1 Fundamentals of digital television

1.1 Digital television

Digital television appeared as a natural evolution of analog television. Previously, the phases that constituted the production of a TV show (shooting the scenes, editing, finalizing and storing videos), broadcasting (generating the video composite, modulation, amplification, radio transmitting) and reception (the capture of the signal by the antenna, the demodulation of the television set receiver and the presentation of the image and sound to the viewer) of the signal by the user were all analog, i.e. the signals that represented the image and the sound generated in the studio were all analog, as well as the signals transmitted to the TV receiver (Carvalho, 2006).

Nowadays, the information is generated digitally in the studio. These signals are converted into analog signals and transmitted to analog television receivers. With digital television, all of the processes are digital; thus the image, the sound and all the additional information are generated, transmitted and received as digital signals. This gives the best definition of image and sound: the image is wider than the original one (panoramic screen), with a higher degree of resolution (high resolution) and stereo sound (Graciosa, 2006, Zuffo, 2006).

A digital television system is made up of a set of standards, as presented in Figure 1.1, which identifies the basic components: video and audio represent the services that are essential to the broadcasting of digital television; interactivity and the new services (e-commerce, Internet access) are added to the system by the middleware (Herbster *et al*., 2005). These new services, introduced by digital television, originated from data transmission with video and audio. They may be used to offer new concepts in the broadcasting of TV programs to the users, or even to send data for applications that do not have a direct connection with television programming (Crinon *et al*., 2006).

With digital television, the viewers will be renamed users, as they participate in interaction with the TV stations and the companies that supply services (Manhaes and Shieh, 2005, Valdestilhas *et al*., 2005).

1.2 High-definition television

High-definition television (HDTV) is a digital television system that presents better image quality than the traditional system. HDTV allows better, more detailed image

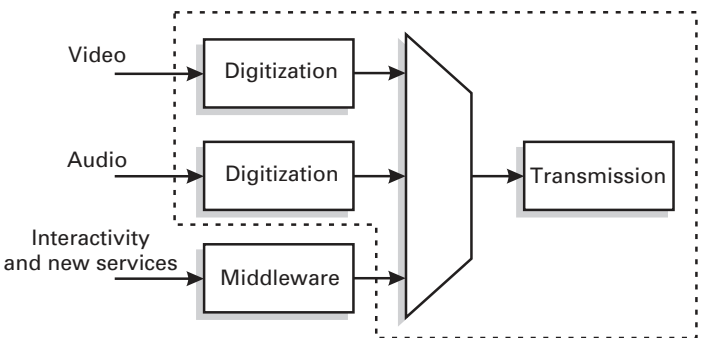

Figure 1.1 Set of standards in a digital television system for land broadcasting (Graciosa, 2006)

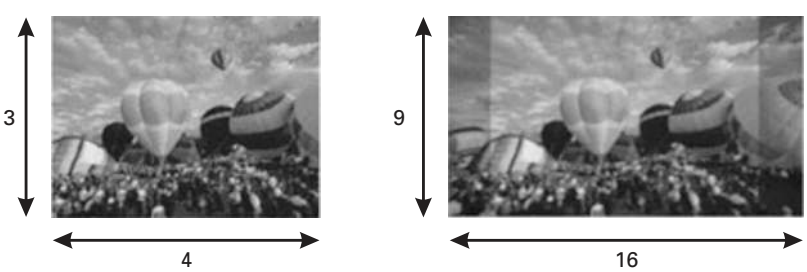

Figure 1.2 Comparison of aspect ratios 4:3 and 16:9

transmission, a wider picture (aspect ratio of 16:9) and stereo sound with up to six channels, which makes it possible to use several languages, among other services (Jones *et al.*, 2006).

Figure 1.2 presents comparison between two television sets with aspect ratios of 4:3 and 16:9. The usual aspect ratios for the presentation of films in movie theaters are 1.85:1 and 2.39:1 The most appropriate comparison between conventional television and HDTV is, however, not based upon the aspect ratio, but on image detail (HDTV makes it possible to see the image from a much wider angle) (Poynton, 2003a).

Currently, the most popular systems of HDTV are:

- The system with 750 lines/picture, 60 pictures/second, progressive scanning of 60 fields/second (non-interlaced) and 720 active lines per picture;
- The system with 1125 lines/picture, 30 pictures/second and alternated scanning of 60 fields/second and 1080 active lines per picture.

In interlaced scanning, only half the picture is on the screen at any given moment: while one frame shows only the odd numbered lines (1,3,5,...), the next frame shows only the even numbered ones (2,4,6,...). This happens so fast that the human eye perceives it as only one image. Progressive scanning shows each complete frame one at a time. Instead of alternating the lines, each is shown as lines 1, 2, 3, and so forth. The final result is a clearer image (HDTV.NET, 2006).

