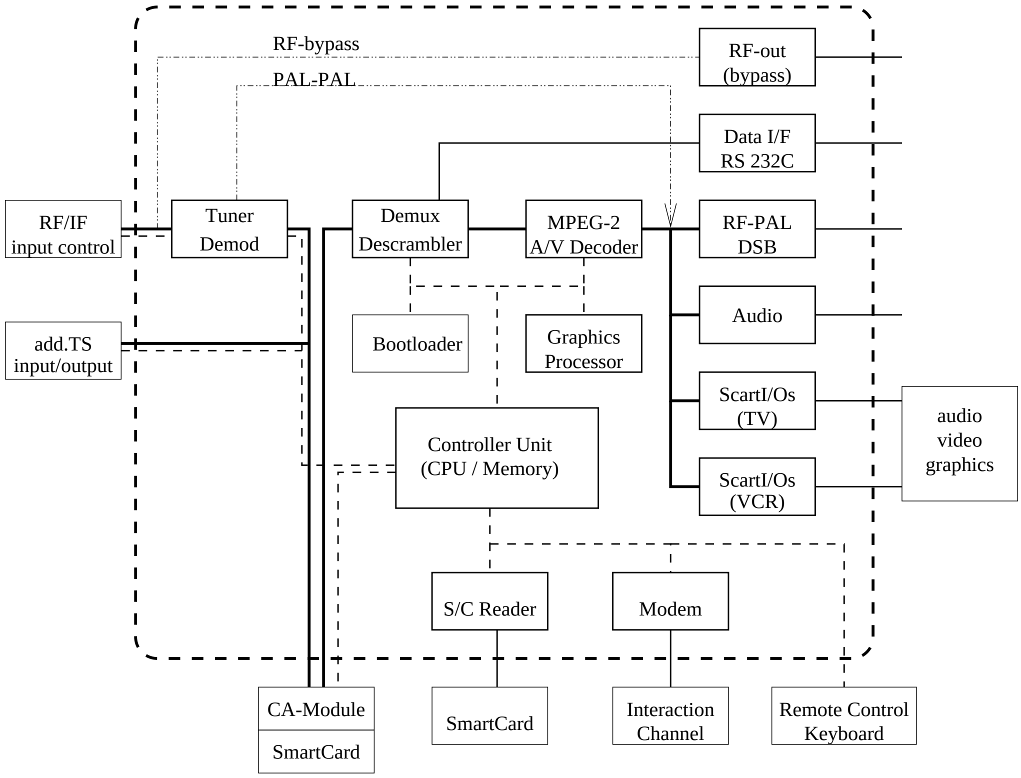

Figure 7: NorDig I — Functionality of Hardware and Firmware

The system and private data streams are managed by the IRD controller unit (main processor), while the audio and video streams are output to the MPEG-2 decoder block.

The MPEG-2 demultiplexer can decode streams with data rates up to 58 Mbit/s. It is capable of utilising at least 32 elementary streams simultaneously, and to utilise several components as video, audio, Teletext, SI, subtitling and data for additional services.

MPEG-2 decoder. The audio and video decoding units retrieve the analogue audio and video signals from the input elementary packet streams. This involves processes like depacketisation, decompression, synchronisation with related services, digital to analogue conversion, etc. The analogue signals are output to external baseband connectors, and an RF modulator.

The video decoder supports data rates up to 15 Mbit/s, several resolutions, and several aspect ratios (mainly 4:3 and 16:9). The audio decoder supports MPEG-1 Layer I and Layer II, while the support of Layer III is optional[20].

Remote Control. The remote control allows the user to move cursors and graphical pointers, and to make selections in menus displayed by the graphics processor. An optional remote keyboard allows the user to enter alphanumeric symbols.

Integrated modem. The modem gives the user a low-bandwidth channel for information retrieval and for the purposes of a return channel, i.e. interactivity. The minimum specification includes V32bis (14400 bit/s).

Plug-in CA module. To achieve conditional access (CA) an external plug-in CA module is attached via the Common Interface, that performs unscrambling of services subject to CA. The CA module may be connected to an external smart card.

IRD Controller unit and hardware spec. The IRD controller unit is a microprocessor system which manages all the internal units and all attached external plug-in units. The minimum Hardware configuration for the NorDig I is 4 Mbytes RAM, 4 Mbytes flash memory, 2 Mbytes

[20]For MPEG-1 Layer III often the term MP-3 is used.

video RAM, watchdog functionality, real time clock running continuously, and an internal timer to switch modes automatically. Two SCART interfaces, one analogue stereo audio output interface, and one RS 232 data interface supporting data rates up to 115.2 kbit/s are provided. Additionally, a smart card reader can be connected.

Graphics processor, OSD. The graphics processor unit generates graphics and text for the user display. Resolution 720 by 576 pixels and lower, RGB-space (8,8,8) bits and 8 bits for transparency. The graphics formats PNG and JPEG are mandatory. It is possible to merge graphics into a video or stills background.

Bootloader. The bootloader is used for downloading all software (drivers, operating system and applications) in the IRD. An upgrade of the software of the IRD unit is the user's responsibility. If the software should be corrupt, the IRD initiates a download automatically when a reset failed. The IRD manufacturer provides the procedure and functions carrying out the upgrade in the receiver. The user procedure for initiating the upgrade is part of the Navigator function. NorDig I defines three main bootloader modes: over-the-air, Common Interface Module (CIM), and by RS-232 or modem. The software files to be downloaded may be stored in a DVB Data Carousel.

6.2 Multimedia Home Platform

Multimedia Home Platform (MHP) is an API defined by DVB Forum. MHP 1.0.1 is defined in a DVB bluebook [12]. An overview on the MHP 1.0.1, and 1.1 is given by Sedlmeyer [49] and Sieburg [50].

A Java-based system architecture was chosen as a basis for the API of MHP, including extensions that are specific for the needs of television. See also [22]. An extension for presentation of content in HTML is planned for a later version, but not yet specified in MHP 1.0.1. See also [41] For the design of MHP the use of interactivity was essential, both local interactivity and interactivity using a return channel to the information provider. The viewer can access a special guide to navigate within the content: the EPG gives an overview on all programmes, including closer information on the content, and previews.

Several interfaces to the environment are necessary to make the MHP work. This includes APIs to control signals from cable, satellite, terrestrial, ISDN, xDSL, modem, and other ways of communication. Also interaction with the user (remote control, keyboard), interaction with other devices (TV screen, speaker), and storage is specified.

Three profiles have been defined, which also are outlined in Figure 9:

- Enhanced Broadcast profile 1 (EBP1)
- Interactive Broadcast profile 1 (IBP1)
- Internet Access Profile 1 (IAP1)

Figure 8 shows the general architecture of MHP. In the upper layer, the MHP applications access the MHP API layer. Several MHP applications can run in parallel. The system software is divided into the Java Virtual Machine, the operating systems, and its drivers. The application manager is responsible for starting, stopping and surveillance applications. The navigator is the user interface for controlling the MHP. The MHP specification defines only the interfaces to the different network components, and between the application and system software (MHP API). MHP does not define the implementation of these elements.

The parts of the MHP below the API are resident in the STB. The task of the loader is to update software, while the CA system controls the access to content delivery. CA system and loader are not part of the MHP specification, but both are necessary parts of a complete digital TV system.

The concept of the MHP framework has its roots from the world of digital broadcast (vs. from networking technology), which impliles that broadcast protocols of DVB are a major part within the MHP specification. We distinguish protocols for "Streamed Video and Audio" and protocols for data and applications. For some data services and applications a cyclic repetition of content is used in order to ensure that the necessary data arrive at the terminals (data carousel, object carousel).

For data services and applications that are not used by many participants, a point-to-point

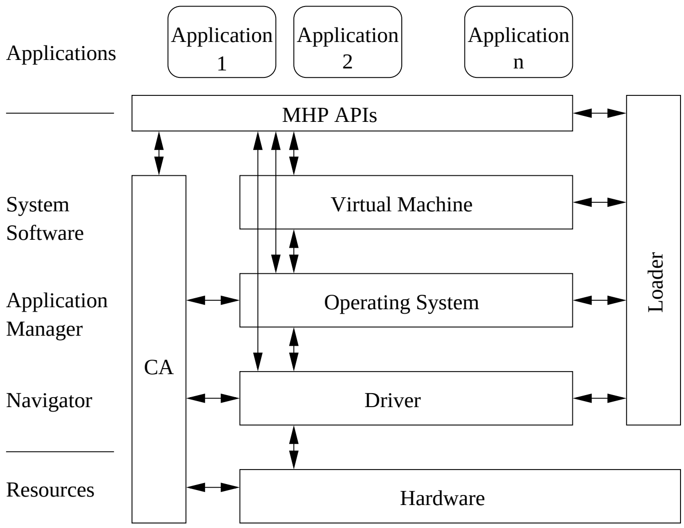

Figure 8: General Architecture of MHP

Area	Specifications	EBP1	IBP1	EAP1
Static Formats				
Bitmap	PNG with PNG restrictions	M	M	
	PNG without restrictions	–	–	
	GIF	–	–	
	MPEG-2 I-Frames	M	M	
	JPEG with JPEG restrictions		–	–
	JPEG without restrictions	–	M	
Audio clips	Monomedia format for audio clips	M	M	
Video drips	MPEG-2 Video drips	M	M	
Text	Monomedia format for text	M	M	
Broadcast Streaming Formats				
	Video	M	M	
	Audio	M	M	
	Subtitles	M	M	
Broadcast Channel Protocols				
	MPEG-2 sections	M	M	
	DSM-CC User-to-User Object Carousel	M	M	
	IP Multicast stack based on DVB Multi-protocol Encapsulation IP, UDP	O	Ro	M
Interaction Channel Protocols				
	TCP/IP	–	M	M
	UDP/IP	–	M	M
DSM-CC U-U RPG	DSM-CC U-U Object Carousel, UNO-RPC, UNO-CDR	–	O	
	HTTP 1.1	–	O	M

Figure 9: MHP functionality for profiles EBP1, IBP1, and IAP1

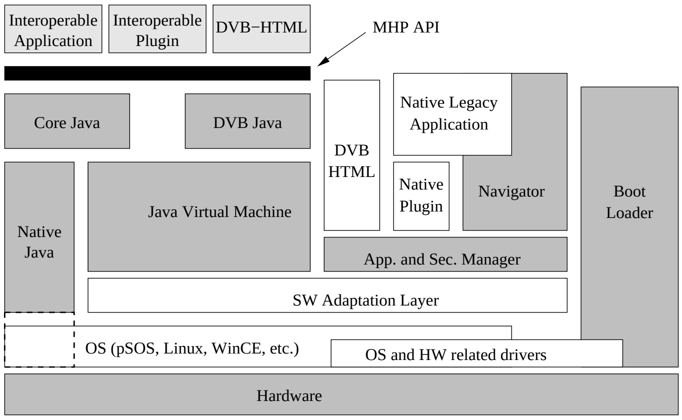

Figure 10: The software structure of NorDig II. The white boxes denote manufacturer's features, while the gray boxes are mandatory according to the DVB specifications.

transfer as in the Internet is supported. For these services bi-directional channels, or a (often low bandwidth) return channel are used. The IP protocol is used for point-to-point transfer.

The content formats within MHP includes MPEG-2 coded audio and video streams. For bitmaps the formats JPEG and PNG are used. However, GIF images are excluded due to licensing conditions. Flash animations are not part of the MHP 1.0 standard. However, Flash animations and other proprietary technologies can be used as plug-ins defined in MHP 1.1. MPEG coded audio clips are used for the presentation of audio. For animations and video sequences, MPEG-2 I-frames and video drips are used. These are transferred within MPEG-2 sections. The possibility to encode video streams from the disk is not (yet) part of the MHP. The reason for this is missing hardware support in some set-top box architectures.

For the presentation of text MHP supports DVB-Subtitles. Teletext can be part of the receiver, but MHP has no API to access Teletext data. Teletext seems to be an outdated technology, according to DVB.

The representation of text content should be as equal as possible on all receivers. Therefore MHP 1.0 defines only one font type, the "Tiresias"-Font in four sizes. All other fonts have to be transferred together with the application. In the same manner buttons and other graphical elements have to be transferred explicitly.

NorDig II supports several levels of interactive services and applications, as they are defined in the DVB MHP interactive broadcast profile. The software structure of NorDig II is shown in Figure 10.

The DVB MHP API consists of three parts, defined by three different organisations. Figure 11 gives a list of packages included in the DVB Java API. The three interfaces consist of:

Davic: Implements functionality and extensions for Java Media Framework (JMF), including graphics, MPEG concepts, and content reference.

DVB: Defines functionality and extensions for concepts defined by DVB.

HAVi: Provides a User Interface library, defined by the HAVi organization.

6.3 OST – Open Standards Terminal

The OST initiative by Nokia (see also Section 2.9) builds technically on the kernel drivers for DVB cards, presented at `linuxtv.org`, Linux, Mozilla, XFree86, etc. The structure of the platform is outlined in Figure 12. Information on LinuxTV and the Linux DVB API can be found at [29], or retrieved from `linuxtv.org`.

Package	Description
org.davic.awt	Provides simple graphics extensions for transparency.
org.davic.media	Provides various extensions to the Java Media Framework for the control of TV oriented audio and video content.
org.davic.mpeg	Provides utility classes for common MPEG concepts.
org.davic.mpeg.dvb	Provides utility classes for common MPEG concepts as used in DVB.
org.davic.mpeg.sections	Provides access to MPEG-2 section filtering.
org.davic.net	Provides general content referencing.
org.davic.net.ca	Provides an interface to various features of a conditional access system for those applications which need it.
org.davic.net.dvb	Provides DVB specific content referencing.
org.davic.net.tuning	Provides access to tuning - MPEG multiplex selection.
org.davic.resources	Provides a framework for scarce resource management.
org.dvb.application	Provides access to lists of applications which are available in this context and the ability to launch those applications.
org.dvb.dsmcc	Provides extended access to files carried in the broadcast stream.
org.dvb.event	Provides access to user input events before they are processed through the event mechanism of the java.awt package.
org.dvb.io.persistent	Provides extensions to the java.io package for access to files held in persistent storage.
org.dvb.lang	Provides those core platform related features not found in the java.lang package.
org.dvb.media	Provides DVB specific extensions to the Java Media Framework.
org.dvb.net	Provides general networking features not found elsewhere.
org.dvb.net.ca	Provides extensions to the conditional access API from DAVIC.
org.dvb.net.rc	Provides session management for bi-directional IP connections which are session based from the point of view of an application.
org.dvb.net.tuning	Provides extensions to the tuning API from DAVIC.
org.dvb.si	Provides access to DVB service information.
org.dvb.test	Broadcast model
org.dvb.ui	Provides extended graphics functionality.
org.dvb.user	Provides access to settings and preferences configured by the end-user.
org.havi.ui	This package implements the HAVi user-interface.
org.havi.ui.event	This package implements the HAVi user-interface event and listener classes.

