Digital TV
— an overview

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Wolfgang Leister
Lars Aarhus
Tore Solvar Karlsen
Anders Kluge

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Wolfgang Leister, Lars Aarhus, Tore Solvar Karlsen, Anders Kluge

Sammendrag/Abstract:

The concept of television does not allow interactivity for the user. NR researchers have looked into the possibilities for digital and interactive TV. We may experience an integration between broadcasting and Internet technology, with enhanced possibilities for the user, producer, and service provider.

This report looks into the different techniques that try to enhance the television medium with interactivity, especially on the possibilities that come with digital TV. 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. An overview on some of the most promising techniques is given, including MPEG, DVB, NorDig, and ATVEF.

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Norsk Regnesentral/Norwegian Computing Center
Gaustadalléen 23, Postboks 114, N-0314 Oslo, Norway
Telefon (+47) 22 85 25 00, telefax (+47) 22 69 76 60

Contents

Part I
What is Digital TV?

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, but also a window on the world. However, the concept of television is still of a purely receptive nature: a few broadcasters send their content and many households passively receive it.

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 are digitally broadcast in the MPEG standard. The DVB (Digital Video Broadcast) Forum has defined several standards for transmission and for equipment. Additional services, such as the Electronic Programme Guide (EPG) will be available. A return channel may provide services as 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, new methods for dialogue patterns must be developed.

Digital TV involves more than using digital techniques for the single tasks or entities in production and broadcasting. The use of digital techniques may open up for more channels at a better quality. The main issue will be the possibility for different shadows 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. However, broadcasting aspects always should be present when we talk of TV. 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. It is the combination of these three techniques that will give us the new possibilities. All three areas have been used separately in the last years. Digital TV will open up for broadcasting with Internet access. Broadcasting with VR will extend the scenarios for games, possibly using the Internet as a return channel. Using the possibilities of MPEG, digital TV can synchronously provide us with TV, interactive TV, multimedia, and information terminal functionality.

Several books have been published recently that present a picture of the future in an information society, including visions of digital TV [20, 12]. There, TV is presented as one integrated part in an information-network rather than a separate phenomenon. While these books approach the topic from the computing perspective, the broadcasters might draw another picture [6]. It is likely that a mixture of both views will describe the phenomenon of TV of the future.

This document is the result of an internal project at Norsk Regnesentral with the goal to obtain an overview over the techniques and the consequences of digital TV. The material in this document is based on textbooks, WWW Internet sites, and material provided by manufacturers and organisations. Due to advancing technology, some standards or products may be obsolete at time of reading.

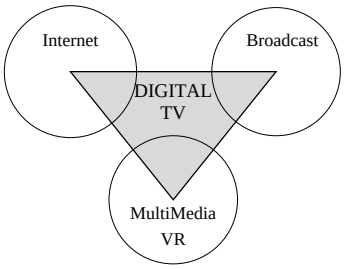

Figure 1: Digital TV as a research area

1 Definition of Digital TV

The end-user will receive a **set-top box** for their TV set, or a computer with additional Digital-TV features. The set-top box is a device, which enables the owner of analogue TV-sets to receive digital TV signals. There are several manufacturers of these boxes that use different application programmer interfaces (APIs). The hardware seems to be standardised to some extent, as a consequence of standardisation pressure and development costs. We extend a classification on digital TV functionality by Brandrud, found in [6]:

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.
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. **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.
4. **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.

The first category will be discussed in Section 3, though this technique does not follow the definition of digital TV. However, the integration between TV and other media, including the possibilities for interaction are considered interesting. The latter three categories are discussed throughout this document as the main subject.

Some related topics are not covered in this report including receiving and grabbing TV signals on a PC. HTDV (High Definition TV) is primarily a definition of the screen format for analogue TV, and not discussed further. Although Videotext (Text-TV, Teletext) is a digitally defined media stream coded in the VBI (Vertical Blanking Interval), it does not contribute to new aspects. However, it is possible to transfer IP packets using IPVBI by the IETF (see [27]).

This report comprises of three main parts. Part I presents an overview over the technology and its impact on a higher level. Part II presents technical background material, while Part III presents a glossary. We start with a presentation of the roles of the participants of digital TV. The new technology will cause changes in the existing structures, as new services and possibilities appear. The most important issue in digital TV is the possibility for interactivity. Facilities such as the EPG, the use of a remote control, new types of services, and production issues are also discussed. Enhancements for analogue TV allowing the use of interactivity in the broadcasting world are presented in Section 3. Standards, initiatives, and organisations for digital TV are presented in Section 4.

Part II 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 5. Relevant parts of the MPEG standard are outlined in Section 6. The Section 7 presents related multimedia initiatives, including the work of the ATVEF and MHEG initiatives. As many new terms are introduced with this technology, we collected a small glossary with explanations for terms within the field. A section of references concludes the report.

2 Characteristics of Todays and Future TV

In the following we discuss the roles in todays and future TV with respect to the introduction of digital TV. As the technological progress will provide us with new possibilities the roles of the parties involved in the TV value chain will change. We discuss both the traditional roles and the roles in the future. This is tightly connected to broadcasting technologies, and the consequences when broadcasting will be done digitally: bandwidth and programme manifold will increase. Additionally the role of the return channel will be discussed together with the issues of interactivity. Interaction patterns, the use of a remote control, and possibilities for new services are outlined.

TV has an over fifty years old history, and most of the readers will have experiences with the medium. Readers interested in historical aspects of TV are referred to [23].

2.1 Roles

In the traditional TV world the distinction between the different roles is somewhat unclear, mainly because a few operators were engaged in several roles at the same time. This may be illustrated by NRK which initially acted as content provider, television channel and signal distributor. A significant part of the used technology was developed by the companies themselves, especially within the production technology.

Traditionally the television broadcast value chain consists of four roles[1] which is presented in [1]. We illustrate these roles in Figure 2. The roles include:

- Content provider
- Channel operator
- Distributor
- Information consumer

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 area. Economical aspects are an important issue.

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 they may be a department within the channel operator's organisation. Today, the content providers may use digital resources to produce the programs, while the final content is brought to the consumers using analogue TV signals. Content providers typically produce content to be used in a broadcast context. This 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 traditional letters.

Within this setting we recognise that all parts will be involved in a migration towards digital TV. While the technical consequences in introducing and operating new type of equipment is quite obvious, the new concepts for creating new formats are still to be generated. The introduction of

[1] In a paper from Microsoft [15] the digital broadcasting infrastructure is divided into Production – Broadcasting – Viewing. This view neglects the role of the TV channels as a part of the process.

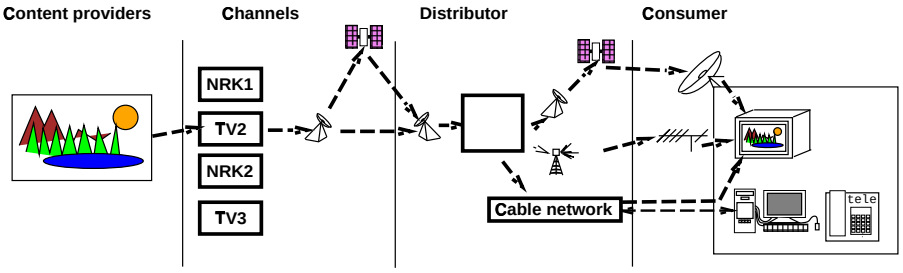

Figure 2: Different roles within the Television Media

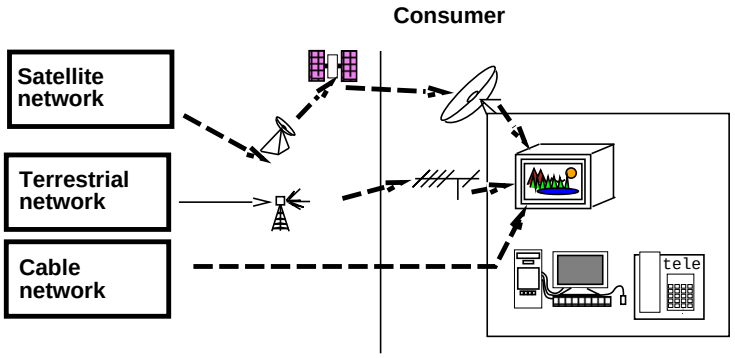

Figure 3: Alternative distribution methods

the new technology might also have consequences for other parties, as advertisers and manufacturers of hardware. They might also have their agenda with respect to the introduction of digital TV.