Figure 11: The DVB MHP API.

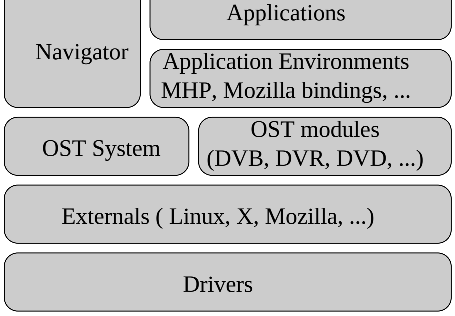

Figure 12: The main structure of the OST platform

The OST platform supports several so called Application Environments, i.e., frameworks or middleware in which certain types of applications may be executed (native Linux, Java, MHP applications, etc). Several applications can be concurrently active in the OST platform.

Applications communicate with the platform using one of several application environments, which form a common interface to the platform. At present, application environments exist for Linux, Mozilla, and MHP applications. Applications especially developed for the OST platform can access the OST system components and the OST modules directly.

6.4 ECCA-Eurobox

The ECCA Eurobox is a set-top converter for reception of digital DVB services, which consists of a front end, a video, an audio, a data decoder, a controller and a CA decoder module. It is planned at a later stage to integrate the Eurobox into the TV set. The range of services spans from video, audio and data services to NSoD (Near Service on Demand)[21]. Real on-demand services (SoD) are currently not considered, there are no obstacles for a Eurobox to handle real video on demand services. The ECCA Eurobox supports reception and processing of digital television, sound and data services as specified by the cable network operators services specification and complies with the mandatory parts of the DVB Implementation guidelines.

The performance of the ECCA Eurobox for the different modules is explained in the specification document [14]. It includes MPEG-1, and MPEG-2 compatibility, and specifies the MPEG demultiplexer, audio- and video decoder. The service information concept follows the recommendations of DVB. The specification contains among others the **OpenTV** API, which allows the use of applications independent of the given hardware, and the **Viaccess** Conditional Access system developed by France Telecom[22].

The hardware parts include the DVB descrambler chip implementing the DVB Common Scrambling Algorithm, and a detachable security module in form of a smart card. This chip receives a (scrambled) MPEG-2 Transport stream from the demultiplexer, and a control word with a key length of 64 bit from the smart card in regular intervals. It outputs a (partly) descrambled MPEG-2 transport stream which can be interpreted by an MPEG-2 decoder.

6.5 OpenTV

The manufacturer of the ECCA Eurobox must provide a multitasking operating system and drivers to access the hardware. The OpenTV API is the software link to applications being transmitted downstream via cable or via modem, serial or parallel interface or via the smart card. The network operators define necessary modifications and extensions to the API according to the special requirements of its decoder. Manufacturers of the ECCA Euroboxes have to adapt their operational system and their hardware related drivers to the interfaces provided by the OpenTV API system and to implement devices and device managers as specified by OpenTV. Figure 13 shows how the OpenTV API is built up.

The network operators provide navigating software and the EPG developed with the OpenTV API. The applications can be stored in Flash EPROM, but can also be downloadable for updates and extensions into the Flash EPROM memory.

The basic control software has a presentation of the information on the screen, independent from the OSD Chip used, the controller type and the manufacturer. The basic functionalities are implemented as an application on basis of the implemented API system. The functionalities for installation and normal operation, the menus, the look-and-feel and more details are specified by the network operator. The API code is implemented in the Flash memory of the decoder as a resident application.

The OpenTV API consists of a library of calls for the programming language C. The reference manual [40] contains 27 chapters with about 476 procedure calls. The following areas are covered by

[21] As an example we mention NVoD, which stands for Near Video on Demand.

[22] Information on the Viaccess CA system is only available by contacting France Telecom directly.

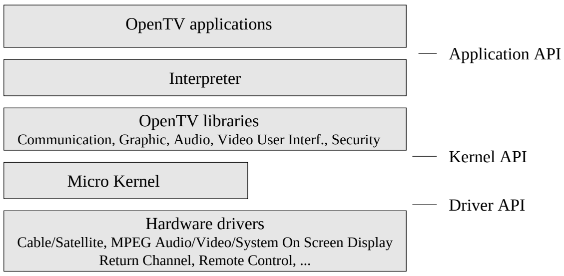

Figure 13: The OpenTV API

Figure 14: Example of remote controls for digital TV: Eurobox distributed by Telia in Sweden (left), CANAL+ (middle), and Nokia Mediamaster (right).

the API: UIMS, gadgets, shapes, rectangles, on-screen display, XY-input, cursor services, program utilities, modules, dynamic linking, audio/video services, sockets, data decompression, resource manager, file system, profiles, memory management, smart variables, strings, system time, timers, authorisation, encryption, system queries, EPG information, Unicode, store and forward libraries, and miscellaneous.

6.6 Remote Control Interface

Remote Control units are specified by each network operator. Usually only the IR-code and the IR-modulation parameter are specified, while the other parameters are left to the manufacturer. It is possible to have some kind of sound response (beep) from the IRD or blinking signals from a LED when a key is pressed. The specification from DVB requires 32 remote control function keys, grouped into 6 separated groups. These include: Basic keys which are continuously available (e.g., on/off, EPG, menu, volume, mute), Numeric Block, Interactivity keys (OK, Info, left, right, up, down, home), Multi-functional colour keys in a horizontal row (red, green, yellow, blue, grey). The remote control receiver supports the reception of the full ASCII character set, to enable the support of future interactive services, where alpha-numeric input is required. In order to protect the IR transmission of a PIN code against unauthorised monitoring, the remote control unit must be able to scramble a four digit PIN code controlled by a four digit code. Figure 14 shows examples for remote controls for Digital TV.

6.7 Conditional Access on Digital TV

The CA module makes sure that the IRD only presents information and streams that the customer has access to. There are several proprietary standards in use by the different broadcasters. The ones mostly used in Europe include (see also Figure 5):

- SECA (also called MediaGuard, French, used by CANAL+)
- Viaccess (by France Telecom)
- Irdeto (by BetaResearch)
- Cryptoworks (by Philips)
- Conax (by Telenor)

DVB has developed two approaches for Conditional Access system interworking, known as **SimulCrypt** and **MultiCrypt**. SimulCrypt is based on the Common Scrambling Algorithm, and allows the same broadcast (with different embedded CA bit streams) to be viewed on several different CA-equipped receivers.

The Common Scrambling Algorithm was designed to minimise the likelihood of piracy attack over a long period of time. The technology is licensed to the distributor of the TV signals. Using the Common Scrambling Algorithm system in conjunction with MPEG-TS and selection mechanisms, multiple messages generated by different CA systems can be used to control one scrambled broadcast.

The Common Interface defines an interface between a standard PCMCIA module and a DVB receiver in order to provide access at the MPEG-TS level. The most common use of DVB-CI at present is to provide interchangeable plug-in CA smart card readers for DVB receivers. Several CA technologies can be used on the same receiver in an approach known as MultiCrypt. This solution also allows broadcasters to use modules containing solutions from different suppliers in the same broadcasting system.

6.8 Operating Systems for Digital TV

Set-top boxes need an operating system to control the basic components. Even though the OS is not as visible as the API, we present some candidates, as they to some extent define the possibilities of the API in the implementation. For most of the set-top boxes we do not have information on what OS they actually use, and some of the manufacturers may use a proprietary OS or BIOS. However, the operating systems QNX and Windows CE seem to be preferred in connection with digital TV due to compactness and real time possibilities. However, also general purpose operating systems (Windows and different flavours of Linux and Unix) are in discussion.

QNX is a compact, micro-kernel based and POSIX certified operating system designed for hand-held computers, consumer electronics and set-top boxes. While many of the internals are borrowed from the Unix operating system, the kernel is based on 14 calls for the four services: IPC, process scheduling, interrupt dispatch and network message redirection. QNX comes with a scalable windowing system and suitable GUI, the Photon Micro GUI, that borrows much from the widget library concept of the X-Windows System. Applications like the QNX Voyager (Web browser), and an email client follow in a suite, as well as developing tools. The operating system is used on some enhanced analogue set-top boxes (e.g., the HomePilot) and on digital TV set-top boxes. For more information see `http://www.qnx.com/`.

Linux is a multi-purpose, open source, and POSIX compatible operating system. Linux is recently more often used for embedded devices and multimedia platforms, though it is not designed as a real-time operating system. For digital TV applications LinuxTV developed drivers for some DVB cards, in connection with the OST plattform. Several software packages are available to support streamed multimedia, also in connection with digital TV. The Nokia Mediaterminal 510S uses Linux as operating system. See also `http://www.linux.org`.

Windows CE is a compact operating system built for business and consumer devices. It implements many APIs of the Windows OS family. It is used for enhanced analogue and digital TV set-top boxes. Microsofts view on digital TV and the use of OS in set-top boxes can be found in [32].

7 MPEG

This section is intended to give an overview on the relevant parts of the MPEG standards with emphasis on digital TV. Especially MPEG-2, MPEG-4 and the DVB standards are of relevance within digital TV. In the following the MPEG-2 transport system is explained in detail, while video and audio compression are omitted. The reader will find introductions to video and audio coding elsewhere [17, 33]. Within the scope of this report on digital TV we take a closer look at MPEG-2.

MPEG is an acronym for Moving Pictures Experts Group, a group formed under the auspices of the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC), in cooperation with the ITU-T (the former CCITT). The committee is formally named ISO/IEC JTC1/SC29/WG11. MPEG is responsible for the standards MPEG-1, MPEG-2, MPEG-4, MPEG-7, and MPEG-21, which have different purposes and application areas. Literature on MPEG can be found in [45, 34], and on the web pages at `http://mpeg.telecomitalialab.it`

The MPEG-1 specification (ISO/IEC 11172) is a standard for coding a combined audio-visual signal at a bit rate around 1.5 Mbit/s, which is about the quality comparable to VHS cassettes. The standard consists of 5 parts:

Part 1 – Systems: Provides a syntax for transporting packets of audio and video bit streams over digital channels and storage media (DSM), including a syntax for synchronising video and audio bit streams.

Part 2 – Video: Describes syntax and semantics of video, including compression and coding.

Part 3 – Audio: Describes three classes of compression and coding methods for audio, known as Layers I, II, and III.

Part 4 – Conformance: Addresses MPEG conformance for parts 1–3.

Part 5 – Software Simulation: Contains an example ANSI C language software encoder and compliant decoder for video and audio.

As of March 1995, the MPEG-2 volume consists of a total of 9 parts under ISO/IEC 13818. Part 2 was jointly developed with the ITU-T, where it is known as recommendation H.262. The structure of parts 1–5 are as in MPEG-1. However, these parts are technically not identical, though MPEG-2 includes most of the features of MPEG-1 with respect to compatibility.

Part 6 – Digital Storage Medium Command and Control (DSM-CC): Provides a syntax for controlling VCR style playback and random access of bit streams encoded onto digital storage media.

Part 7 – Non-Backward Compatible Audio (NBC): Addresses the need for a new syntax to efficiently decorrelate discrete multichannel surround sound audio.

Part 8 – 10-bit video extension: Has been withdrawn due to lack of interest by industry.

Part 9 – Real-time Interface (RTI): Defines a syntax for video on demand control signals between set-top boxes and head-end servers.

For the purposes of digital TV, the part 1 and part 6 are the most important, and will be described to some extent in the following.

7.1 MPEG-2 Systems Layer

The MPEG-2 Systems Layer (specified in Part 1) describes how elementary streams (i.e. MPEG-compressed video, audio, and data streams) may be multiplexed together to form a single data stream suitable for digital transmission or storage. The MPEG-2 Systems Transport Stream (TS) are intended to be transported via lower level protocols.

Since MPEG-2 TS has been designed to carry a large number of television programmes, service information tables within the data stream describe which programmes can be found where. The specification has been extended by regional initiatives to identify features such as the nature of the program, the scheduled time, the interval between starting times, etc. Copyright protection and management are supported by means of a copyright descriptor, including monitoring of the flow of copyrighted material through a network.

MPEG-2 Systems define two special streams called ECP and EMM that carry information to decrypt information carried by the MPEG-2 TS for use by the CA systems.

A **programme** in MPEG-2 context is a single broadcast service or channel.[23] A programme contains one or more **Elementary Streams**, that are single, digitally coded components of a programme, for example coded video or audio. The MPEG-2 Systems Specification defines two alternative multiplexes: the **transport stream (TS)** and the **programme stream (PS)**.

The output of an MPEG-2 multiplexer is a contiguous stream of 8 bits wide data bytes. There are no constraints on the data rate, but clearly it must at least equal the total combined data rate of the contributing elementary streams. The multiplex may be fixed or have variable data rate, and may contain fixed or variable data rate elementary streams. MPEG-2 does not specify any electrical or physical properties, nor does it give any form of error protection in the multiplex.

In addition to the elementary streams, a variety of additional information may be included in the multiplex:

- A system of time stamps to ensure that related elementary streams are replayed in synchronism at a decoder.
- Tables of service information (SI) may be included, giving detailing network parameters, details of the programmes within the multiplex, and the nature of the various elementary streams.
- Support for scrambling and conditional access applied to one or more of the elementary streams.
- Any number of additional *private data* channels may be accommodated, where the content is not specified by MPEG. Such data streams may be used to carry data services such as Teletext, additional service information specific to a particular network, commands intended to control modulation and network distribution equipment, and any other type of data required by a particular application.

The **programme stream** is based on the established MPEG-1 multiplex. It can accommodate a single programme only and is intended for the storage and retrieval of programme material from digital storage media. It is intended for use in error-free environments.

The **transport stream** was developed for multi-programme applications such as broadcasting and a single transport stream can accommodate independent programmes. It comprises of a succession of 188 bytes long packets called **transport packets**. The use of short, fixed length packets means that the transport stream is not as susceptible to errors as the programme stream. Additional error protection can be applied by using e.g., the Reed Solomon encoding.

In a video stream, each picture in its uncompressed form is termed a **presentation unit**. The encoder compresses each presentation unit to give a coded picture which is termed an **access unit**. Video access units representing an I, P or B picture frame are not all of the same size. A video-, audio-, or data stream is termed an **Elementary Stream (ES)**.

Each Elementary Stream is converted into a **Packetised Elementary Stream (PES)** in the next stage, which consists of PES-packets (see figure 15), that are of variable length (maximum length is 64 kBytes). It consists of a header and bytes taken sequentially from the original elementary stream as a payload. The start of access units and the start of PES packet payloads need not be aligned. Thus a new access unit may start at any point in the payload of a PES packet and it is possible for several small access units to be contained in a single PES-packet.

Figure 16 shows the fields of a PES-packet header. A unique start-code, a stream-ID, and flag fields for time stamps are the most important entries. Time stamps are the mechanism provided by MPEG-2 systems layer to ensure correct synchronism between related elementary streams in a decoder.

In a **programme stream**, PES-packets derived from the contributing elementary streams are organised into packs (see Figure 17), that consists of a pack-header, an optional system header and

[23] As far as MPEG is concerned, TV channels as the Norwegian NRK 1 or TV2 are programmes.

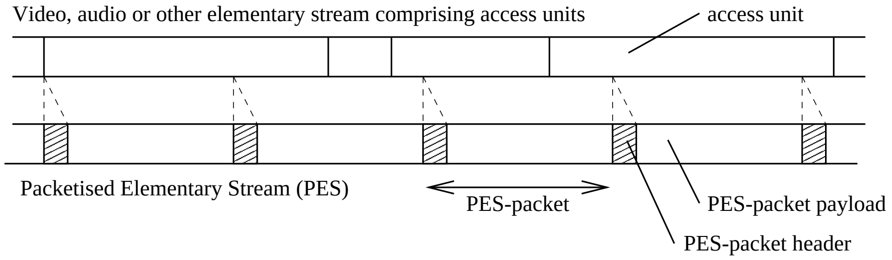

Figure 15: Conversion of an elementary stream to a Packetised Elementary Stream

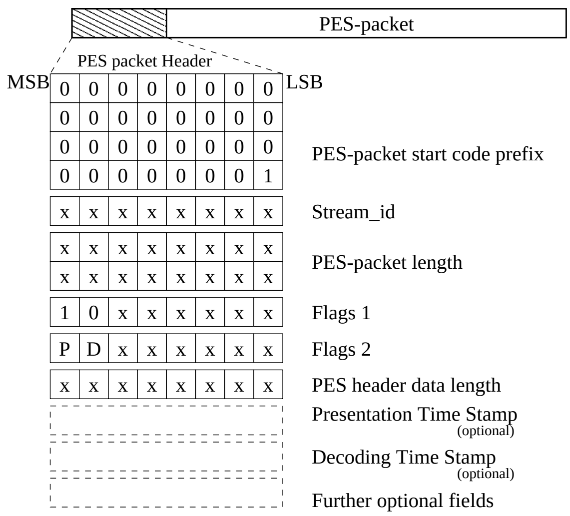

Figure 16: A PES-packet header

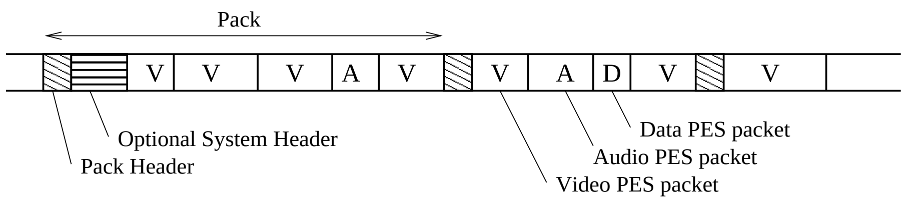

Figure 17: Structure of the MPEG-2 Programme Stream multiplex

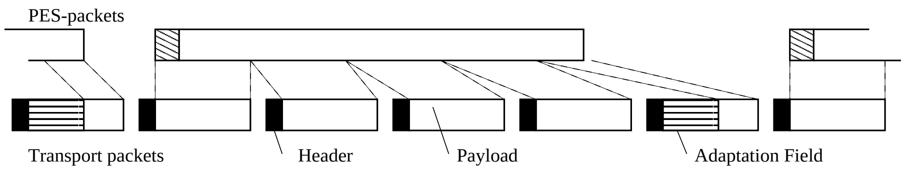

Figure 18: Dividing a PES packet into a number of transport packets

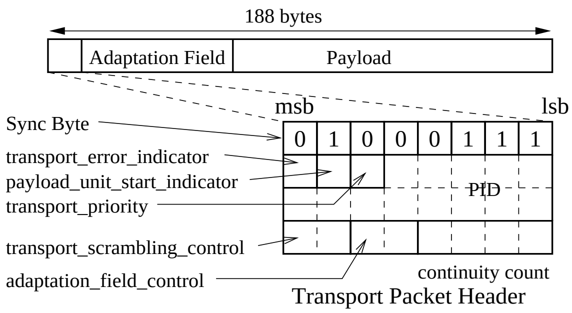

Figure 19: The structure of a transport packet and the transport packet header

any number of PES-packets taken from any of the contributing elementary streams in any order. There is no constraint on the length of a pack except that a pack header must occur at least every 0.7 seconds within the program stream as the pack header contains important timing information. The system header contains a summary of the characteristics of the programme stream such as its maximum data rate, the number of contributing video and audio elementary streams and further timing information.

The **transport stream (TS)** multiplex consists entirely of fixed length transport packets of exactly 188 bytes. It has a 4 byte header followed by an adaptation field and/or a payload. In a transport stream the PES packets from the various elementary streams are each divided among the payload parts of a number of transport packets, as shown in Figure 18. The following constraints apply:

- The first byte of each PES-packet must become the first byte of a transport packet payload.
- Only data taken from one PES packet may be carried in any one transport packet.
- The adaptation field is used to fill unused space when the length of the packet is not appropriate.

All packetised elementary streams are multiplexed together and converted to transport packets in this way. The resulting transport packets form an MPEG-2 transport stream, including packets containing service information and empty transport packets to soak up spare capacity. There are no constraints on the order in which transport packets appear within the multiplex except that the chronological order of packets belonging to the same elementary stream must be preserved.

The transport packet header consists of 4 bytes, see Figure 19. The most important fields are:

- The first byte of the packet header is a sync-byte with the value 0x47. This value is not unique within a transport packet. As it occurs every 188 bytes within a transport stream, it enables a decoder to identify the start of each new transport packet.
- A single transport stream may carry many different programmes each comprising several PES. The 13-bit PID (Packet Identifier) is used to distinguish the transport packets of the different elementary streams. 17 values are reserved for special purposes.
- The payload_unit_start_indicator is set to show special conditions in the payload of the transport packet, e.g., that the first byte of the payload is also the first byte of a PES packet.
- The continuity count field is incremented between successive transport packets of the same

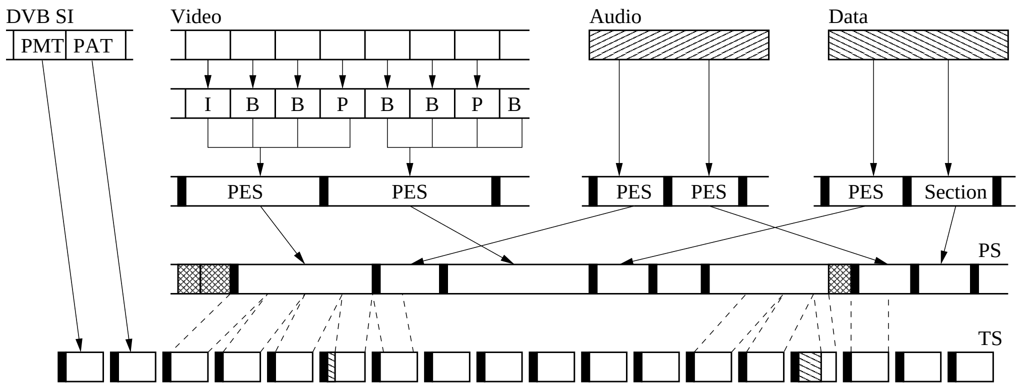

Figure 20: The MPEG/DVB transport system — overview

elementary stream. This enables a decoder to detect the loss or gain of a transport packet.

An overview of the MPEG transport system is given in Figure 20. The figure shows how the packetised elementary streams are multiplexed into a programme stream, and transport stream. The stream types include:

1. Elementary stream (ES):
   is the stream that contains the actual compressed audio and video data, like I, P, B-Frames etc., with respective headers and some other information.

2. Packetised elementary stream (PES):
   is composed of Packets containing ES data. The packets have headers, that specify the respective ES data, like 0x000001E0 for the first video stream. The header also holds the packet length and stuff like the PTS.

3. Program Stream (PS):
   mainly contains PES packets with some additional packets containing some more information for the decoder, like the SCR, buffer sizes and mux rates. PSs are used by DVDs and distributed .vob files.

4. Transport Stream (TS):
   is composed of packets that all have the same size (188bytes). They all start with 0x47. The packets are identified by their PID. Some of them contain audio and video data in the form of PES packets which are spread over many packets of size 188 bytes. Other packets contain sections which contain various things like the PMT, the PAT or videotext data. A TS is meant for transporting data over networks.

5. AV_PES:
   is the format used by the Siemens (Technotrend) DVB card internally. The audio AV_PES packets contain audio PES packets with a header that tells you whether there is a PTS in the packet. The video packets are video PES packets without the PES header (that really means the are ES streams) with a header that may contain a PTS. The data originally comes from a TS, but has already been processed by the decoder and is read from the decoders buffer.

7.2 Service Information

An MPEG-TS comes with several information tables that provide informational and technical data on the stream and its programmes. This set of tables is called service information (SI) or programme specific information (PSI). Within DVB the recommendations DVB-SI and DVB-SI DAT are used.

- PAT (Programme Association Table)
- PMT (Programme Map Table)
- NIT (Network Information Table)
- CAT (Conditional Access Table)
- PSM (Programme Stream Map)
- BAT (Bouquet Association Table)
- ECM (Entitlement Control Messages)
- EMM (Entitlement Manage Messages)
- EIT (Event Information Table)

Box 4: Examples for PSI tables in the MPEG programme stream

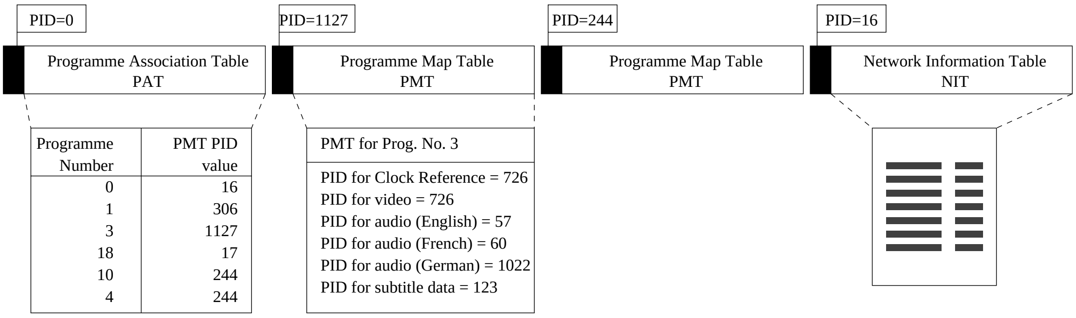

Figure 21: Programme Service Information example

Since a TV programme can be made up of several streams, a table is included that indicates where the different packets of a program can be found. While this functionality has not been defined for MPEG-2, both DVB and ATSC have provided solutions. DVB defines information on the content and service provider, content description (classification and text), type of service (TV, radio, Teletext, NVoD), parental rating description, space/time localisation of the event, and, for each component the type and a textual description.

In an MPEG TS, each transport packet is tagged with an appropriate PID value indicating to which elementary stream its payload belongs. The Programme Specific Information (PSI) specifies which transport streams belong to a program. It comprises of four types of tables: The PAT (Program Association Table), the PMT (Program Map Table), the NIT (Network Information Table) and the CAT (Conditional Access Table).

Every programme carried in a transport stream has a PMT associated with it. This table gives details about the programme and its elementary streams. A decoder can determine the PID for the coded elementary streams from the PMT. The PMT may also contain other descriptors that convey further information about a programme or its component elementary streams. The descriptors include video encoding parameters, audio encoding parameter, language identification, pan-and-scan information, conditional access details, copyright information, etc. A broadcaster may define additional private descriptors if required.

A complete list of all the programmes available in a transport stream is maintained in the PAT, which always has the PID value 0. Each programme is listed along with the PID value of the transport packets that contain its PMT.

The programme number 0 within the PAT always points to the NIT. This table is optional and its content is private (i.e. defined by the broadcaster). Where present, the table is intended to provide information about the physical network carrying the transport stream such as channel frequencies, satellite transponder details, modulation characteristics, service originator, service name and details of alternative networks available.

The CAT is present if any of the elementary streams within a transport stream are subject to conditional access. The table provides details of the scrambling system(s) in use and provides the PID values of transport packets that contain the conditional access management and entitlement information. The format of this information is not specified within the MPEG-2 Systems specification as it depends on the type of scrambling system employed.

Programme Specific Information is also defined for use in the programme stream multiplex.

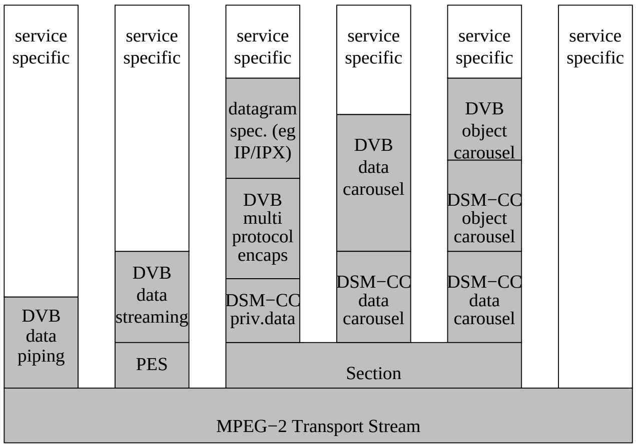

Figure 22: Graphical overview and relation between standards

Since a programme stream may only carry a single programme, all elementary streams present in the multiplex must belong to the same programme. A table called a PSM (Programme Stream Map) is defined for use in the programme stream and states the type (audio, video, other) of information carried in each elementary stream.

7.3 DSM-CC

Part 6 of MPEG-2 specifies a set of protocols which provide the control functions and operations specific to managing MPEG bit streams, abbreviated DSM-CC (Digital Storage Medium Command and Control). In the DSM-CC model, server and client are both considered to be users of the DSM-CC network. DSM-CC defines a logical entity called the "Session and Resource Manager" (SRM) which provides a logically centralised management of the DSM-CC sessions and resources. The DSM-CC architecture uses the Common Request Broker Architecture (CORBA) as defined by the Object Management Group (OMG) to implement the interaction between objects in distributed systems [4, 5].

DSM-CC provides protocols to set up and tear down network connections using DSM-CC User-to-Network (U-N) primitives, which are defined as a series of messages to be exchanged among the client, the network, and the server. It also defines messages and behaviour for dynamic and automatic configuration, and assumes that a SRM resides somewhere within the network. DSM-CC U-N is a session interface, that has no comparable functionality in the IP-world.

For communicating to a server across a network the DSM-CC User-to-User (U-U) primitives are used, which are implemented in an RPC-type protocol. DSM-CC U-U has comparable functionality as RTSP on the Internet, i.e. it implements the stream interface.

DSM-CC U-U defines library sets in order to facilitate inter-operation: The DSM-CC U-U *Core Interfaces* represent the most fundamental functionality, the *Stream* interface provides VCR-like control to the client, the *File* interface allows clients to read and write files stored on a server, the *Directory* interface provides navigation facilities, and the *Session* interface allows attachment to and detachment from service gateways.