While we see the channel operator as the most recognised part in the beginning of the TV age, the four roles are more or less divided up in separate companies today. However, these roles may not be stable yet, and may undergo more changes. Already today distributors add local news and commercials in analogue TV broadcasts. When demand for digital TV increases, the ownership of the EPG (see Section 2.5) will be an important issue as the EPG may take over the roles of the channel operator.

2.2 Distribution and Transmission

There are mainly three 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

All three 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.

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 are very expensive to build and maintain due to big investments into infrastructure in the form of a network of emitters and transmitters. However, bandwidth and number of channels is limited.

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

- **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 transmission modes

may also provide pay channels and other services to the consumers. Cable networks are often owned by the consumers themselves. Since 1996 some cable operators provide Internet access[2] through the cable network.

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. Though there is no need for a terrestrial infrastructure, there remain huge costs in maintaining the satellite network. Satellite transmission was the first mode that was used for digital TV transmission.

There exist other possible solutions for transmission: 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.

In a digital TV setting both broadcasting and individual data traffic is necessary. This individual traffic will flow both up- and downstream. While it is possible to transfer all data by IP traffic on the Internet, this might pose economical and technical problems.

The TV media streams (e.g. MPEG programmes) are based on application-level protocols. They can be transported on any packet-oriented network, e.g. ATM, IP or MPEG-TS. MPEG-TS is typically a protocol designed for simplex broadcasting, while IP is designed for an (interactive) duplex point-to-point communication pattern. Also IP multicast can be used.

In a broadcast situation information will be sent to everybody on the ether (i.e. everybody who can receive and decode the signal). The relevant information is filtered from the incoming stream and interpreted. Also personal or confidential information can be broadcast, but cryptography methods have to be applied in this case.

The discussion whether to use broadcasting or point-to-point transfer is important from a perspective of seamlessness. The digital TV techniques will provide us with a mixture of broadcast material and individual information both up- and downstream. We have to find the balance between the different data transport mechanisms also of economical reasons, and possibly implement several transmission modes to provide seamlessness.

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.

[2] This is valid for Norway, and might vary for other countries.

2.3 Bandwidth and Program-manifold

For standard 6.7 or 8 MHz TV channels, the DVB standard (see Section 4) 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 the MPEG-2 TS standard (see Section 6) several programmes can be multiplexed to one media stream. Using digital TV techniques the number of channels that can be transported on one TV channel, multiplies with at least the factor 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 language.

Besides the increased distribution capacity the programmes can be cheaper in distribution 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. We estimate, that there will be between 20 and 200 TV channels available for the customers in the future.

Digital traffic with the possibility of auto-correction is more robust with respect to disturbances. Digitally transferred media will also achieve a better technical quality. More services and choices will be available for the user. Data download will be possible with data piping, streaming, multiprotocol encapsulation, or data carousel methods. In including application programs in the media stream multimedia material can be delivered, giving the user the possibility for increased interactivity.

2.4 Return Channel

For interactivity 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.** This comprises the use of PSTN and ISDN. The technology has rather low bandwidth. Also the use of radio transmitters could be useful as a return channel, especially in mobility situations. The use of low-effect equipment can open up for higher bandwidth.
- **TV cable.** Together with a cable modem a return channel to the network provider can achieve the possibility for high bandwidth.
- **High bandwidth networks.** The use of a high bandwidth IP connection based on Ethernet, ATM or ADSL technology is possible.
- **LMDS.** The Local Multipoint Distribution System uses microwaves for direct delivery to the customers' homes.
- **Satellite** The use of satellites as a return channel is mentioned within DVB.

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.

2.5 Electronic Programme Guide

The Electronic Programme Guide (EPG) is a navigation system for the consumer, giving detailed information on the contents of programmes and services with their respective events. The EPG

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

also forms 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.

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 the service information (SI) data provided with the incoming MPEG stream. The presenting application could come with additional functionality 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 a program that is built upon the API of the digital TV set-top box. The EPG presenting application is locally installed in the set-top box. It may be pre-installed by the set-top box manufacturer, be provided by the service provider (e.g. in a smart card in the Common Interface), be installed locally by the customer, or be downloaded from the media stream.

The information structures in the EPG are based on service information data. The API system and the information structure definitions should be decoupled as far as possible. It should be possible to make use of differences in the capabilities of user terminal devices enabling an EPG application to serve low and high end user requirements, depending on the platform, in a scalable way (computing power, DRAM, I/O and storage device capabilities and display performance are varying parameters).

For the user the EPG is a tool running on the set-top box to navigate in the program jungle. It may give additional functionality due to personal profiles. Additionally it may provide the possibility to order programmes, interaction, and integration with Web, IRC, News, etc.

2.6 Interactivity

Todays TV companies still think within a broadcasting pattern. Therefore, being interactive with the viewers is something new, with respect to both technology, organisation, journalism, and programme creation. Within the DVB framework, interaction is the issue that has been considered as the last one. Therefore, it is unlikely that the broadcasters should be innovators within this field. It is more likely that people from marketing related companies (advertisement, sales) will be first out with services and solutions. Services that have been a success in the past, e.g. Internet services within banking or electronic commerce will set an example.

Different forms of interaction are possible in connection with TV. We attempt a classification with respect to technology and interaction type in Box 3. A more application-oriented set of requirements based on short- and medium-term business plans of broadcasters would include the following areas:

- 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 todays TV usage, the EPG and the built in navigator will give 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

- **Local interaction**
  - Videotext
  - Electronic Programme Guide (EPG)
  - Applets, games and applications can be downloaded (from data carousel)
  - High bandwidth content that is sent together with the program, and that is stored in the set-top box locally
- **Interaction with information over a network**
  - Additional information that is generated by the information provider.
  - Electronic commerce, advertisements in program content, possibility to order
  - On-Demand Access, and access to the Web and Internet
  - Electronic mail
- **Real time contributions while the programme is ongoing**
  - Votes
  - Respond with answers quiz programs.
  - Auctions.
  - Smart Home concept (controlling house installations with the TV set)
- **Customisation**
  - Personal profile, with choice of materials
  - Be your own producer or director. Possibilities to choose camera, slow motion, repetition-on-demand, etc.

Box 3: Categories for interactivity

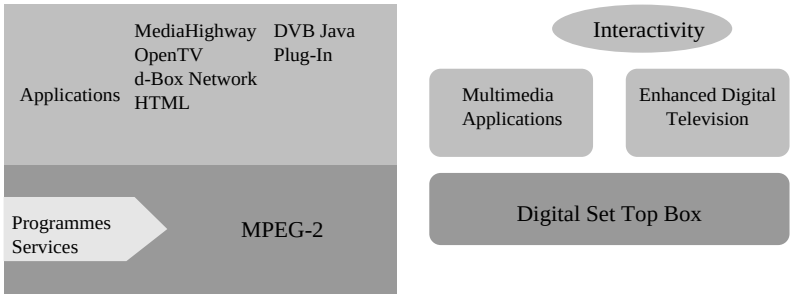

Figure 4: Schematic view of the DVB Multimedia Home Platform

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.