DSM-CC also provides application delivery mechanisms. Application scripts and contents are grouped together in applications objects, which are converted into **DSM-CC carousel objects**. These are extracted in the DSM-CC U-U interface from the broadcast stream. DSM-CC also includes compression tools to format the application objects and carousel modules, and mechanisms to ensure the secure downloading of the carousel objects.

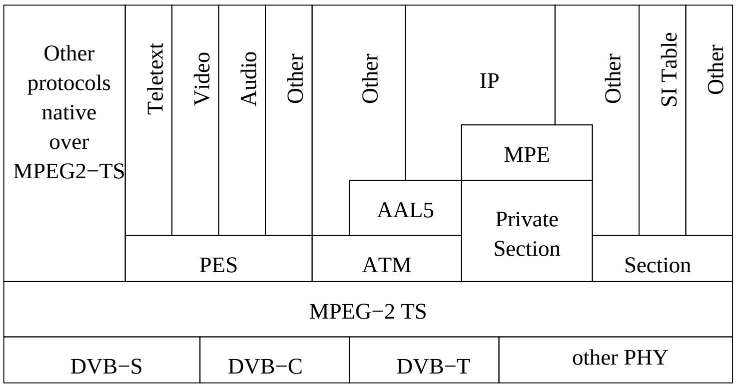

Figure 23: Overview of protocol stack for DVB

7.4 Data broadcasting

The standards of data transfer are defined by several bodies: ISO has standardised the MPEG-2 TS (ISO/IEC 13181-1) and the DSM-CC framework (ISO/IEC 13181-6). IETF has standardised the Internet Protocol (RFC 791) and other protocols, including UDP and RTP. DVB has specified the data services above (EN 301 192). Figure 23 shows how these standards and protocols are related to each other.

MPEG-2 PES provides a mechanism to transmit datagrams of variable size with a maximum length of 64 kBytes. Additionally it provides the facility to synchronise different data streams accurately.

MPEG-2 Sections can be used to transmit datagrams of variable size with a maximum length of 4 kBytes. The transmission is asynchronous. MPEG-2 Sections are built in a way that MPEG-2 demultiplexers can filter out single sections in hardware. Therefore the MPEG-2 Sections have been chosen as a mechanism for the transmission of encapsulated protocols and Data carousels.

The **Data Pipe** is an asynchronous transportation mechanism for data. The data are inserted directly in the payload of MPEG-2 Transport Packets. There is no mechanism for fragmentation and reassembly of datagrams defined, and hence the application has to handle this. Some fields in the MPEG-TS header can used for this.

For **Asynchronous Data Streaming** the PES mechanism is used for the asynchronous transmission of datagrams. Since no synchronisation is necessary for this kind of transmission the stream-id `private_stream_2` has been chosen which implicitly excludes the usage of the PES packet header fields. Therefore the PES_packet_length filed is immediately followed by the datagram. The datagram format is application-dependent.

For **Synchronous** and **Synchronised Data Streaming** The PES mechanism is used with an extra additional header. This implies the use of the stream-id `private_stream_1`, which allows the usage of the PES header fields, especially the PTS (which in term requires the definition of Access Units). Synchronous Data Streaming may be used if the output data rate at the receiver side needs to be very accurate. Synchronised Data Streaming is used when the data stream shall be synchronised with another MPEG-2 PES stream.

The **Multiprotocol Encapsulation** provides a mechanism for transporting data network protocols on top of the MPEG-2 Transport Streams in DVB networks. It has been optimised for carriage of the Internet Protocol (IP), but can be used for transportation of any other network protocol using the LLC/SNAP encapsulation. It covers unicast, multicast and broadcast. 48-bit MAC addresses are used for addressing receivers. However, address allocation is beyond the DVB specification. The encapsulation allows secure transmission of data by supporting encryption of the packets and dynamically changing MAC addresses.

The datagrams are transported in datagram sections, which are compliant to the DSM-CC section format for private data. The section format permits fragmenting datagrams into multiple sections. If the length of the datagram is less or equal than 4080 bytes (including the possible

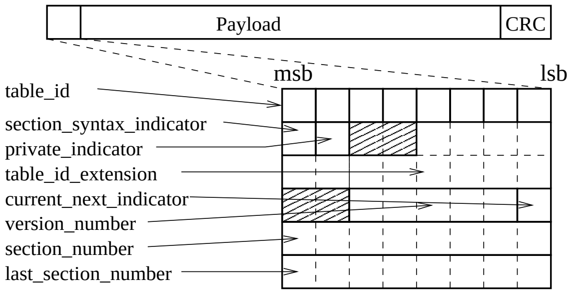

Figure 24: DSM-CC Section Format

LLC/SNAP header), the datagram shall be sent out in one section. For IP this means an MTU of 4080 bytes or 4074 bytes, depending on the presence of the LLC/SNAP header. For services using multiprotocol encapsulation, the data broadcast descriptor must be present in the SDT or the EIT (service information tables).

The **Data Carousel** is a transport mechanism that allows a server to present a set of distinct data modules to a decoder by cyclically repeating the content of the carousel one or more times. Within a Data Carousel the data is structured into Modules, while each Module is divided up to form the payload of one or more **download data messages** in the DSM-CC DownloadDataBlock syntax. Information describing each Module and any logical grouping is provided by **download control messages** using the DSM-CC DownloadServerInitiate or DownloadInfoIndication syntax. The DSM-CC messages are sent on top of MPEG-2 sections.

A logically consistent set of Modules within the Data Carousel may be clustered together into a Group, while several Groups can be clustered into SuperGroups. We distinguish between a **One-layer Data Carousel** and a **Two-layer Data Carousel**. There are also mechanisms for versioning of content within a data carousel (both temporal, and dependent on hardware, software, profile, or application).

The **DSM-CC Object Carousel** facilitates the transmission of a structured group of objects, by repeatedly inserting the objects in the DVB compliant MPEG-2 TS using the Object Carousel. The Object Carousel is platform-independent and compatible with the DSM-CC User-to-User specification, and with the Object Request Broker (ORB) framework as defined by CORBA (See `http://www.corba.org`). Within the DSM-CC U-U system environment, a structured group of objects is referred to as a Service Domain.

The data and attributes of one U-U Object in an Object Carousel are transmitted in one message. The message format is specified by the Broadcast Inter ORB Protocol (BIOP). These BIOP messages are broadcast in Modules of Data Carousels. A Module is formed by one or more concatenated BIOP messages. The Object Carousel also defines Events and References to objects.

The object carousel supports the transmission of structured groups of objects from a server to receivers using directory objects, file and stream objects. The DVB Object Carousel supports time-critical data broadcast using a mechanism called “stream events”. The Object carousel does not care about the contents of the file object. Object carousels may also carry private data services such as set-top box software updates.

Three different type of objects carried within a DVB carousel: Data files are called File Objects, typically applications and data referenced by the applications. The Object Carousel Structure is bound using Directory Objects, which the receiver uses to resolve the location of specific File Objects within the carousel stream. MHP applications can make use of real time stream events to trigger time or context related behaviour within the application. Stream events, each with their unique ID and associated data, are broadcast within the Object Carousel as Stream Objects.

One or more Object Carousels may be carried within a DVB multiplexed transport stream in the same way as the other video, audio and service information streams. Each OC stream is allocated a unique packet id (PID) and is referenced in the DVB SI service tables. An OC stream typically occupies a payload bandwidth of up to 1Mbps.

Any number of MHP applications can be included in the same carousel at the same time.

The Object Carousel generator has to share the overall carousel bandwidth between the various applications being carried at one time.

An Application Information Table (AIT) has to be transmitted either within or alongside an object carousel carrying MHP content. The AIT provides information to the decoder about the data services and the state of each MHP applications. MHP capable receivers rely in information carried within the AIT for house-keeping activities such as clearing old application data from local memory.

DVB Protocol stack

We refer to the DVB document on guidelines for data broadcasting [11]. The basis of the specification for DVB data broadcasting is formed by the MPEG-2 Transport Stream (TS) as defined in ISO/IEC 13818-1 (MPEG-2 Systems), also called DSM-CC. It is designed to be used in conjunction with the DVB-SI standard. Dependent on the application area, data can be transported in several manners within the MPEG-2 TS:

- Data Piping: Transport of anonymous, non-synchronised bit streams, asynchronous end-to-end delivery of data through DVB compliant networks.
- Data Streaming: Transport of synchronous or synchronised bit streams. This supports data broadcast services that require a streaming-oriented, end-to-end delivery of data in either an asynchronous, synchronous or synchronised way through DVB compliant networks.
- Multiprotocol Encapsulation: Use of the DVB transport mechanism for different communication services. It supports data broadcast services that require the transmission of datagrams of communication protocols via DVB compliant broadcast networks.
- Data Carousel: Periodic transmission of comprehensive files of data (as in e.g., Teletext). It supports data broadcast services that require the periodic transmission of data modules through DVB compliant broadcast networks.
- Object Carousel: (as specified by Network Independent Protocols for Interactive Services ETS 300 8022). Note: The Object Carousel is a DVB specification, and is not part of MPEG. It supports data broadcast services that require the broadcasting of objects as defined in the DVB-NIT specification (see Section 7.2).

7.5 IP/DVB

IP networks can be implemented using the Multi-Protocol Encapsulation (MPE) and DVB physical layer schemes (such as DVB-S). This can form the basis of data transfer systems including two-way Internet services, on-board (regenerative) satellite multimedia services, etc. A number of EU and ESA projects are working on IP over DVB systems. There are also related ETSI activities on DVB-RCS (DVB return channel via satellite) and BSM (broadband satellite multimedia).

Currently an activity within the IETF wants to use IP technology over DVB [15]. The working group's focus is on:

- A leaner and more IP oriented encapsulation, possibly directly layered on the MPEG-TS.
- The need for address resolution protocols to allow IP addresses to be mapped to MPEG-TS PIDs for unicast, and multicast services.
- Considerations for use of IPv6 and multicast.

From the data transport perspective, the MPEG-TS standard has overlaps with other communication protocols, i.e., the protocols on the Internet (e.g., IP, UDP, RTSP) defined by the IETF (`http://www.ietf.org`). Since the MPEG-TS can transport application program code and data to the receiver, we discuss the interrelations between MPEG-TS and IP.

In an MPEG transport stream data packages of 188 bytes arrive at the receiver. The data packages can arrive from a network (e.g. over ATM or UDP/IP), or from a broadcast from a radio transmitter or a satellite. As shown in Figure 20 the incoming packet stream must be regrouped and split into the appropriate elementary streams that contain video, audio or digital data information. The information on how this data is organised, is contained in tables sent

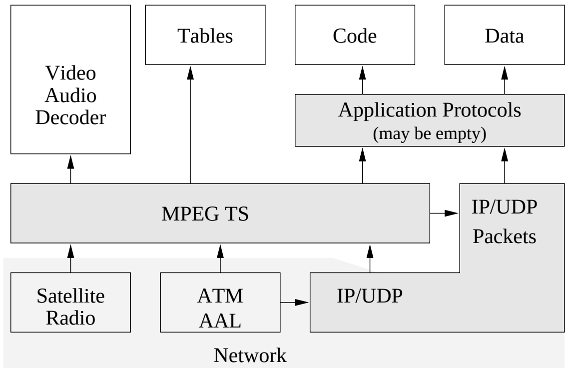

Figure 25: Relations between MPEG and IP

together with the data stream. As the MPEG-TS is simplex, e.g., a broadcast from a satellite, some kind of data will be sent repeatedly in a data carousel like in today's Teletext.

As data packets can be sent packaged in MPEG-TS, a software layer can emulate other protocols, e.g., use an API similar to UDP on top of the MPEG-TS stream. Using this as an interface, HTTP or push-technology protocols can be used to download web pages into an internal proxy server. The downloaded web pages can be accessed (using a locally installed web server) when the user wants to access this information. Therefore, it is possible to add new content to the streaming data, e.g., access to web pages or games. In Figure 25 the interrelations between MPEG and IP are sketched, where both protocols may be encapsulated within each other.

Similarly, MPEG-TS can also transport electronic mail and news, and web pages. Authentication and other security features are then necessary. Scrambling and conditional access must be used to protect private data.

7.6 The RTP protocol

RTP (Real Time Protocol) is defined in RFC 1889 [47], and provides end-to-end network transport functions suitable for applications transmitting real-time data over multicast or unicast network services. RTP provides services like payload type identification, sequence numbering, timestamping, and delivery monitoring. Applications typically run RTP on top of UDP to make use of its multiplexing and checksum services. Both protocols contribute parts of the transport protocol functionality. RTP may be used with other suitable underlying network or transport protocols.

RTP itself does not provide any mechanism to provide quality-of-service guarantees, but relies on lower-layer services to do so. It does not guarantee delivery or prevent out-of-order delivery, nor does it assume that the underlying network is reliable and delivers packets in sequence. The sequence numbers included in RTP allow the receiver to reconstruct the sender's packet sequence, but sequence numbers might also be used to determine the proper location of a packet, for example in video decoding, without necessarily decoding packets in sequence.

The RTP control protocol (RTCP) is used to monitor the quality of service, and provides feedback on the quality of the data distribution, carries a persistent transport-level identifier for an RTP source, and supports rate control in order to make a large number of participants possible. RTCP also conveys information about the participants of on-going sessions in order to provide a minimal session control. RTCP is based on the periodic transmission of control packets to all participants in the session, using the same distribution mechanism as the data packets. The underlying protocol must provide multiplexing of the data and control packets, for example using separate port numbers with UDP.

Within digital TV RTP seems to be preferred when transporting a MPEG-TS stream over UDP/IP. (See e.g., the dvbstream package, Section 8.8.3). Using RTP the receivers can detect potential problems that can occur on IP networks; e.g., changes in the sequence of packages can be detected using the sequence number field.

RFC 2250 [20] describes the RTP Payload Format for MPEG-1/MPEG-2 Video, while there are drafts for other multimedia formats [46]. For our purposes within digital TV the encapsulation of MPEG-TS packets in RTP (payload type 33 described in RFC 2250) applies. Several 188 bytes large packets of MPEG-2 TS will be encapsulated in RTP packets. The number of packets is limited by the MTU value on the host. To avoid limitations, a dynamic payload type 96 is defined in an IETF Internet-Draft (`draft-ietf-avt-rtp-mp2t-00.txt`) that extends the base clock frequency for the timestamps from 90 kHz to 27MHz.

Each RTP packet contains a timestamp derived from the sender's 90KHz clock reference. This clock is synchronised to the system stream Program Clock Reference (PCR) or System Clock Reference (SCR) and represents the target transmission time of the first byte of the packet payload. The RTP timestamp will not be passed to the MPEG decoder.[24]

For MPEG2 Transport Streams the RTP payload will contain an integral number of MPEG transport packets. To avoid end system inefficiencies, data from multiple MPEG-TS packets are aggregated into a single RTP packet. The number of transport packets contained is computed by dividing RTP payload length by the length of an MPEG-TS packet.

The RTP header fields are used as follows for MPEG-TS: The Payload Type is set to 33 (MP2T) according to the Internet draft [46]. The M-bit is set to 1 whenever the timestamp is discontinuous (switch of data source in mixers or translators). The timestamp is a 32 bit 90 KHz timestamp representing the target transmission time for the first byte of the packet.

RTP provides three ways of encapsulating MPEG streams:

- Payload based on encapsulating PS and TS (RFC 2250: Encapsulation of MPEG System and Transport Streams);
- Payload based on separate packetisation of MPEG audio and video elementary streams (RFC 2250: Encapsulation of MPEG Elementary Streams);
- Payload based on joint packetisation of MPEG audio and video elementary streams (RFC 2343).

7.7 MPEG-4

The MPEG-4 specification (ISO/IEC 14496) was finalised in October 1998, and became a standard with MPEG-4 Version 2 in the year 2000. Several extensions were added since and work on some specific work-items work is still in progress. MPEG-4 builds on the following three fields:

- Digital television;
- Interactive graphics applications (synthetic content);
- Interactive multimedia (World Wide Web, distribution of and access to content).

Besides on `http://mpeg.telecomitalialab.com`, the MPEG-4 Industry Forum (M4IF) provides information at `http://www.m4if.org`.

The MPEG-4 standard provides a set of technologies to satisfy the needs of authors, service providers and end users. The goal is to avoid a multitude of proprietary, non-interworking formats and players.

In MPEG-4 multimedia content is represented as media objects. The standard describes the composition of these objects to create compound media objects that form audiovisual scenes. MPEG-4 also provides means to multiplex and synchronise the data associated with media objects, and interaction with the audiovisual scene generated at the receiver's end.

MPEG-4 scenes are composed of several media objects, which are organised hierarchically. MPEG-4 standardises a number of primitive media objects representing natural, synthetic, 2- and 3-dimensional content. In addition MPEG-4 defines the coded representation of objects (e.g., text and graphics, talking synthetic heads, synthetic sound).

[24] Normally RTP defines timestamps asmedia display or presentation timestamp. For MPEG-2 TS packets the primary purpose of the RTP timestamp is to estimate and reduce any network-induced jitter and to synchronise relative time drift between the transmitter and receiver.

MPEG-4 provides a standardised way to describe a scene for placement of media objects, geometrical transformations, grouping, interaction, etc. The scene description builds on several concepts from VRML in terms of both structure and functionality.

An object descriptor identifies all streams associated to one media object. This allows handling hierarchically encoded data, and the association of meta-information (content description, intellectual property rights). Each stream itself is characterised by a set of descriptors for configuration information. The descriptors may also carry hints to the QoS it requests for transmission.

Synchronisation of elementary streams is achieved through time stamping of individual access units within elementary streams. The synchronisation layer manages the identification of such access units and the time stamping. Independent of the media type, this layer allows identification of the type of access unit in elementary streams, recovery of the time base of media objects or scene descriptions, and it enables synchronisation among them.

The synchronised delivery of streaming information from source to destination, exploiting different QoS as available from the network, is specified in terms of the synchronisation layer and a delivery layer containing a two-layer multiplexer.

The first multiplexing layer is managed according to the DMIF (Delivery Multimedia Integration Framework) specification, part 6 of the MPEG-4 standard. This multiplex may be embodied by the MPEG-defined FlexMux tool, which allows grouping of ES with a low multiplexing overhead. Multiplexing at this layer may be used, for example, to group ES with similar QoS requirements, reduce the number of network connections or the end to end delay.

The TransMux (Transport Multiplexing) layer offers transport services matching the requested QoS. Only the interface to this layer is specified by MPEG-4. A suitable transport protocol (e.g., (RTP)/UDP/IP, (AAL5)/ATM, or MPEG-2 TS) over suitable link layer represents a specific TransMux instance.

Use of the FlexMux multiplexing tool is optional, and this layer may be empty if the underlying TransMux instance provides all the required functionality. However, the synchronisation layer is always present.

The author of a scene can specify the possibilities for the user to interact with a scene, like change viewing/listening point, navigation through a scene, drag objects in the scene to a different position, trigger a cascade of events by clicking on a specific object, starting or stopping a video sequence, selecting language track, etc.

MPEG-4 supports the possibility to identify intellectual property in MPEG-4 media objects [24]. Intellectual property is identified by storing unique identifiers, which are issued by international numbering systems (e.g., ISAN, ISRC, etc.). These numbers can be applied to identify a current rights holder of a media object. As these unique identifiers are not available yet, MPEG-4 Version 1 also offers the possibility to identify intellectual property by key-value pairs. MPEG-4 offers a standardised interface that is integrated tightly into the Systems layer in order to control access to intellectual property.

Part IV
Software Catalogue for digital TV

8 Software and Projects for digital TV

In this section we present and classify software for digital TV. Most of these packages are Open Source software, but we also mention proprietary software packages. Other Open Source software packages related to multimedia in general are listed and discussed within the project report of a separate project on open source multimedia software [27].

8.1 Encoding and Decoding

8.1.1 mgadvd

Package:	mgadvd	**Version:**	0.4	**Date:**	October 3, 2002
Exports:				**Type:**	Hardware decoder driver
Uses:				**License:**	GPL
Url:	`http://marvel.sourceforge.net/`				
Author(s):	Merrick Johnson				

mgadvd is a Matrox G200/Zoran 36700 hardware MPEG decoder driver for Linux. It allows to play MPEG-1 and MPEG-2 streams through the Zoran 36700 Vaddis III decoder (connected to the G200) with very low CPU usage. Supported audio formats are AC3 (Dolby Digital) and PCM. Included is the player application **mzplay** which plays MPEG-1 and MPEG-2 video and audio (Layer II only) files.

8.1.2 sampeg-2

Package:	sampeg-2	**Version:**	0.6.4	**Date:**	
Exports:				**Type:**	encoder
Uses:				**License:**	GPL
Url:	`http://rachmaninoff.ti.uni-mannheim.de/sampeg/`				
Author(s):	Dirk Farin				

SAMPEG-2 is a software MPEG-1 and MPEG-2 encoder, designed to generate good image quality and provide a flexible framework for the design of new coding algorithms.[25]

Features:

- supports parallel encoding on SMP systems with very high speed-ups,
- scene-change detection integrated to provide good reference frames for motion-estimation at scene-changes, and to exploit the temporal masking effect of the human visual system,
- adaptive quantization used to expoit the activity masking effect,
- several standard motion-estimation algorithms are implemented,
- MJPEG-AVI input with audio extraction,
- direct BTTV-device input for real-time encoding,
- MMX (x86) and VIS (UltraSparc) optimized code available.

[25] The development of SAMPEG-2 has been set on hold in favour of the SAMPEG-4 project which will also provide an integrated MPEG-4 encoder.

8.1.3 FFmpeg

Package:	FFmpeg	**Version:**	CVS-2002-12-9	**Date:**	December 10, 2002
Exports:				**Type:**	Encoder
Uses:				**License:**	(L)GPL
Url:	`http://ffmpeg.sourceforge.net/`				
Author(s):	Gerard Lantau, Sourceforge				

FFmpeg is a complete and free Internet Live Audio and Video Broadcasting solution written in C. FFmpeg is a command-line tool to handle audio and video. The FFmpeg project consists of two main parts: **FFmpeg**, which encodes and decodes the multimedia streams, and **FFserver**, which provides streams via HTTP (or RTSP/RTP in the latest CVS) for various multimedia clients.

Features:

- Fast audio and video encoders which generate multiple formats in real time on a typical PC. A sound card and a (low end is enough) TV card.
- Conversion between several audio and video formats. The concept reminds to the audio application **sox**, which is well-known for audio processing.

The **libavcodec** library, which contains all the FFmpeg codecs, provide codecs for MJPEG, H263, H263+ (aka RealVideo 1.0), as well as MPEG-1 (VCD) and MPEG-2 video and MPEG audio layer 1/3 and 2, MPEG-4 (aka DIVX4/5), MSMPEG4 V3 (aka DIVX 3) under the LGPL (except a AC3 decoder which is released under the GPL).

8.1.4 libmpeg2

Package:	libmpeg2	**Version:**	0.3.0	**Date:**	November 27, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://libmpeg2.sourceforge.net/`				
Author(s):	Sourceforge				

libmpeg2 is a free library for decoding MPEG-2 and MPEG-1 video streams. The stated goals of libmpeg2 developement are:

- **Conformance** — libmpeg2 is able to decode all MPEG streams that conform to certain restrictions: "constrained parameters" for MPEG-1, and "main profile" for MPEG-2. In practice, this is what most people are using. For streams that follow these restrictions, the libmpeg2 authors claim that libmpeg2 is 100% conformant to the MPEG standards - and they have a pretty extensive test suite to check this.
- **Speed** — there has been huge efforts there, and the library authors claim libmpeg2 is the fastest library around for what it does.
- **Portability** — most of the code is written in C, and when the code use platform-specific optimizations (typically assembly routines, currently used for the motion compensation and the inverse cosine transform stages) the code also provide a generic C routine to fall back on.
- **Reuseability** — the authors does not include any project-specific code in libmpeg2

libmpeg2 is amongst others being used by the following projects: xine, MPlayer, Movietime, mpeg2decX, drip, OMS, XMPS, GStreamer, mpeglib, daphne, and GOPchop.

8.1.5 MEncoder

Package:	MEncoder	**Version:**	0.90rc1	**Date:**	December 7, 2002
Exports:				**Type:**	
Uses:				**License:**	GPL
Url:	`http://www.mplayerhq.hu/`				
Author(s):	A'rpi/ESP-team, MPlayer community				

MEncoder can encode/transcode from MPlayer-playable movies (codecs include AVI, VCD, VOB, MPG, MOV, VIV, FLI, RM, NUV, NET) to other MPlayer-playable codecs like DivX4 (1 or 2 passes), libavcodec, PCM/MP3/VBRMP3 audio. MEncoder also supports stream copying and video resizing.

8.1.6 lame

Package:	lame	**Version:**	3.92	**Date:**	April 14 2002
Exports:	lame			**Type:**	tools
Uses:	lavtools			**License:**	LGPL
Url:	`http://www.mp3dev.org`				
Author(s):	Mike Cheng				

LAME originally stood for LAME Ain't an Mp3 Encoder. The reason for this is that it was only a patch for the ISO demonstration mp3-encoder source. In May 2000 the LAME project became a stand-alone mp3-encoder with no dependency of the ISO source. Lame can encode MPEG1/2 Layer 3 audio with constant and variable bitrate.

8.1.7 liba52

Package:	liba52	**Version:**	0.7.4	**Date:**	December 10, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://liba52.sourceforge.net/`				
Author(s):	liba52 Team, Sourceforge				

liba52 is a library for decoding ATSC A/52 streams. The A/52 standard (also known as AC-3) is used in a variety of applications, including digital television and DVD. The liba52 distribution contains a test program, a52dec. It decodes ATSC A/52 streams, and also includes a demultiplexer for MPEG-1 and MPEG-2 program streams.

8.1.8 fftw

Package:	fftw	**Version:**	2.1.3	**Date:**	October 21, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://www.fftw.org/`				
Author(s):	Matteo Frigo and Steven G. Johnson, MIT				

FFTW is a C subroutine library for computing the Discrete Fourier Transform (DFT) in one or more dimensions, of both real and complex data, and of arbitrary input size.

8.1.9 libdv

Package:	libdv	**Version:**	0.98	**Date:**	July 29, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://libdv.sourceforge.net`				
Author(s):	Charles Krasic and Erik Walthinsen, Oregon Graduate Institute of Science and Technology				

Libdv was developed according to the official standards for DV video: IEC 61834 and SMPTE 314M. The Quasar DV codec (libdv) is a software codec for DV video, the encoding format used by most digital camcorders, typically those that support the IEEE 1394 (a.k.a. FireWire or i.Link) interface.

8.1.10 mpeglib

Package:	mpeglib	**Version:**	0.4.1	**Date:**	
Exports:				**Type:**	library
Uses:	liba52			**License:**	GPL
Url:	`http://mpeglib.sourceforge.net/`				
Author(s):	Martin Vogt				

mpeglib is a MPEG-1 video/audio library written in C using pthreads. Library features:

- MPEG-1 audio player (layer I,II,III (mp3))
- MPEG-1 video player
- MPEG-I system layer player
- WAV player

8.1.11 libfame

Package:	libfame	**Version:**	0.9.0	**Date:**	October 28, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://fame.sourceforge.net`				
Author(s):	Vivien Chappelier				

libfame is a video encoding library. It can currently encode MPEG-1 and MPEG-4 rectangular video, as well as MPEG-4 video with arbitrary shape.

8.1.12 recmpeg

Package:	recmpeg	**Version:**	1.0.5	**Date:**	October 28, 2002
Exports:				**Type:**	tools
Uses:				**License:**	GPL
Url:	`http://fame.sourceforge.net`				
Author(s):	Vivien Chappelier				

recmpeg is a simple video encoder, based on libfame (see Section 8.1.11), which compresses raw video sequences to MPEG video.

8.1.13 MAD

Package:	mad	**Version:**	0.14.2	**Date:**	September 29, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://mad.sourceforge.net`				
Author(s):	Robert Leslie				

MAD is a high-quality MPEG audio decoder. It currently supports MPEG-1 and the MPEG-2 extension to Lower Sampling Frequencies, as well as the so-called MPEG 2.5 format. All three audio layers are fully implemented. However, MAD does not yet support MPEG-2 multichannel audio nor AAC.

According to the authors, the output from MAD is compliant to the ISO/IEC 11172-4 computational accuracy requirements. In almost all configurations, MAD is a Full Layer III ISO/IEC 11172-3 audio decoder as defined by the standard.

The MAD distribution contains a library (libmad), a ID3 tag manipulation library (libid3tag), and a commandline front-end (madplay).

8.1.14 RTE

Package:	rte	**Version:** 0.5		**Date:**	October 4, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://zapping.sourceforge.net/doc/librte`				
Author(s):	Inaki Garcia Etxebarria, Michael H. Schimek				

RTE is a frontend or wrapper of other libraries or programs for real time video and audio compression on Linux. Currently it works on x86 CPUs only. The library is designed to interface between codecs and the Zapping TV viewer (see Section 8.5.10).

8.1.15 MP1E

Package:	MP1E	**Version:** 1.9.2		**Date:**	June 24, 2002
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://freshmeat.net/projects/mp1e/`				
Author(s):	Johannes Feigl				

MP1E is a small MPEG-1 encoder based on ffmpeg (see Section 8.1.3) with a lot of optimizations for SSE, MMX, and 3DNow!.