As one attempt to specify a high level solution for interactive TV we consider the MHP work by DVB. The DVB-TAM working group currently works on standardising an API (application programming interface), and specifying the possibilities for interaction. This work is supposed to be concluded within the current year, if an conclusion can be achieved. The MHP specification presents a generic reference model [10, 14]. However, most of the official information on the standardisation work seems still to be intentional, rather than a technical definition. Most of the discussions are about the choice of the API, where the usual goals for openness, interoperability, high level abstractions, etc. are still in progression. Several alternatives are currently discussed, such as different Java interfaces (MHEG-5 with Java, JavaTV, HTML/Java), OpenTV or MediaHighway. It is expected that a Java based solution will be chosen at last. However, MediaHighway as a proprietary system is considered to play an important role, as it already is established in the Northern European countries.

The MHP framework defines two levels of navigation: the **navigator** and the **EPG**. The

navigator is activated when switching on the receiver. It presents an overview of all services or bouquets of services available on the network to which the receiver is connected to. The navigator makes use of the service information data supplied by the network operator. It will also utilise the SI data provided by the service itself and give information on the events within a programme or service.

2.7 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 is the average person, and has typically 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 should be avoided.

Regarding the design of the remote control the DVB has defined some recommendations (see Section 5.5). DVB specifies which buttons on the remote control are mandatory. The list includes 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. However, pointing on a position on a map could be a possibility to specify places.

When using an interactive TV service, long waiting periods to set up a stream should be avoided, or the breaks must be used to show other material. TV as a medium implies also that a service must play without user interaction. The state of a program must be kept, when the user switches to other channels, in order to continue the service when the user returns (zapping). Interaction features such as stopping a service are only possible when changing the TV channel, or switching the box off.

2.8 New Services

The new technology gives the possibility for new services from the user's perspective. Examples might be information retrieval, news services, weather forecast, etc. The services will have a closer connection to the information channel than web browsing can offer. The new possibilities and interactivity allow more diversified services than ordinary TV. The services could follow a user's profile, and provide tailored information for certain areas or subjects.

Digital TV allows the download of applications, that can be stored and run on the hardware of the set-top box. These applications include the possibilities for games, both stand-alone and interactive with other participants[3]. 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.

New services that are directed more towards the TV as such, is to receive several media streams for one programme and let the user be his own producer. This could include several video or audio streams that the user can combine to her own preferences. Sports arrangements could be sent from several camera positions, or with several commentators or languages. Also postprocessing of images, 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, grab still pictures, provide slow motion etc. Locally stored application programs could give the possibility to automate this

[3]This might be the first step to form virtual communities. The social aspects could have more consequences as the introduction of the Internet has brought us. 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 likely that we will experience changes in sociological patterns in connection with digital TV in the future. However, an overview of sociological consequences are beyond the scope of this overview.

- Chose between several video streams
- Chose between several audio streams
- Arrange screen image
- Play back, still pictures, slow motion
- Access additional material (archive)
- Transfer of meta data / Events
- Database access, indexes, automatic classification
- Digitally generated animations, supportive material

Box 4: Examples of new services

process for the user, and give a better user interface. Using attached meta-data applications can sort out important events for guiding the user. Access to an archive, automatic classification, database access, and digitally generated animations will complete the possibilities.

When including the return channel, interactive storyboards can be written, where the community of users decide how a story continues, or what part of a soap opera the community of users would focus. This format has been discussed earlier as interesting (cf. [5]). New formats will arise that make use of the new possibilities for programme makers.

The content provider is interested in distributing and selling the content to a broad public. 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 lately as possible, especially of economical reasons to save costs in the production process.

The introduction of digital TV has an impact on the production of TV material. The range of different type 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 have to be established. Access to archives with search capabilities will create totally new activities within the broadcasters' organisations. Especially digitising and archiving existing material is a laborious task. Maintenance of the EPG, increased interactivity from the users, and delivery of different media types for the same content will be challenges.

3 Enhanced Analogue TV

Improved user interactivity is expected to be one of the most important new aspects of digital TV. In this section we cover methods to enhance analogue TV with interactivity. We give an overview of some of the systems available.

All approaches require that the user installs what is known as a *set-top box*, which is a device (computer) that receives a number of analogue or 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 and ISDN (Integrated Services Digital Network) are used. Other techniques include ADSL (Asymmetric Digital Subscriber Line), with a bandwidth up to 2 Mbps downstream, and 640 Kbps upstream. As an alternative the cable TV network can be used for data transfer, using a cable modem. The available bandwidth ranges typically from 256 Kbps to 10 Mbps downstream, and 256 Kbps to 1.6 Mbps upstream.

The available communication infrastructure for return channels allows to implement a return channel that can be used with add-ons to todays analogue TV. Interactivity has to be extended from a PC to using a TV screen as the visual user interface. The integration of the WWW with TV content, and adding new functionality will be a challenge.

The degree of integration between the TV and Internet content mostly distinguishes the current technical solutions. Simple approaches limit the Internet functionality to email and web browsing, while more advanced approaches link the information offered by the two media to a certain degree. We present four solutions with a different degree of content integration:

- Internet TV, by Teknema
- HomePilot, by PCTVNet of Norway
- Internet TV over cable, by WorldGate
- WebTV Plus, by WebTV

3.1 Internet TV

Internet TV by Teknema (http://www.teknema.com/) is pre-configured to connect to an Internet access provider with a built-in 33.6 Kbps modem. Internet TV can access the WWW and email with the built-in software. The device does not provide any local mass storage, besides the 4 MB cache memory. File-downloads are therefore not possible. A PC card slot allows users to plug in additional boards. An infrared remote control is used to interact with Internet TV, and a wireless keyboard is optional. The unit is equipped with a smart card reader that makes the device prepared for electronic transactions and storage of user profiles. Support for printers is also available. Java is not supported.

3.2 HomePilot

The HomePilot from PCTVnet (http://www.pctvnet.no/) enables the access to services and communication channels using the PSTN or cable as return channel. Some examples of services are: Internet access, email, TV programme guides, home banking, e-commerce and Smart House services.
The HomePilot uses the Spyglass browser with support for HTML 3.2 and JavaScript. It uses the operating system QNX/Neutrino. The email client supports the POP3 and SMTP protocols, and provides functionality to create and read messages off-line.
The HomePilot offers enhanced TV with the picture-in-picture (PiP) facility, where the active TV program may be viewed - and listened to - in a selectable sized window while surfing on the Internet. Furthermore, the HomePilot offers an EPG. It can receive data from other sources than the Internet, e.g. from VBI. Content providers may distribute information that is matched with the local profile in the HomePilot.

The HomePilot is prepared to be upgraded with add-in cards to receive digitally distributed TV signals in the DVB format. The set-top box may also be used for digital telephony in the future. The Smart Home functionality enables the HomePilot to communicate with other electrical devices in the home through the electrical wiring system. Controllers for devices with different power consumption, measuring units (e-meters) and alarms can be connected.