8.2 Transcoder software

8.2.1 mpegtools

Package:	dvb-mpegtools	**Version:** 0.9.4		**Date:**	2002-03-21
Exports:				**Type:**	applications
Uses:	code from MPEG			**License:**	GPL
Url:	`http://people.debian.org/~blade/dvb.html`				
Author(s):	Eduard Bloch, Markus Metzler (2001), Christoph Moar (1995)				

mpegtools supports conversion between several MPEG stream types and formats: TS, PES, ES, and a special format for the Siemens DVB card. Additionally there are tools to retrieve characteristics and type of a stream.[26]
The functions include:

- streamtype: information about stream.
- ts2pes: transforms a transport stream into an MPEG2 program stream.
- ts2av_pes transforms a TS into the AV_PES format used by the Siemens dvb card.
- pes2aud, pes2vid, pes2aud_es, pes2vid_es: extract audio or video streams from PES or PS streams depending on their respective names. The _es part of the name indicates that elementary streams are extracted in contrast to PES streams.
- av_pes2aud, av_pes2vid_es: same as above but for AV_PES streams.
- pes2av_pes, ps2av_pes, av_pes2ps, av_pes2pes, av_pes2ts: transform AV_PES in PS, PES and TS, respectively.
- check_av_pes: Information about AV_PES packets while outputting an AV_PES stream.
- tspids: return PIDs available in a stream.
- es2av_pes: turns a video ES into AV_PES.
- pes2ts2: transforms a PES stream into a TS (muxed).
- analyze: gives information about a PS/PES stream and all the packets contained therein.
- pes_demux, es_demux: demuxes a PS/PES into separate audio and video streams.
- ts_demux: demuxes a TS into PES.
- ts_es_demux: demuxes a TS into PES.
- ts2es: demuxes a TS into ES, but only for the given PID.
- pesplot: returns the audio and video PTS of the PES packets in a gnuplot plattable format.

[26] mpegtools is included in the HIOF DVB package. It is also part of the dvb Debian package.

- remux: is the first try of a program to remux a PS/PES stream.
- pes_repack: repacks your PES packets into smaller sizes.
- mplex: the main part of mplex is a rewrite of the multiplexing routines of bbmpeg, (mplex by Christoph Moar, see Section 8.2.3).

8.2.2 transcode

Package:	transcode	**Version:**	0.6.2	**Date:**	December 10, 2002
Exports:				**Type:**	tools
Uses:				**License:**	GPL
Url:	`http://www.theorie.physik.uni-goettingen.de/~ostreich/transcode/`				
Author(s):	Thomas Östreich				

transcode is a text console video-stream processing tool that supports elementary video and audio frame transformations. Some example modules, e.g. ffmpeg (see 8.1.3), are included to enable import of MPEG-1/2, Digital Video, and other formats. It also includes export modules for writing to AVI files with DivX, OpenDivX, XviD, Digital Video or other codecs. Direct DVD transcoding is also supported. A set of tools is available to extract and decode the sources into raw video/audio streams for import and to enable post-processing of AVI files.

8.2.3 mjpegtools

Package:	mjpegtools	**Version:**	1.6.1	**Date:**	December 10, 2002
Exports:	lavtools, xlav, mplex, aenc, mjpeg			**Type:**	tools
Uses:	lavtools			**License:**	GPL
Url:	`http://mjpeg.sourceforge.net/`				
Author(s):	Gernot Ziegler, Ronald Bultje, Bernhard Praschinger, Andrew Stevens				

The **mjpegtools** package provides Linux Audio and Video tools Motion-JPEG and MPEG. It implements MJPEG recording and playback, and simple cut-and-paste editing as well as MPEG compression of audio and video. The package consists of the following parts / directories:

- **lavtools, xlav and utils:** contains a version of lavtools by Rainer Johanni, to handle AVI and Quicktime MJPEG files. The package contains applications to record, encode, replay and decode these files, user interface components, and some conversion tools for adding and extracting components (`lav2yuv`, `lav2wav`). The package also includes image processing filter utilities for raw video: medianfilter, scaling, and transitions. It also contains an encoder to MPEG-1/2 video streams from the YUV-format.
- **aenc:** Contains the source files for “mp2enc” which is MPEG-1 layer 2 audio compressor.
- **mplex:** Mplex is a simple two-stream audio/video multiplexer for MPEG-1/MPEG-2. It accepts an MPEG-1/2 video stream and/or an MPEG layer II/III audio stream and multiplexes them into a combined program/system stream according to the constraints specified. Many different types of output structure are supported along with presets for standard VCD and SVCD streams[27]. Mplex is capable of automatically splitting the output stream into chunks of a specified size either independently or a sequence end/start points in the input video stream.
- **mjpeg, utils:** contains libraries to handle the new MJPEG movtar video format and a library to simplify MJPEG software and hardware playback.

[27] VCD and SVCD streams can be used in the `vcdimager` software to produce (S)VCD media.

8.2.4 MSYS toolkit

Package:	MSYS toolkit **Version:** 1.0	**Date:**	1995-01-06
Exports:	encode, decode	**Type:**	appl/library
Uses:		**License:**	educational
Url:	`ftp://ftp.tek.com/tv/vnd/`		
Author(s):	Guy Cherry, Tektronix		

The MSYS Toolkit is a set of C++ classes for building and manipulating MPEG system streams. These classes can be used to build MPEG system multiplexers and demultiplexers, ond other MPEG related applications. The package is written to be instructional, and is therefore not optimized for efficiency.[28]

8.3 Recording software

8.3.1 dvgrab

Package:	dvgrab **Version:** 1.1b2	**Date:**	December 10, 2002
Exports:		**Type:**	application
Uses:		**License:**	GPL
Url:	`http://kino.schirmacher.de/`		
Author(s):	Arne Schirmacher		

dvgrab receives audio and video data from a digital camcorder via an IEEE 1394 (widely known as FireWire) link and stores them into an AVI file. It features autosplit of long video sequences into several files, and supports saving the data as raw frames, AVI type 1, and AVI type 2.

8.3.2 grab

Package:	grab **Version:** 1.40	**Date:**	October 3, 2002
Exports:		**Type:**	MPEG-2 Video Recorder
Uses:		**License:**	GPL
Url:	`http://niemayer.freewebsites.com/`		
Author(s):	Peter Niemayer		

grab allows the user to record MPEG-2 streams from a DBox (DBox1/DVB2000 or DBox2) running GNU/Linux to an MPEG file. Some features include MPEG Audio Layer II and AC3 sound support, automatic multi-file write, and built-in channel-select feature.

8.3.3 VDR

Package:	VDR **Version:** 1.0.4	**Date:**	December 10, 2002
Exports:		**Type:**	application
Uses:	libsi, libxl, libvdr (from DTV)	**License:**	GPL
Url:	`http://www.cadsoft.de/people/kls/vdr`		
Author(s):	Klaus Schmidinger		

The program package Video Disk Recorder (VDR) is based on the DVB driver of the LinuxTV project.[29] The package provides an open digital satellite receiver and timer controlled video disk recorder. The user interface provides the functionality to perform timer controlled recording, file management and to a certain extend "on disk editing".

VDR includes the `libdtv` package by Rolf Hakenes. The `libdtv` library is derived from the DTV package above (libsi, libxl, libvdr). (version unknown).

[28]The software is no longer available, as also noted on the web site `http://mpeg.org`. However, we are in the posession of the library. We used and improved the library for our studies.

[29]A remote control unit is described at tha same pages, which can be used together with the VDR package.

8.4 Server software

8.4.1 VideoLAN Server

Package:	VideoLAN Server	**Version:**	0.4.0	**Date:**	December 10, 2002
Exports:				**Type:**	Streaming Server
Uses:	libdvdread, libdvdcss, libdvbpsi, Linux DVB drivers			**License:**	GPL
Url:	`http://www.videolan.org/vls/`				
Author(s):	The VideoLAN Team				

The **VideoLAN Server** (vls) is designed for handling many MPEG sources and broadcasting data over an IP network (full IPv6 support). Supported formats and devices include MPEG-1 PS, MPEG-2 PS, MPEG-2 TS, encrypted DVDs, the Kfir video encoder and the WinTV-Nova satellite receiver. The output is MPEG-2 TS over an IP network or to a file. It is implemented for GNU/Linux (tested on Debian GNU/Linux i386, powerpc and sparc), but compiles on Solaris and *BSD systems.

8.4.2 FFserver

Package:	FFserver	**Version:**	CVS-2002-12-09	**Date:**	December 10, 2002
Exports:				**Type:**	Streaming Server
Uses:	FFmpeg			**License:**	GPL
Url:	`http://ffmpeg.sourceforge.net`				
Author(s):	Gerard Lantau, Sourceforge				

FFserver is capable of streaming live or pre-recorded content or to turn your video camera into a video monitoring system. In the latest CVS versions of FFmpeg it is possible to record and serve live video from video4linux compatible devices. The FFmpeg project consists of two main parts: **FFmpeg**, which encodes and decodes the multimedia streams, and **FFserver**, which provides streams via HTTP for various multimedia clients.

Features:

- Stream several formats at several bit rates and resolutions simultaneously. You can broadcast for modems and high bit rate connections at the same time. Your site can broadcast for all users regardless the player they are using.
- Handles thousands of concurrent users.
- Uses the HTTP protocol to be compatible with all major players including Shoutcast (aka mpg123, xmms, winamp), MTV (to play streaming MPEG video and audio), "Real" compatible players and Microsoft Windows Media Player.
- Allows time shifting of live streams. Clients can seek to a specified point in the past of a live stream.
- One FFserver instance can stream from multiple live encoding sources and/or multiple static files.

8.4.3 ts-rtp

Package:	ts-rtp	**Version:**	0.1	**Date:**	April 5, 2000
Exports:				**Type:**	MPEG-2 TS over RTP
Uses:				**License:**	GPL
Url:	`http://linuxtv.org/mbone/Developer/ts-rtp.tar.gz`				
Author(s):	David Podeur				

ts-rtp provides {uni,multi,broad}cast MPEG-2 transport streams over RTP. A simple client, dumprtp, is also provided.

8.5 Player software

8.5.1 MPlayer

Package:	MPlayer **Version:** 0.90rc1	**Date:**	December 7, 2002
Exports:		**Type:**	application
Uses:	ffmpeg, libmpeg2	**License:**	GPL
Url:	`http://www.mplayerhq.hu/`		
Author(s):	A'rpi/ESP-team		

MPlayer is a movie player for Linux/Unix systems, e.g., based on the X11 display system. MPEG-1 and MPEG-2 formats are decoded with the native library libmpeg2. MPlayer supports a wide range of output drivers: X11, Xv, DGA, OpenGL, SVGAlib, fbdev, AAlib, SDL, VESA, and low-level drivers specific to some graphics cards (Matrox, 3DFX and Radeon). Most of these drivers support software or hardware scaling for full-screen playback. MPlayer also support some MPEG decoder boards, such as DVB and DXR3/3 Hollywood+. An impressive list of supported software codecs is available from `http://www.mplayerhq.hu/DOCS/codecs-status.html`. Some codecs are decoded using modified win32 libraries.

8.5.2 XMovie

Package:	XMovie **Version:** 1.9.7	**Date:**	December 10, 2002
Exports:		**Type:**	application
Uses:		**License:**	GPL
Url:	`http://heroinewarrior.com/download.php3`		
Author(s):	Heroine Virtual		

XMovie supports playback of MPEG-1, MPEG-2, MP3 audio, MP2 audio, AC3 audio and a range of other formats. According to the authors, "XMovie is primarily used for uncompressed, high resolution playback of output from an editing program". Recent versions support MPEG-2 transport stream, HDTV program and ATSC transport streams play back.

8.5.3 XINE

Package:	Xine **Version:** 0.9.13	**Date:**	December 3, 2002
Exports:		**Type:**	application/library
Uses:		**License:**	GPL
Url:	`http://xine.sourceforge.net/`		
Author(s):	Guenter Bartsch		

XINE plays MPEG-2 and MPEG-1 video, video CDs, SVCDs, and AVI files (some using proprietary Windows 32 codecs) with synchronized audio and video, and optionally full-screen using the Xv extensions in Xfree86 4.x. XINE provide C libraries for building a user interface (xine-ui), input, demuxer, decoder, and output plugins (xine-lib).

8.5.4 gxine

Package:	gxine **Version:** 0.2	**Date:**	December 10, 2002
Exports:		**Type:**	application
Uses:		**License:**	GPL
Url:	`http://xine.sourceforge.net/`		
Author(s):	Guenter Bartsch		

gxine is both a GNOME frontend and a Mozilla plugin based on the core XINE library, xine-lib.

8.5.5 mpeg_play

Package:	mpeg_play **Version:** 2.4	**Date:**	April 6, 1998
Exports:		**Type:**	application
Uses:		**License:**	GPL
Url:	`http://bmrc.berkeley.edu/frame/research/mpeg/mpeg_play.html`		
Author(s):	Lawrence A. Rowe, Ketan Patel, Brian Smith		

The Berkeley MPEG Player, mpeg_play, is an MPEG player written in C. It uses X11 to display the decoded movies by default. It can optionally produce PPM files, SVGA graphics (Linux), Windows graphics calls, or work in a Mac window. It does not handle real-time synchronisation or audio streams.

8.5.6 VideoLAN Client

Package:	VideoLAN **Version:** 0.4.6	**Date:**	December 10, 2002
Exports:		**Type:**	application
Uses:		**License:**	GPL
Url:	`http://www.videolan.org/vlc/`		
Author(s):	The VideoLAN Team		

The VideoLAN Client, vlc, is a MPEG player, that support network streams (HTTP and TS, FIXME: RTP?), slow motion, fast forward, pause, arbitrary jumps within the stream.. It uses X11 to display decoded movies.

8.5.7 Hades

Package:	Hades **Version:** 0.1.0	**Date:**	October 3, 2002
Exports:		**Type:**	application
Uses:	GdkPixbuf, GNOME, libmpeg3	**License:**	(L)GPL
Url:	`http://lumumba.luc.ac.be/takis/hades/`		
Author(s):	Panagiotis Issaris		

Hades is an easy-to-use GNOME video player which provides application of special effects in real time. Because it uses `libmpeg3` it can play both MPEG-1 and MPEG-2 program streams.

8.5.8 Playvideo

Package:	Playvideo **Version:** 0.0.2	**Date:**	August 16, 2000
Exports:		**Type:**	Svgalib Video Player
Uses:		**License:**	Non-com.
Url:	`http://www.arava.co.il/matan/svgalib/video/`		
Author(s):	Matan Ziv-Av		

Playvideo is a video player for svgalib that supports AVI, Quicktime (though not all codecs are supported), MPEG-1, and MPEG-2 video formats. It only supports 8/16 bit mono audio.

8.5.9 GStreamer

Package:	Gstreamer **Version:** 0.4.2	**Date:**	November 1, 2002
Exports:		**Type:**	library/player
Uses:		**License:**	LGPL
Url:	`http://www.gstreamer.net`		
Author(s):	Erik Walthinsen, GStreamer community		

gstreamer is a multimedia framework for the GNOME desktop (Running on Linux and Solaris). It allows the construction of graphs of media-handling components, ranging from simple mp3 playback to complex audio (mixing) and video (non-linear editing) processing. Applications can take advantage of advances in codec and filter technology transparently. Developers can add new codecs and filters by writing a simple plugin with a clean, generic interface. **gst-player** is a mediaplayer using the gstreamer framework.