3.3 Internet TV over Cable

WorldGate Communications (http://www.wgate.com/internet_tv.html) provides a service for Internet access through the cable system. The service is not yet available in Norway. The existing 2-way store-and-forward addressable communications system used for pay per view has been altered to operate in real time. WorldGate uses the existing cable infrastructure to allow subscribers to access the Web at 192 Kbps with an analogue converter, and with 27 Mbps with a digital converter.
Using a remote control users can access an on-screen pointing device, and a pop-up on-screen keyboard. An optional remote wireless keyboard can be used to enter web addresses and create e-mail. Incoming and outgoing mail is stored at the cable head-end server, and an indicator on the converter indicates when new mail has arrived. Additionally, community chat rooms, real estate listings, classified ads, advertising, and important local information can be accessed. It also incorporates an EPG.
The proprietary Channel HyperLinking technology allows the user to access web sites that correspond to the actual TV programs within some seconds. Internet sessions are established and web sites can be cached in advance at the head-end server. For upgrades of the converter box the new software is downloaded from the head-end server.

3.4 WebTV

WebTV provides the user with enhanced TV with additional web-based information accessible on the remote control (http://www.webtv.com/). There are two versions, the WebTV Classic and the more advanced WebTV Plus. The set-top boxes depend on a service from a provider and are rented on a monthly subscription basis. This service is expected to be introduced in Norway in 1999. WebTV is owned by Microsoft.
The information access is done over modem, though a version for cable TV is planned. Support for several satellite receivers (mainly US based) is available. The WebTV set-top devices are manufactured by Sony, Philips, and Mitsubishi. A standard printer can be connected to the WebTV set-top box.
The Web access is enhanced by crossover links during TV-programs that are implemented using TVML. WebTV also supports WebPIP, that is a picture-in-picture facility. Additionally, local TV listings are available (EPG-functionality). The concept supports up to six email accounts per household. However, off-line email composing is not yet possible. By using the TV listings feature, also VCR programming for recording is possible.
A smart card concept will be available for the access to the account, and to give possibilities for electronic commerce. SSL (Secure Socket Layer) is implemented to offer secure online banking and electronic commerce to subscribers.

3.5 Set-top Box Functionality Comparison

Table 1 gives an overview over some examples of enhanced TV set-top boxes. *Internet TV* offers Internet functionality to the TV set. *Home Pilot* offers more advanced functionality including SmartHouse and some content integration. Both solutions are available in Norway. *Internet TV over cable*, enhances the existing cable converter (i.e. cable set-top box) to support Internet data traffic in addition to regular cable TV programs. *WebTV Plus* offers the a strong integration between Internet and TV. However, none of the last two solutions are available in Norway yet.

Apart from Internet TV over Cable, all other approaches use the phone line as return channel. Remote control or keyboard is always the user interaction method. Generally speaking, the level of Web/TV integration and new interactive services is rather low.

Features—Product	InternetTV	HomePilot	WorldGate	WebTVPlus
Picture-in-picture	no	yes	not yet	yes
TV/web integration	no	some	Channel Hyper-Linking	TVML
EPG	no	yes	yes	TV Listings
Interaction	remote control / wireless kbd	cordless infrared w/mouse	remote control / wireless kbd	remote control / wireless kbd
Smart card	yes	yes	?	not yet
Modem	PSTN 33.6/56, ISDN 64/128	PSTN 33.6, VBI	cable (192kbps, 27Mbps)	PSTN 56
Return channel	yes	yes	14kbps, 256kbps	yes
MPEG-2 TS	no	planned	yes	?
Local storage	4MB RAM	8MB RAM	no	1GB HD, 8MB RAM
Browser	?	Spyglass, QNX Voyager	?	proprietary
Web	HTML3.2, JavaScript, SSL	HTML3.2, JavaScript, SSL	HTML3.2	HTML3.2, JavaScript, SSL
Java	no	no	yes	no
Email	4 accts.	5 accts., offline editing	yes	6 accts., MIME, no offline editing
USENET News	no	yes	no	yes
Processor	?	i486/99	?	?
OS	?	QNX	?	?
Extension	PCMCIA	PCMCIA	?	?

Table 1: Comparison of Enhanced analogue TV set-top boxes.

There are more products available on the market. The market is not stable at the moment and several alternative boxes with different functionalities are available. An example of a product that was developed for the European (especially the French) market is the Netbox (see http://www.netgem.com/). A QNX based product that integrates TV with Web functionality is offered by the German based Loewe Opta (http://www.loewe.de), the French based SurfTV and the Californian based Neon Technology. However, it is not within the scope of this overview to cover all products currently on the market.

4 Standards for Digital TV

This section is intended to give an overview of the current actors, standards and implementations within digital TV. The availability of various standards allows manufacturers to integrate several standards in one set-top box, instead of producing different set-top boxes for each standard. Both open and proprietary standards are available. However, most of the standards and implementations seem to follow the DVB (Digital Video Broadcasting) recommendations.

A digital TV system can be characterised by the following three subsystems:

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

The specifications of most of the IRD units follow the relevant DVB/MPEG recommendations, but the CA systems and APIs are different and incompatible between the platforms. However, both CA system and API can be exchanged using the common interface and the loader capability[4]. Additionally, there is an incompatibility between IRD for cable, satellite, and terrestrial distribution regarding the tuner.

The hardware of the DVB compliant set-top boxes (also denoted as IRD unit) consists of the engine that provides presentation of the content of an MPEG transport stream. This includes tuner, CA module, demultiplexer, and decoder for delivery of digital TV programmes. The main board computer (including graphics processor and CPU) gives the enhanced features together with a smart card reader, remote control, and a network connection. Figure 5 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 knowing its exact 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, and architectures like MHEG. The applications are supposed to be transported in an MPEG stream, or be stored on smart cards for several hardware types.

NorDig is an initiative from the Northern European broadcasters and telecom companies with the goal to specify both the IRD and the API. Before it was initiated, two API platforms were already established in the Nordic market[5]:

- **Eurobox/OpenTV/Viaccess** introduced by Telia and Tele Danmark for CATV (Community Antenna Television) and SMATV (Satellite Master Antenna Television system) markets.
- **MediaSat/MediaHighway/Conax** established by Canal Digital Nordic for DTH (direct to home), CATV and SMATV markets. In the start-up phase the system will combine a Nokia operating system.

In the following, organisations and technical standards are presented that play a role within

[4]The software implementing the API for a specific IRD can be downloaded with the MPEG-TS, if the provider supports the IRD. The software is usually sent with the MPEG-TS cyclically in a carousel.

[5]We characterise the systems by IRD-unit/API/CA-system.

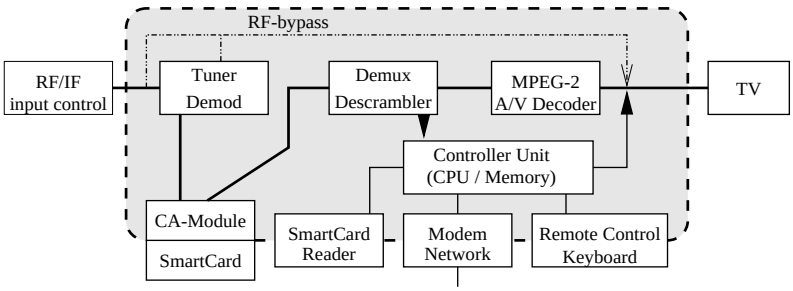

Figure 5: Hardware components of digital TV (simplified)

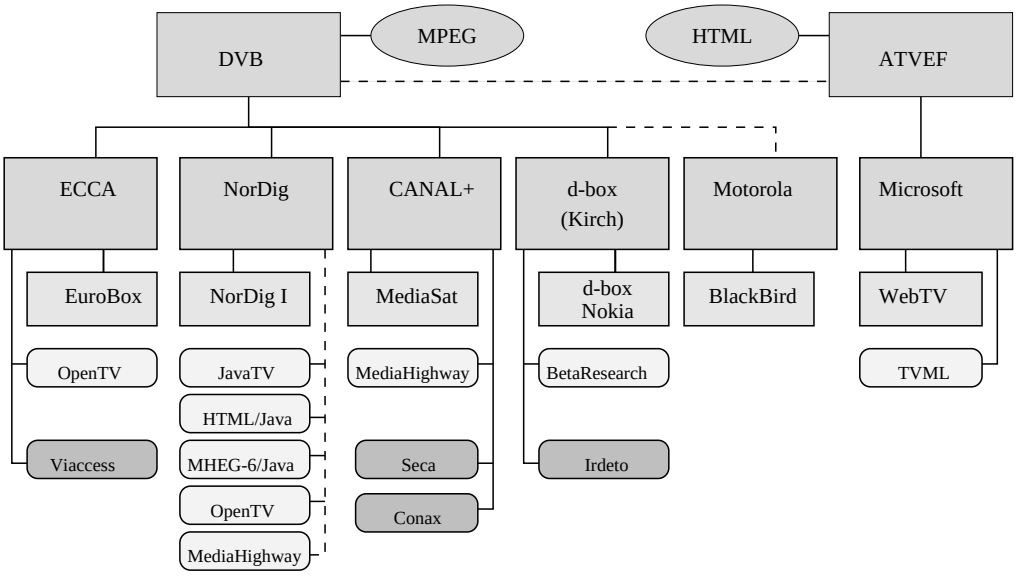

Figure 6: Overview on standards and initiatives in digital TV. The figure shows the initiatives with their respective IRD, API, and CA system in the columns.

digital TV. We give an overview of how these different actors and standards are related to each other in Figure 6. The two basic initiatives are the DVB and the ATVEF, which base their technology around MPEG and HTML, respectively. 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.

For Nordig I the choice of the API is not yet concluded, depending on the decisions of the DVB. Candidates include JavaTV, OpenTV, MediaHighway, HTML/Java and MHEG-6/Java. We choose to draw all the alternatives in Figure 6. The CA system is not yet decided, and will probably be the choice of the single providers, using the Common Interface specification.

4.1 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. 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 5) the DVB is now working on the Multimedia Home Platform (MHP) (see Section 5.2), which is supposed to be an API standard within digital TV. However, the framework is more of a conceptual basis, and no decision on an implementation is taken yet. DVB has also suggested architectures for conditional access (see Section 5.6). More information on the activities of the DVB project can be found at http://www.dvb.org/.

4.2 NorDig

NorDig is a consortium 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 specification is compliant with the DVB and MPEG specifications. The Common Interface, a transport port, a Loader mechanism and Memory expansion options are of major concern. As there are already several CA systems introduced in the Nordic market, it is considered difficult to achieve the definition of one single standard. NorDig tries to standardise on one single software platform for applications (e.g. EPG, PPV, NVoD, information and transaction services). NorDig has suggested the NorDig I specification for a Digital Integrated Receiver Decoder for use in cable, satellite and terrestrial networks [21]. Part A describes the Hardware specifications, while part B specifies the API. Part B is not yet released (april 1999). The technical issues of the NorDig specification are outlined in Section 5.1. The web pages of NorDig can be found on http://www.svt.se/nordig/.

4.3 CANAL+

CANAL+ is a major broadcaster based in France, 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 5.6). 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.

4.4 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 Eurobox-agreement is open to all cable operators. The specification for the Eurobox describes both hard- and software aspects [9]. 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 more information on technical details see Section 5.3.

4.5 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/.

4.6 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, and is a possible NorDig API platform. See also Section 5.4.

4.7 JavaTV

JavaTV is a proposal for an API for digital TV platforms by SUN, and considered a possible platform to be selected by NorDig. 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/.

4.8 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 been opened recently. The original software comes from Beta Research. To some extent it seems technically possible to replace the original software with other software. However, this is legally not allowed. The d-box seems mainly to be used as a decoder box for pay-TV. The d-Box is 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.
http://www.nokia.com/products/multimedia/dbox.html

4.9 ATVEF

ATVEF (Advanced Television Enhancement Forum, http://www.atvef.com/) is a group 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 [2] 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 7.1.

4.10 Nokia and Mediamaster

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 11). More information can be found on http://www.nokia.com/multimedia/

4.11 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

- Norway: Canal Digital (satellite) 1998
- Sweden: Telia + TV9 (cabel) 1998, Teracom (terrestrial) 1999
- France: CANAL+ (satellite) 1996
- Great Britain: SkyDigital (satellite) 1998, ONDigital (terrestrial) 1998
- Germany: Digitales Fernsehen (satellite) 1998, ARD Digital (satellite, cable, terrestrial) 1998
- USA: DirecTV (satellite) 1994

Box 5: Introduction of digital TV in Europe

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/

4.12 Motorola and the Blackbird

The Blackbird [18] is a set-top box for multimedia developed by Motorola utilising PowerPC- and Project-X technology (i.e. a media processor designed for home theatre applications). Blackbird is conceptually similarly to a set-top box, but it can deliver high-performance entertainment, movies, games, video conferencing, and other multimedia applications using several alternative communication protocols. The user interface is operated by a remote control. The range of applications includes audio, video and graphics applications, Web browsing, Internet access as well as acting as a broadband router.

Regarding features for digital TV it includes an MPEG-2 Transport Demultiplexer, MPEG Audio/Video Decoder, PAL/NTSC, Digital Video Encoder, and high performance 2D and 3D Graphics, including rendering algorithms, and interactive audio synthesis. The media processor outputs video and audio to audio-visual peripherals, such as televisions, audio receivers, and Dolby™ AC-3 decoders.

4.13 Available Services

The DVB initiative seems to be the leading force in the business of digital TV in Europe. Most manufacurers and providers follow the standards recommended by DVB. However, the American ATVEF initiative takes steps into other directions. With Microsoft as driving force, ATVEF thinks more of analogue TV with triggers and HTML enhancements[6]. DVB uses MPEG as the underlying standard, and is therefore more within a narrower definition of digital TV.

The introduction of digital TV has only recently started in Europe. Not many services are up and running, and many of them are still in a trial and evaluation phase, where both broadcasters and distributors still experiment with the new medium. A short overview on some broadcasters which have introduced digital TV, or will in the near future, is shown in Box 5.

[6] See Section 7.1 for more technical information on ATVEF.

Part II
Digital TV — Technical Issues

In this part we introduce the technical details of digital TV. We cover architectural issues of DVB-compliant digital TV, starting with the NorDig specification. This includes both hardware and the API. However, as the API is not yet defined, 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.

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.

5 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.

5.1 NorDig I

NorDig I is a specification of a Digital Integrated Receiver Decoder (IRD) for use in cable, satellite and terrestrial networks [21]. An IRD implements the services by a combination of hardware and software solutions. Part A describes the hardware specifications, that are conform to the DVB standard. Therefore this short overview also denotes the propositions of the DVB on hardware for digital TV.