8.5.10 zapping

Package:	zapping	**Version:**	0.6.5	**Date:**	October 9, 2002
Exports:				**Type:**	library/player
Uses:				**License:**	GPL
Url:	`http://zapping.sourceforge.net`				
Author(s):	Erik Walthinsen, GStreamer community				

zapping is a TV viewer for the GNOME desktop.[30]

8.6 Editing software

8.6.1 Kino

Package:	Kino	**Version:**	0.51-1	**Date:**	October 3, 2002
Exports:				**Type:**	Non-Linear Editor
Uses:				**License:**	GPL
Url:	`http://kino.schirmacher.de/`				
Author(s):	Arne Schirmacher				

Kino is a non-linear DV (digital video) editor for GNU/Linux. It features integration with IEEE-1394 for capture, VTR control, and recording back to the camera. It captures video to disk in RawDV and AVI format, in both type-1 DV and type-2 DV (separate audio stream) encodings. You can load multiple video clips, cut and paste portions of video/audio, and save to an edit decision list (SMIL XML format). Most edit and navigation commands are mapped to equivalent vi key commands. Also, Kino can load movies and export the composite movie in a number of formats: DV over IEEE 1394, Raw DV, DV AVI, still frames, WAV, MP3, Ogg Vorbis, MPEG-1, MPEG-2, and DivX. Still frame export uses Imlib1, which has built-in support for PPM, JPEG, PNG, TIFF, GIF, and whatever your ImageMagick installation supports.

8.6.2 Film Gimp

Package:	Film Gimp	**Version:**	0.5	**Date:**	October 3, 2002
Exports:				**Type:**	Motion Picture Editor
Uses:				**License:**	GPL
Url:	`http://filmgimp.sourceforge.net/`				
Author(s):	Robin Rowe, Sourceforge				

Film Gimp is a motion picture editing tool primarily used for painting and retouching of movies. Film Gimp is the most successful open source tool in feature motion picture work today. Film Gimp runs on Linux and SGI Irix. A Windows version is planned for release in December 2002, and Macintosh native in 2003.

Gimp is a widely-used alternative to Adobe Photoshop, a popular tool for professional image editing. Film Gimp extended Gimp to operate upon a series of images (with a frame manager) and in 16-bit linear or floating point color depths. With sixteen bits per component instead of eight, Film Gimp has much more color depth capacity than Gimp, and is therefore more suitable for working with the higher dynamic range of film.

8.7 Testing software

8.7.1 VK Tools

Package:	VK Tools	**Version:**	0.4	**Date:**	
Exports:				**Type:**	MPEG stream testing
Uses:	GTK+			**License:**	GPL
Url:	`http://personal.vallnet.com/thepaces/vk_tools_index.html`				
Author(s):	wpace@acm.org				

[30] GNOME (GNU Network Object Model Environment) is a user-friendly set of applications and desktop tools to be used in conjunction with a window manager for the X Window System.

The **VK Toolset** is intended to aide MPEG developers in understanding and creating conformant MPEG streams. The current version focuses on the MPEG system layer bitstreams (MPEG-1 System, MPEG-2 Program Stream).

8.8 Digital TV software

8.8.1 linux dvb / LinuxTV

Package:	LinuxTV **Version:**	**Date:**	
Exports:		**Type:**	linux kernel modules
Uses:	mpeg code (Laredo)	**License:**	GPL
Url:	`http://linuxtv.org`		
Author(s):	convergence.de		

The **LinuxTV** package is a set of kernel modules that handle streaming MPEG. This is one of the main parts within the OST platform. Most of the package is developed by `convergence.de`. The linux_dvb package is the basis for LinuxTV. It provides Linux kernel modules for the Siemens, Hauppauge, and Technotrend DVB cards. A description on the API is available at [29]. More information is available at `http://www.linuxtv.org`.

The LinuxTV API consists of the following components:

SEC: Control external hardware like LNBs and antennas.

Frontend: The frontend down-converts and demodulates the signal received from antenna, satellite dish or cable into a MPEG-TS.

CA: The complete TS is passed through the CA hardware. Programs to which the user has access (controlled by the smart card) are decoded in real-time and re-inserted into the TS.

Demux: The demultiplexer splits the TS into its components (like audio and video streams).

Audio, Video: The MPEG2 audio and video takes the MPEG components to present them on the TV screen.

8.8.2 DTV

Package:	DTV **Version:** 1.2.1	**Date:**	
Exports:	libsi, libxl, libvdr	**Type:**	application
Uses:	dvb-linux, lirc_serial, xawtv	**License:**	GPL
Url:	`http://`		
Author(s):	Rolf Hakenes		

DTV is a suite of programs to support digital TV functionality on Linux using the OST drivers. The suite parses and provides digital television services as defined in DVB SI data, carousel, etc.

The functionality includes ETSI compliant IRD to control an arbitrary number of DVB devices (satellite/Diseqc, cable) independent for one or more input devices (LIRCD, built-in remote device, TCPIP, KEYBOARD) with support of all DVB features, OSD display and menu-driven user interface, caching videotext/teletext decoder, PAT/PMT/SDT based transponder scanning, and EPG through EIT scanning. It also provides a Dcl(Tcl)-based configuration and scripting language, user definable events, and user definable menus.

DTV contains `ir_rec` device driver (linux kernel module) that records pulse- and pause-lengths (space-lengths) between DDCD event on a serial port. The DTV main package contains a DCL library, a SI library, a channel scanner and liblx (memory management functions).

8.8.3 DVBstream

Package:	dvbstream	**Version:**	0.4pre2	**Date:**	2002-01-31
Exports:				**Type:**	library,application
Uses:	ts-rtp package from LinuxTV			**License:**	GPL
Url:	`http://linuxstb.org/dvbstream/`				
Author(s):	David Podeur, Dave Chapman				

DVBstream is based on the ts-rtp package available at `http://www.linuxtv.org`. It broadcasts a (subset of a) DVB transport stream over a LAN using the rtp protocol. There were a couple of small bugs in the original ts-rtp application, which have been fixed within this project. This software requires Linux, a supported DVB card, the Linux DVB drivers from www.linuxtv.org and a kernel with Multicast networking enabled.

8.8.4 librtp

Package:	librtp	**Version:**	0.1-1	**Date:**	
Exports:				**Type:**	library
Uses:				**License:**	GPL
Url:	`http://librtp.sourceforge.net`				
Author(s):	Roland Dreier				

Librtp is a library for writing RTP/RTCP applications. The code was originally part of gnome-o-phone (see `http://gphone.sourceforge.net`).

8.8.5 liveMedia

Package:	liveMedia	**Version:**	2002.10.22 (Daily)	**Date:**	22. October 2002
Exports:				**Type:**	library
Uses:				**License:**	LGPL
Url:	`http://www.live.com/liveMedia/`				
Author(s):	Live Networks, Inc.				

LIVE.COM Streaming Media forms a set of C++ libraries for multimedia streaming, using open standard protocols (RTP/RTCP and RTSP). These libraries – which can be compiled for Unix (including Linux and Mac OS X), Windows, and QNX (and other POSIX-compliant systems) – can be used to build streaming applications. The libraries can also be used to stream, receive, and process MPEG video, and can easily be extended to support additional (audio and/or video) codecs. They can also be used to build basic RTSP clients and servers, and have been used to add streaming support to existing media player applications, such as "MPlayer".

8.8.6 HIØ DVB package

Package:	HIØ DVB package	**Version:**		**Date:**	2001-10-31
Exports:				**Type:**	collection
Uses:	Mplayer 0.50, bfr 1.3, dvbstream 0.3, mpegtools			**License:**	GPL
Url:	`http://`				
Author(s):	Håvard Rast Blok, Høgskolen i Østfold				

This package contains the programs neccessary for receiving the RTP stream of high quality, MPEG2 video from Høgskolen i Østfold. The package includes the following programs and libraries:

- LinuxTV (mpegtools and DVB driver) `http://www.linuxtv.org/`
- mpegtools, see Section 8.2.1.
- DVBStream (dumprtp) version 0.3 from `http://www.linuxstb.org/`. See Section 8.8.3. dvbstream is used to broadcast a DVB transport stream over a LAN using the RTP protocol.

- The buffering software `bfr 1.3` by Mark Glines from `http://www.glines.org/software/buffer.html`. The software buffers data in order to avoid artefacts from jitter and delays on the network.
- OST (some header files only, probably necessary for a stand-alone version.)
- MPlayer 0.50; see Section 8.5.1.

8.8.7 DVB Debian package

Package:	dvb-debian	**Version:**	0.9.4	**Date:**	2002-03-21
Exports:				**Type:**	applications
Uses:	code from MPEG			**License:**	GPL
Url:	`http://people.debian.org/~blade/dvb.html`				
Author(s):	Eduard Bloch (debian), Ralph Metzler, Marcus Metzler, (based on work from Michael Hunold, Christian Theiss, Nathan Laredo, et.al)				

The **DVB Debian package** contains the following sub-packages / applications:

- dvb-mpegtools, see Section 8.2.1;
- szap (based on DTV);
- tuxzap;
- drivers (linuxTV); and
- OST include files.

The following applications are found in tuxzap:

tuxzap: is used to switch channels on a dvb card which is using the new API developed by Nokia and Convergence. It uses gVideos .dvbrc file for its DVB tree.

ntuxzap: is a console version of tuxzap (uses ncurses).

tuxview: can be used to watch any video4linux device, e.g., the v4l part of the dvb driver.

ntuxplayer: uses the DVB API to playback video, in order to use a viewer (like tuxview, xawtv, fbtv, etc.) and playback an MPEG file at the same time. `ntuxplayer` can also playback TS

tuxplayer: is the gtk version of ntuxplayer.

rtuxzap: is a zapper that uses the lirc driver and libraries to implement a simple remote control.

Part V
Glossary

The number of terms within digital TV is rather high. Many of the terms come from a broadcasting tradition, and are therefore unknown to people with a computer science background. This glossary is intended to explain some of the most used abbreviations and terms within the field of digital TV used in this document. For deeper insight in the terms we refer to part I and part II of the document.

ADSL: Acronym for Asymetric Digital Subscriber Line; used for transfer of high bandwidth data over copper cable for individual broadband traffic. ADSL can be used as a return channel.

API: Acronym for Application Programming Interface.

ATVEF: Acronym for Advanced Television Enhancement Forum. Name for a group and a specification for enhanced TV. WebTV is using this specification.

BAT: Acronym for Bouquet Association Table (see MPEG standard).

bouquet: A collection of services marketed as a single package/entity.

broadcaster: An organisation which assembles a sequence of events or programmes to be delivered to the viewer based upon a schedule.

CA: Conditional Access system. A system to control subscriber access to services, programmes and events e.g., Nagra, Viaccess, Irdeto, Seca, Videoguard, Eurocrypt. The CA module is the device responsible for decoding of scrambled signals in the set-top box.

CANAL+: major french broadcaster that has set own proprietary standards within digital TV.

CAT: Acronym for Conditional Access Table. (see MPEG standard)

Common Interface: Hard and software architecture for CA systems whereby the generic set-top box is not dedicated to one particular encryption system. The interface between set-top box and module is standardised (PCMCIA-Interface).

Conax: DVB compliant CA system for digital TV.

Cryptoworks: CA system by Philips.

DAVIC: The Digital Audio Video Council, an international group, is set up to define the interfaces and protocols necessary to support delivery of international digital video services.

DVB: Digital Video Broadcasting group was created to establish a technical framework for the introduction of digital broadcasting systems to suit the whole range of delivery mechanisms, including cable, satellite, terrestrial and MMDS. DVB have developed the MHP.

d-box: DVB compatible digital TV set-top box used in Germany by Kirch Group.

DMIF: Acronym for Delivery Multimedia Integration Framework, which is a multiplexing layer as described in part 6 of the MPEG-4 standard.

DSM-CC: Acronym for Digital Storage Medium Command and Control, which is a part of the MPEG-2 standard.

DTH: Direct-To-Home. Used to denote satellite TV signals received by a single household via an individual dish installation.

downlink: Term used to describe the retransmitting of signals from a satellite back to Earth.

download: The download function enables service providers to update the system software of their set-top boxes via their transmission channels, and to provide services and files that are stored locally in the set-top box.

EBU: Acronym for European Broadcasting Union

ECCA: Acronym for European Cable Communications Association.

ECM: Entitlement Control Messages. Are private Conditional Access information which maintain the ordered authorization.

EIT: Acronym for Event Information Table (see MPEG standard).

EMM: Entitlement Management Messages. Private Conditional Access information which specify the authorization levels or the services of specific decoders.

EPG: A software that enable viewers to navigate amongst the large number of channels provided by digital technology in order to select the service they desire.

ETS: Acronym for European Telecommunication Standard

ETSI: Acronym for European Telecommunication Standard Institute

Eurobox: Digital TV set-top box standard by ECCA.

event: A grouping of elementary broadcast data streams with a defined start and end time belonging to a common service, e.g., first half of a football match, news and weather forecast, a film, a talk show.

flash memory: A memory module used for permanent data-storing.

HDTV: Acronym for High Definition Television. Several definitions exist in Europe, America and Japan. HDTV primarily increases quality of analogue TV.

HomePilot: Enhanced analogue TV set-top box by PCTVNet of Norway.

IRD: Acronym for Integrated Receiver Decoder. Another word for a **set-top box** that provides additional services on a TV, e.g., enhanced analogue or digital TV services.

Irdeto: CA system orginally used in the d-box.

ISDN: Acronym for Integrated Services Digital Network. Series of CCITT Recommendations related to the transmission of voices and data. ISDN is often used as a return channel.

InternetTV: Enhanced analogue TV set-top boxes by Teknema, and WorldGate respectively.

IPVBI: Proposal from the IETF to transport IP over VBI (vertical blanking interval).

JavaTV: Java based API for digital TV set-top boxes proposed by SUN Microsystems.

LMDS: Acronym for Local Multipoint Distribution System, based on microwaves.

Mediaguard: Encryption system used by CANAL+.

MediaHighway: API for digital TV set-top boxes used by CANAL+.

Mediamaster: DVB-compliant set-top box developed by Nokia.

MHEG: Acronym for Multimedia and Hypermedia information coding Expert Group. Part 5 of the standard by this group is a possible API candidate for digital TV set-top boxes.

MHP: Acronym for Media Home Platform, defined by DVB.

MMDS: Microwave Multichannel Distribution System. A distribution service for TV signals using microwave transmissions. Also called multichannel video distribution system (MVDS). In the US, it is called wireless cable.

MPEG: Motion Picture Expert Group Body established by the International Standards Organisation to provide the basis for a picture coding, compression system, and transport system. See Section 7.

MultiCrypt: Conditional access system by DVB, where the same receiver can receive different broadcasts having different decryption systems.

multiplex: A stream of all the digital data carrying one or more services within a single physical channel.

Network: A collection of MPEG-2 Transport Stream multiplexes transmitted on a single delivery system, e.g., all digital channels on a specific cable system.