The main functional blocks are shown in figure 7. The IRD includes a bootloader as firmware for upgrade of resident system- and application-software in the receiver loaded either via the distribution channel or locally. A set-top box is the implementation of an IRD. 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 8. 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 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 descrambling of services subject to conditional access data in the smart card. 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

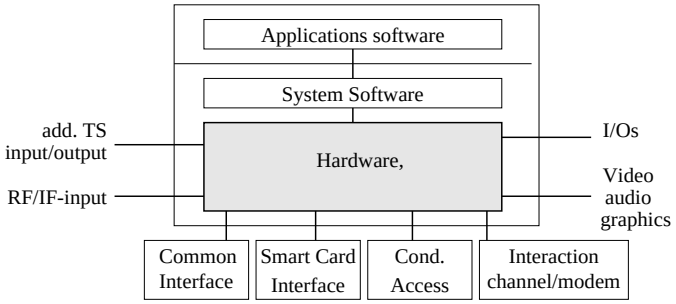

Figure 7: Basic IRD architecture

video, audio, Teletext, SI, subtitling and data for additional services.

MPEG-2 decoder. The audio and video decoding units recover 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[7].

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 descrambling 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 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. As for 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 has three main bootloader modes: over-the-air, Common Interface Module (CIM), and by RS-232 or modem. The software files to be downloaded are stored in a DVB Data Carousel, and output cyclically to the broadcast multiplexer. The cycle time and instantaneous data rate are configuration parameters depending on the IRD type. One or more download services can be defined by a number of IRD manufacturers.

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

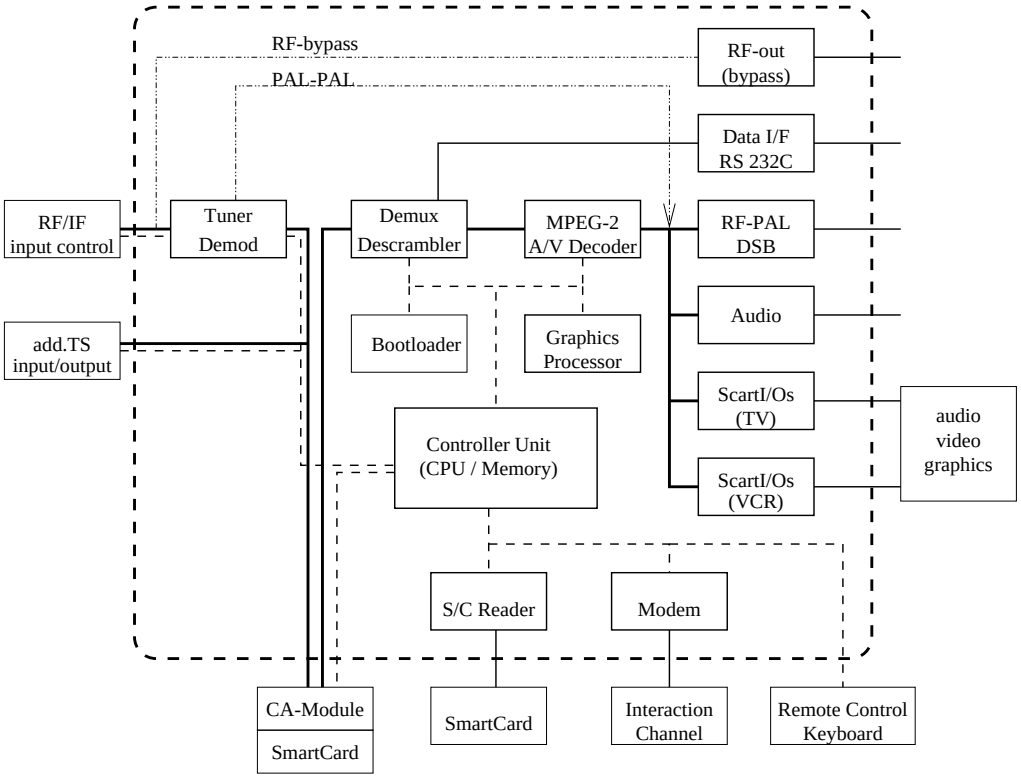

Figure 8: NorDig I — Functionality of Hardware and Firmware

5.2 Multimedia Home Platform

MHP (Multimedia Home Platform) is a framework for an API suggested by DVB Forum. MHP encompasses the peripherals and the interconnection of multimedia equipment in the home, including protocols, common API languages, interfaces, etc. With an MHP system, users would be able to access enhanced broadcasting services, interactive broadcasting services, and Internet services. An overview of the MHP is given by Evain [10], and Luettke [14].

DVB-TAM (a subgroup in DVB Forum working on technical issues associated with MHP) is currently considering several API implementations, which will have to be open, in order to suit the requirements of a horizontal market. The candidates include **MHEG-6/Java**, **MediaHighway+**, **JavaTV**, and **HTML/Java**.[8]

DVB-TAM has defined an API as a set of high-level functions, data structures and protocols which represent a standard interface for platform-independent application software. The requirements for the API are openness, abstraction, evolution, and scalability. The API should support applications that are locally stored as well as those that are downloaded. The API should also preserve the look-and-feel of the application, enable access to databases, and allow room for competition among implementors.

The MHP architecture is at a conceptual level, and includes features as application launch and control, session/event management, security and access, content loading, navigation and selection, declarative content and streams presentation control, communication and I/O control, signalling, bit transport, driver, and management functions. A possible API architecture including middleware for pipes and streams is outlined in Figure 9. DVB has also proposed a reference model for the API that consists of five layers:

- application (content, script) and media (audio, video, subtitle) components.

[8]Rumours in November 1998 say that the API will be Java with plug-ins for MediaHighway+, and OpenTV. It has also come to our knowledge that OpenTV will support the JavaTV initiative from SUN Microsystems.

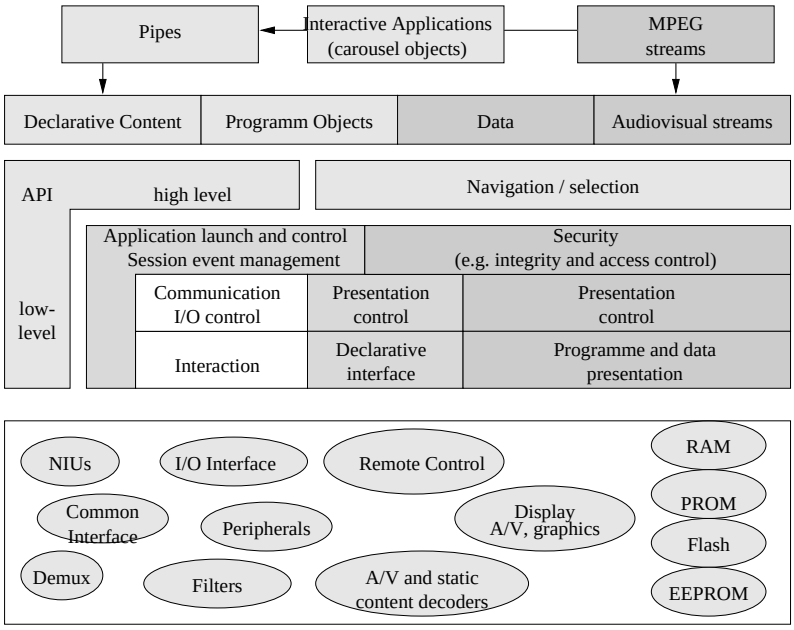

Figure 9: A possible API architecture and middleware for pipes and streams (from [10]).

- pipes and streams
- the API and native navigation/selection functions
- platform/system or middleware including the interactive engine, the run-time engine (RTE) or virtual machine, the application manager, etc.
- hardware and software resources, and associated software

An interactive application in the MHP is basically built on application scripts (declarative or procedural), and scenes (declarative interfaces or media streams). **Procedural applications**, based on low-level functions and primitives are used when very strong optimisation is required at the host level. These are generally platform dependent. **Declarative applications** use high-level functions and primitives that are defined due to a platform-independent reference model.

The standardisation process of the MHP is still in an early phase, and the MHP framework might be too ambitious to implement. The existing proprietary standards must be taken into consideration, as they already are implemented. It is less likely that an entire framework like the MHEG standard that is proposed as a platform, will succeed on the hardware specification chosen for the set-top boxes. The lack of standardisation is a reason for serious delays in the introduction of digital TV.

5.3 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)[9]. 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.

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

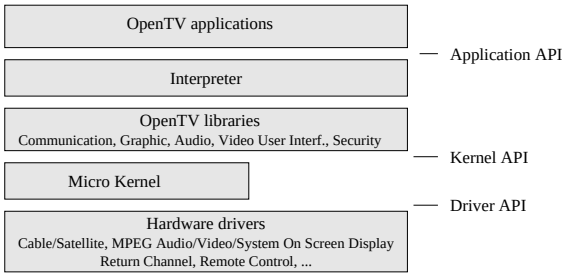

Figure 10: The OpenTV API

The performance of the ECCA Eurobox for the different modules is explained in the specification document [9]. 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[10].

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.

5.4 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 10 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 [22] contains 27 chapters with about 476 procedure calls. The following areas are covered by 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.

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

Figure 11: Example of remote controls for digital TV: Eurobox distributed by Telia in Sweden (left), CANAL+ (middle), and Nokia Mediamaster (right).

5.5 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 11 shows examples for remote controls for Digital TV.

5.6 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 6):

- SECA (also called MediaGuard, French, used by CANAL+)
- Viaccess (by France Telecom)
- Irdeto
- 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 technical details of the specification are distributed, and 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 in the same scrambled broadcast.

The Common Interface is an interface between a standard PCMCIA module and a DVB receiver, that gives 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 different CA technologies can be used on the same receiver in an approach known as MultiCrypt. MultiCrypt allows the same receiver to receive several broadcasts having different CA systems. This solution also allows broadcasters to use modules containing solutions from different suppliers in the same broadcasting system.

5.7 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 handheld 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/.

Windows CE is a compact and portable operating system built for business and consumer devices. It implements many APIs of the Windows OS family. It is used as operating system for enhanced analogue set-top boxes and digital TV set-top boxes. Microsofts view on digital TV and the use of OS in set-top boxes can be found in [16].

6 MPEG

This section is intended to give an overview on the relevant parts of MPEG-2 with emphasis on digital TV. The MPEG-2 transport system is explained in detail, while video and audio compression are omitted. These can be found elsewhere [11, 17]. Introductory literature on MPEG can be found in [26, 19].

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 Electro-technical Commission (IEC), in cooperation with the ITU-T (the former CCITT). The committee is formally named ISO/IEC JTC1/SC29/WG11. 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-Backwards 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.

6.1 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 (e.g. ATM AAL5).

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.

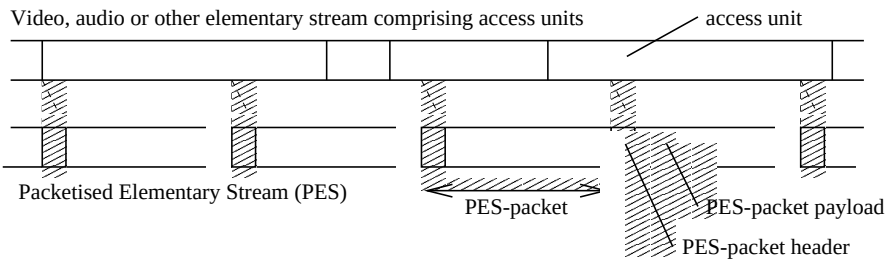

Figure 12: Conversion of an elementary stream to a Packetised Elementary Stream

A **programme** in MPEG-2 context is a single broadcast service or channel.[11] 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 12), that are of variable length (maximum length is 64 kBytes). It consists of a header and bytes taken sequentially form 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

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

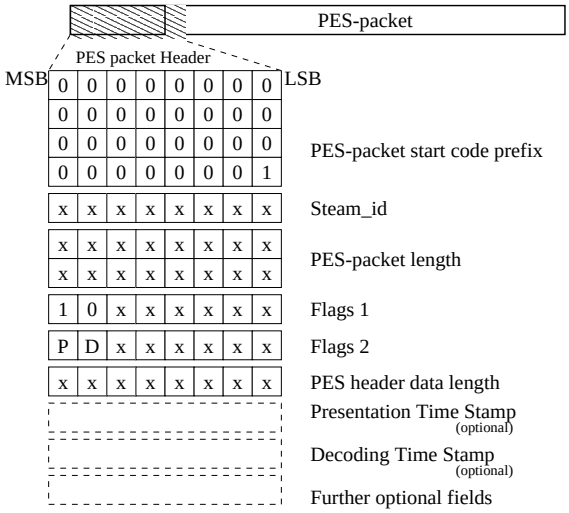

Figure 13: A PES-packet header

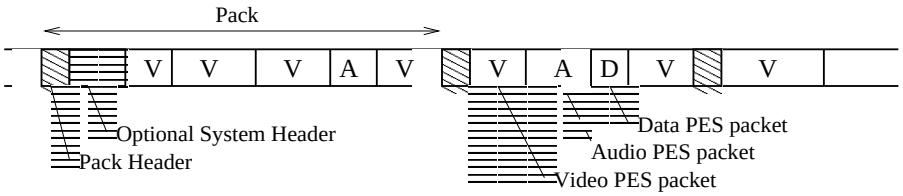

Figure 14: Structure of the MPEG-2 Programme Stream multiplex

and it is possible for several small access units to be contained in a single PES-packet.

Figure 13 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 14), that consists of a pack-header, an optional system header and 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 15. 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

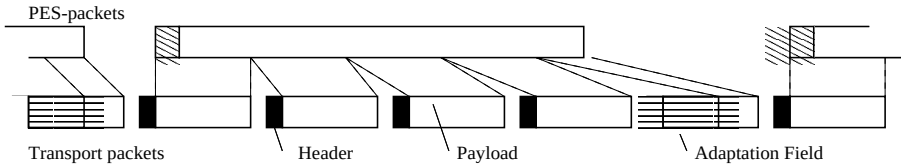

Figure 15: Dividing a PES packet into a number of transport packets

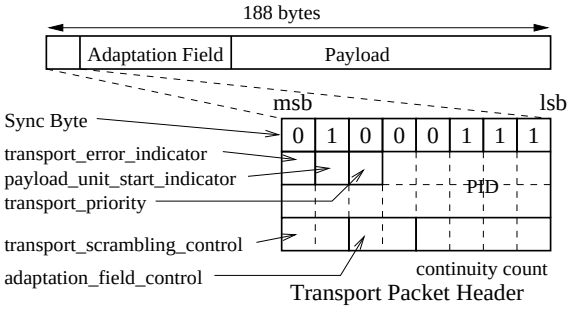

Figure 16: The structure of a transport packet and the transport packet header

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 16. 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 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 17. The figure shows how the packetised elementary streams are multiplexed into a programme stream, and transport stream.

6.2 Service Information

An MPEG-TS comes with several information tables that provide informational and technical information 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.