NorDig: Initiative from the Norhern broadcasters and telecom companies to make a common standard for digital TV.

NTSC: The colour TV system established by the US National Television Standards Committee which is used in North America, Japan and their dependents. NTSC produces interlaced 525 line 30 frame/s pictures.

NMT: Nokia Media Terminal.

NVOD: Near Video On Demand. Term referring to services where viewers are able to see a given program of a partially individual basis at a given time interval.

OpenTV: API for digital set-top boxes.

OST: Open Standards Terminal. Open software based initiative by Nokia to implement a MHP based digital TV platform. The goal of the software is to provide a hardware independent, simple platform for home entertainment applications.

PAL: Phase Alternation Line A colour TV system, developed in Germany, which is used in most of Europe, Africa, Australia, and South America. Pal produces interlaced 625 line, 25 frame/s pictures.

pay TV: Encrypted TV programmes, which can only be accessed by subscribers, using entitled smard cards of the broadcasters. Generally Pay TV is distiguished into two categories *Pay per Channel* and *Pay per View* (PPV).

PES: Acronym for Packetised Elementary Stream, used in the MPEG-2 standard.

PID: Packet Identifier. PID is a code used for identifying of the components that forms a particular service in the transmitted datastream.

PiP: Acronym for Picture-in-Picture. This term is often used when the TV image and other content (e.g., Web pages) are overlayed and visible at the same time on the screen.

play-out: Generation of a DVB signal from the stream, in order to transmit the signal on DVB networks.

point-to-multipoint: A connection between a service provider and a number of receivers. (E.g., PPV service)

point-to-point: A (temporary) separate connection between a service provider and one receiver. (E.g. VOD service)

PPV: Acronym for Pay Per View. Customers pay for viewing one single movie or e.g., sport event which is selected individually from the TV channels. A smard card registers the access to the programme in order to charge the customer for the selected service.

programme: A concatenation of one or more events under the control of a broadcaster e.g., news show, entertainment show.

PSI: Acronym for Program Specific Information. See MPEG standard.

PSTN: Acronym for Public Switched Telephone Network

QNX: Unix based operating system used on Digital TV set-top boxes.

return channel: To enable interactive services, a direct communication channel between the service provider and the consumer is needed. Often, this back- or return-channel is realised via the normal telephone line. Other techniques are possible (see Section 1.3).

SCART: Connector-standard used for TV/VCR-devices. Also referred to as Euro-connector.

scrambling: Encryption of data to be transmitted for a specific service.

SECA: Acronym for Societé Européenne de Contrôle d'Access. CA sytem used by CANAL+.

SECAM: Sequentiel Couleur a Memoire. The colour TV standard developed in France, also used in Eastern Europe, and parts of the Middle East and Africa. SECAM produces interlaced 625 line, 25 frames/s picture.

service: A sequence of programmes under the control of a broadcaster which can be broadcast as part of a schedule.

Service provider: A company that collects the contents from a number of program/content providers and distributes the services to customers.

set-top box: A set-top box is a device, which enables the owner of analogue TV sets to receive digital TV signals.

SI: Service Information. Service Information data is a part of all the EPG data.

SimulCrypt: CA system developed by DVB, where the same broadcast can be viewed on several different CA-equipped receivers.

smart card: A (credit card-size) card that contains logic and chip memory for storing user profiles, CA system information and other services in connection with set-top boxes. Sometimes this term is also (wrongly) used for updateable magnetic or chip memory, used for accessing encrypted TV services.

smart house: Concept where electrical devices and appliances in the home can be controlled by a remote control attached to the set-top box.

SMIL: Acronym for Synchronized Multimedia Integration Language.

SRM: Acronym for Session and Resource Manager, used in the DSM-CC model.

transponder: A satellite is divided up in parts called transponders. A transponder is one distribution channel of the satellite. Each transponder can be used for distribution of several programs.

triggers: Real time events in a broadcast stream, used in the ATVEV specification.

TVML: Acronym for Television Meta Language. Description language (HTML extension) for implementing cross-over links in WebTV.

UHTTP: Acronym for Unidirectional Hypertext Transfer protocol, used to transfer resource data in a one-way broadcast. Used in the AVTEV specification.

VBI: Acronym for Vertical Blanking Interval. This part of a TV signal can be used to transport data. VBI is also used for Videotext.

Viaccess: CA system developed by Franc Telecom.

VOD: Video On Demand. Term properly describing movie service, but now generally referring to all types of on-demand services where viewers are able to order and see a given program of an individual basis at the time specified.

WebTV: Enhanced analogue TV set-top box by Microsoft.

xDSL: xDSL is a generic abbreviation for the many flavours of DSL (Digital Subscriber Line technology). Examples are ADSL, SDSL, etc. These technologies are used as a return channel.

References

[1] EUREKA 147. Digital Audio Broadcasting. Web document, http://www.worlddab.org/public_documents/eureka_brochure.pdf, 2002.

[2] S. Andersen. Over den digitale dørstokken. Word document, NRK, http://www.nrk.no/info/digital/digibros.doc, 1998.

[3] ATVEF. Advanced Television Enhancement Forum Specification (ATVEF). web pages, http://www.atvef.com/atvef_spec/TVE-public.html, 1998.

[4] R. Baier. Implementation of a DSM-CC-Server for a DAVIC-Terminal. In T. Plagemann and V. Goebel, editors, *Interactive Distributed Multimedia Systems and Telecommunication Services*, pages 237–247. Springer, 1998.

[5] V. Balabanian, L. Casey, N. Greene, and C. Adams. An Introduction to Digital Storage Media – Command and Control (DSM-CC). Web pages, http://mpeg.telecomitalialab.com/documents/dsmcc/dsmcc.htm, 1996.

[6] J. Bing. *Boken er død! Leve boken! og andre essay om informasjonspolitikk.* Universitetsforlaget, Oslo, 1982–1984. ISBN 82-00-07310-6.

[7] R. Brandrud. Digital TV and public service in the Nordic countries. *Web pages, http://www.nrk.no/interaktiv/news/M61.html*, 1998.

[8] Shenchang Eric Chen and Lance Williams. View interpolation for image synthesis. *Computer Graphics*, 27(Annual Conference Series):279–288, 1993.

[9] L. Chiariglione. MPEG-2 Generic coding of moving pictures and associated audio information. Web pages, http://mpeg.telecomitalialab.com/standards/mpeg-2/mpeg-2.htm, 2000.

[10] Andersen Consulting. Outlook of the development of technologies and markets for the european audiovisual sector up to 2010. Finalised study, Andersen Consulting, june 2002. http://europa.eu.int/comm/avpolicy/stat/tvoutlook/tvoutlook_finalreport%.pdf and http://europa.eu.int/comm/avpolicy/stat/tvoutlook/tvoutlook_finalreport%_attachments.pdf.

[11] DVB. Digital Video Broadcasting: Implementation guidelines for Data Broadcasting. DVB Document A047, 1999.

[12] DVB. Multimedia Home Platform 1.0.1. DVB Blue Book A057 Rev.1, 2001.

[13] DVB Forum. The DVB Terminology. Web pages, http://www.dvb.org/dvb_dvbdefinitions.html, 1998.

[14] ECCA. Specification of an Integrated Receiver Decoder (IRD) for cable systems (ECCA-EUROBOX). Technical Specification, http://www.ecca.be/eurobox/specificaties/), 1998.

[15] G. Fairhurst, H. Clausen, and H. Lindner. IP/DVB requirements. IETF draft, http://www.erg.abdn.ac.uk/users/gorry/ib/dvb/ibs/draft-fair-ipdvb-req-0%1.txt, 2002.

[16] C. Fehn, P. Kauff, M. Op de Beeck, F. Ernst, W. IJsselsteijn, M. Pollefeys, L. Van Gool, E. Ofek, and I. Sexton. An Evolutionary and Optimised Approach on 3D-TV. In *Proc. IBC 2002, Amsterdam.* available on http://bs.hhi.de/~fehn/publications/IBC02.pdf, 2002.

[17] Chad Fogg. MPEG-2 FAQ. Web pages, http://bmrc.berkeley.edu/projects/mpeg/faq/MPEG-2-FAQ.html, 1996.

[18] B. Gates, N. Myhrvold, and P. Rinearson. *The Road Ahead.* Viking Penguin Books, 1995.

[19] L. Habib. Interactive Digital Television — A Literature Review. notat IMEDIA/02/02, Norsk Regnesentral, Oslo, 2002.

[20] D. Hoffman, G. Fernando, V. Goyal, and M. Civanlar. RTP Payload Format for MPEG-1/MPEG-2 Video. *IETF*, RFC 2250, 1998.

[21] Heinz Johner, Selei Fujiwara, Amelia Sm Yeung, Anthony Stephanou, and Jim Whitemore. Deploying a public key infrastructure. Redbook sg24-5512-00, IBM International Technical Support Organization, 2000. `http://www.redbooks.ibm.com/pubs/pdfs/redbooks/sg245512.pdf`.

[22] John Jones. DVB-MHP/Java TV Data Transport Mechanisms. In James Noble and John Potter, editors, *Proc. Fortieth International Conference on Technology of Object-Oriented Languages and Systems (TOOLS Pacific 2002), Sydney, Australia.* Australian Computer Society, 2002. `http://www.jrpit.flinders.edu.au/confpapers/CRPITV10Jones.pdf`.

[23] R. Joseph and J. Rosengren. MHEG-5: An Overview. Web pages, `http://www.fokus.gmd.de/ovma/mug/archives/doc/mheg-reader/rd1206.html`, 1995.

[24] ISO/IEC JTC1/SC29/WG11. Intellectual Property Management and Protection in MPEG Standards. Web document, `http://mpeg.telecomitalialab.com/standards/ipmp/index.htm`, january 2001.

[25] W. Leister, L. Aarhus, T. Karlsen, and A. Kluge. Digital TV — and overview. notat IMEDIA/05/99, Norsk Regnesentral, Oslo, 1999.

[26] W. Leister, T. Lunde, L. Aarhus, A. Kluge, M. Gritzman, I. Taylor, A. Berven, A. Instefjord, and G. Sylthe. MIT – Multimedia med interaktive tjenester. notat, not publically available IMEDIA/06/99, Norsk Regnesentral, Oslo, 1999.

[27] W. Leister, B. Nordlund, E. Maus, O. Aamot, and J. Lous. Project Report SETUP. notat DART/02/02, Norsk Regnesentral, Oslo, 2002.

[28] W. Leister and H. Olsen. Virtually moving cameras for digital TV using IBR. In *submitted to "Nasjonalt seminar innen grafisk databehandling"*. not yet published, 2003.

[29] R. Metzler and M. Metzler. LINUX DVB API, V 0.9.4. Document attached to drivers available at `http://linuxtv.org`, Convergence integrated media GmbH, 2001.

[30] Microsoft. White paper: Microsoft TV Advanced 1.5. Microsoft confidential, 1996-1999.

[31] Microsoft. Broadcasting Media Innovations: From the Web to Digital Television. Web pages, `http://msdn.microsoft.com/library/backgrnd/html/msdn_innovating.htm`, 1998.

[32] Microsoft. Overview: The Business of Digital Television. Web pages, `http://www.microsoft.com/dtv/overview/ov_busdtv_01.asp`, 1998.

[33] J. Mitchell, W. Pennebaker, C. Fogg, and D. LeGall. *MPEG Video Compression Standard.* Chapman Hall, New York, 1997.

[34] MpegTV. MPEG Pointers and Resources. Web pages, `http://www.mpeg.org/`, 1998.

[35] N. Negroponte. *Being Digital.* Vintage Books, 1996.

[36] N.N. Study on the development of competition for electronic communications access networks and services. Report to the european comission, information society drectorate, on the regulation of conditional access systems and related facilities, Ovum, Squire Sanders, 2001. `http://europa.eu.int/ISPO/infosoc/telecompolicy/en/OVUM-regcasys.pdf`.

[37] NorDig. NorDig I – Digital Integrated Receiver Decoder Specification. Working Document, NorDig 1.0-A(980512), 1998.

[38] NorDig. NorDig II – Digital Integrated Receiver Decoder Specification, Version 1.0. Working Document, NorDig, `http://www.svt.se/nordig/`, 2001.

[39] H. Olsen. *Bruk av "Image Based Rendering" for beregning av virtuelle kameraposisjoner som digital-TV tjeneste.* Hovedfagsoppgave, Institutt for informatikk, Universitetet i Oslo, 2002.

[40] OpenTV. OpenTV API. Web pages, `http://www.opentv.com/products.html`, 1998.

[41] P. Perrot. DVB-HTML – An opotional declarative language within MHP 1.1. *EBU Technical Review*, september 2001.

[42] J.-J. Peters. Television 50 years. *DVB Feature Articles*, 1998. `http://www.dvb.org/dvb_articles/dvb_tv-history.pdf`.

[43] A. Rahimzadeh and R. Doherty. ATVEF and BHTML. web pages, `http://www.atvef.com/dase-pe.html`, 1998.

[44] Ulrich Reimers. Digital Video Broadcasting (DVB) the future of television. *PhysicsWorld*, April 1998. also available on DVB Feature Articles, `http://www.dvb.org/dvb_articles/dvb_physics.pdf`.

[45] A. Sarginson. MPEG-2: A Tutorial Introduction to the Systems Layer. *Colloquium on MPEG-2 – what it is and what it isn't, Organized by Professional Group E14, The Institution of Electrical Engineers, London*, 1995.

[46] H. Schulzrinne and S. Casner. RTP Profile for Audio and Video Conferences with Minimal Control. *IETF*, draft-ietf-avtt-profile-new-12, 2001.

[47] H. Schulzrinne, S. Casner, R. Frederick, and V. Jacobson. RTP: A Transport Protocol for Real-Time Applications. *IETF*, RFC 1889, 1996.

[48] H. Schulzrinne, A. Rao, and R. Lanphier. Real Time Streaming Protocol (RTSP). *IETF*, RFC 2326, 1998.

[49] R. Sedlmeyer. Multimedia Home Platform – Standard 1.0.1. *Fernseh- und Kino-Technik, 55.Jahrgang*, 2001. `http://www.irt.de/IRT/mhp/aufsatz/irt-mhp5.pdf`.

[50] M. Sieburg. Vergleich von MHP 1.0 mit MHP 1.1. *Fernseh- und Kino-Technik, 55.Jahrgang*, 2001. `http://www.irt.de/IRT/mhp/aufsatz/irt-mhp5.pdf`.

[51] M. Silbergleid and M. Pescatore, editors. *The Guide to Digital Television.* United Entertainment Media, 3rd edition, 2000. `http://www.digitaltelevision.com/publish/dtvbook`.

[52] N. Thorn. The Transmission of IP over the Vertical Blanking Interval of a PAL Television Signal. *IETF*, draft-thorne-vbi-00.txt, 1999.

[53] A. Watt and F. Policarpo. *The Computer Image.* Addison-Wesley, 1998. chapter 21.

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