As 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 four types of tables: The PAT (Program

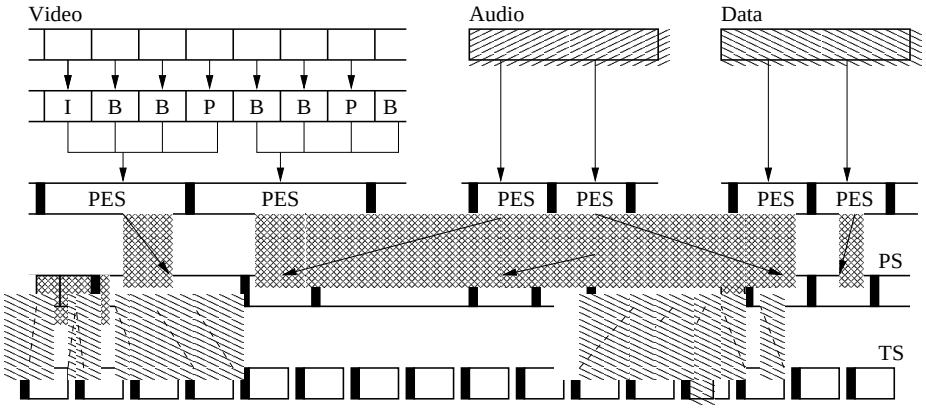

Figure 17: The MPEG transport system — overview

- 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 6: Examples for PSI tables in the MPEG programme stream

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. As 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.

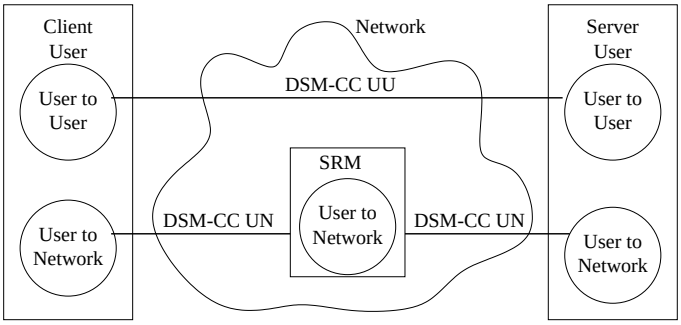

Figure 18: DSM-CC model

6.3 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 (see Figure 18). 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 [3]. See also [4].

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.

6.4 DVB Data Broadcasting Standards

The DVB Data Broadcasting Specification is based on MPEG-2 DSM-CC and is designed to be used in conjunction with the DVB-SI standard. Although DSM-CC is complex, it allows the selection of only the relevant sections. The specification is designed to allow operators to download software over satellite, cable or terrestrial links, to deliver Internet services over broadcast channels (using IP tunnelling), to provide interactive TV, etc. The DVB data broadcasting standards include:

- 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

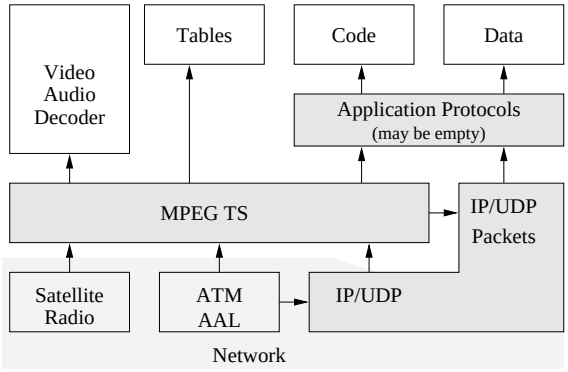

Figure 19: Relations between MPEG and IP

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 Carousels: 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.

In addition to these four profiles, an object carousel specification has been added in order to support data broadcast services that require the broadcasting of objects as defined in the DVB-NIT specification (see Section 6.2).

6.5 The Role of MPEG

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 17 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 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 19 the interrelations between MPEG and IP are shown, where both protocols may be encapsulated within each other.

Similarly, MPEG-TS can also transport electronic mail and news, and web pages that are prepared or ordered. Authentication and other security features are then necessary. Scrambling and conditional access must be used to protect private data. When using asymmetric protocols these protocols can be modified for use in interactive applications.

7 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.

7.1 ATVEF

The ATVEF (Advanced Television Enhancement Forum) specification version 1.0 comprises 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, for resource transfer, and for 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 [27]) or MPEG-TS. However, ATVEF does not specify how content or triggers are transported.

7.2 Triggers

Triggers are real-time events that are broadcast inside IP multicast packets delivered to the address and port defined in the 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.

Triggers are used with the following mechanism to avoid repeated or unrelated execution of scripts: 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 is considered a new enhancement and should be offered to the viewer. If the URLs do not match, and there is no name, the trigger should be ignored by the receiver.

7.3 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 to support cross-references within the content for use in hyper links or to embed one piece of content in 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.

7.4 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 (as 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.

7.5 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 (abbreviation for 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 the needs of engine and application developers whose interest are in Digital Television, both broadcast and interactive, Home Shopping, Multimedia Information Retrieval, and Near or Video on Demand Applications. MHEG-5 is being considered as a standard for Digital TV applications on set-top boxes, and promises to provide interoperability among a variety of platforms. An overview of MHEG-5 can be found in [13]. 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-5 applications run on any platform that is MHEG-5 compliant. MHEG-6 provides an API for MHEG-5, a Java Virtual Machine specification for handling Byte Code for the MHEG programming objects; and an Applet Class specification for WWW application compatibility.

The developed applications will 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 (ingredients), that represent information (graphics, sound, video, etc.) along with localised behaviour based on events firing (e.g., the 'Left' button being pushed activating a sound). At most one Scene is active at any one time. Navigation in an application is done 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. Therefore the group defining MHEG-5 must define which content encoding schemes to apply for the different objects in order to achieve interoperability. This encoding is an instance of ASN.1, using the Basic Encoding Rules (BER).

7.6 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 Locator (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/.

Part III
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: Abbreviation for Asynchroneous Digital Subscriber Line. It is used for transfer of high bandwidth data over copper cable.

API: Abbreviation for Application Programming Interface.

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

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

bouquet: A collection of services marketed as a single 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: Abbreviation 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.

Blackbird: Multimedia set-top box developed by Motorola.

DSM-CC: Abbreviation 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: Abbreviation for European Broadcasting Union

ECCA: Abbreviation for European Cable Communications Association.

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

EIT: Abbreviation 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: Abbreviation for European Telecommunication Standard

ETSI: Abbreviation 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: Abbreviation 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: Abbreviation 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: Abbreviation 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: Abbreviation 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: Abbreviation 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 6.

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.

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.

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: Abbreviation 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: Abbreviation 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.

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: Abbreviation 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: Abbreviation for Program Specific Information. See MPEG standard.

PSTN: Abbreviation 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 2.4).

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: Abbreviation 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: Abbreviation for Synchronized Multimedia Integration Language.

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

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

VBI: Abbreviation 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.

References

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

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

[3] 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.

[4] V. Balabanian, L. Casey, N. Greene, and C. Adams. An Introduction to Digital Storage Media – Command and Control (DSM-CC). *Web pages, http://drogo.cselt.stet.it/ufv/leonardo/mpeg/documents/dsmcc.html*, 1996.

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

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

[7] L. Chiariglione. MPEG-2 FAQs. Web pages, http://www.cselt.stet.it/mpeg/ and http://www.cselt.stet.it/mpeg/faq/faq_mpeg-2.html, 1998.

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

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

[10] J.-P. Evain. The Multimedia Home Platform – an overview. *EBU Technical Review*, Spring 1998. also available on DVB Feature Articles, http://www.dvb.org/dvb_articles/dvb_mhp98.pdf.

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

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

[13] 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.

[14] Georg Luettke. The DVB Multimedia Home Platform, November 1998. http://www.dvb.org/dvb_articles/dvb_mhp98cm.pdf.

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

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

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

[18] Motorola. Blackbird White Paper. White Paper, http://208.21.175.63/whitepaper.cfm), 1998.

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

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

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

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

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

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

[25] 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.

[26] 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.

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

Index