The HDTV signals are broadcast in the 720p or 1080i format, respectively: 720p means that there are 720 horizontal lines which are scanned progressively, and 1080i shows that there are 1080 horizontal lines which are scanned alternately. Despite the fact that there is a significant difference between the number of scanned horizontal lines, the images obtained by means of the 720p and 1080i systems are very similar (Poynton, 2003).

A television channel can broadcast HDTV programs as well as those of standard-definition television (SDTV), or even both simultaneously. The number of programs depends on the allotted bandwidth. Many countries still broadcast their digital television programs in the SDTV format (Jones *et al*., 2006). SDTV is a system with a spatial resolution of 480 lines, with 640 picture elements (pixels) per line, and a timing resolution of 60 pictures per second in interleaved mode. A pixel is the smallest information element of an image; it has a unique set of attributes, such as color and luminance. The image quality of SDTV is higher than that received by open analog television stations, as it does not present problems such as the crossing over of colors and static that occur in the domestic reception of analog signals.

Currently, most of the transmissions are made in 4:3 format, though there is a trend to move to the 16:9 format (widescreen). Comparatively, the bit rate corresponding to one program on HDTV allows the broadcasting of four SDTV programs.

As well as HDTV and SDTV, there is also (HDTV.NET, 2006):

- Enhanced-definition television (EDTV): EDTV is of intermediate quality and, despite not having the same resolution as HDTV; it has better image quality than SDTV. Typically, it uses wide screen format (16:9) and a resolution of 480 lines, 720 pixels per line, and progressive mode scanning. The audio is stereo (5.1), as in HDTV.
- Low-definition television (LDTV): LDTV has a resolution quality lower than SDTV. A typical example is the system with 240 lines, 320 pixels per line and progressive scanning. A large amount of software and many microcomputer capture circuits currently run on images at this resolution level. Another typical example is the home-use VHS, which gives a resolution of 480 interleaved lines and an average 330 pixels per line (besides a clear decay in the chromatic resolution, which does not happen on the LDTV).

1.3 The digital programming platform

Middleware is the software layer, or programming platform, between the system and its applications, and permits interactive services on digital TV. Its main objective is to offer a set of tools that make possible interoperability of video transmission systems with various kinds of transmission media, including satellites, cables, land networks and microwaves.

At its most basic level, middleware has a software that has access to the flow of video, audio and data, routing them to an output element (television screen) or a storage element. The middleware receives input from the viewer's input gadgets (remote control

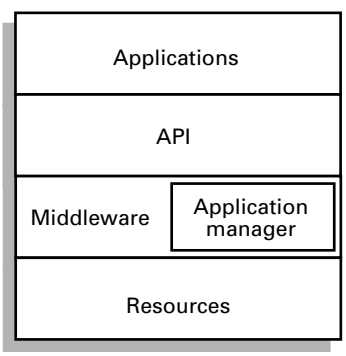

Figure 1.3 Basic structure of the elements of middleware (MC/MCT/FINEP/FUNTTEL, 2004)

or keyboard), and sends out information to the television screen and speakers, and also provides communication with remote entities by means of a remote channel.

The basic organizational structure of the elements of middleware, as shown in Figure 1.3, may be described as follows (MC/MCT/FINEP/FUNTTEL, 2004):

- Resources: the lower layer represents the hardware and software resources of the platform, whose elements (motherboards, microprocessors, subsystems, and operational systems in real time (RTOS)) vary according to the manufacturer. The middleware visualizes the resources in an abstract manner, in such a way that they may be charted in one or more distinct hardware entities.
- Middleware: the applications do not have direct access to the resources, and the middleware provides them with an abstract view of the resources. It isolates the hardware application, making its portability possible. In addition, middleware is responsible for managing all applications, including the resident ones.
- Applications programming interface (API): the API provides the services associated with the applications. In practice, there are several APIs that implement different interfaces. The middleware implements the API, presenting an abstract model of:
  - streams of audio and video executed from different sources and channels to carry them;
  - commands and events;
  - records and files;
  - hardware resources.
- Applications: these implement interactive services in the form of software to be executed in one or more hardware entities. The middleware API is the view that the applications have of the systems software.

Currently, there are four middleware standards in use: DASE, from the American digital television standard (ATSC), MHP, from the European standard (DVB), ARIB, from the Japanese standard (ISDB), and Ginga, from the Brazilian standard (ISDTV). Apart from these, other standards have been developed to support interactive video, such as MHEG and MPEG-4.

1.4 Interactivity

In an interactive digital television system, local storage of information is needed. Independently of the existence of the interactivity channel, user interaction is basically provided by the locally stored information processing. Thus, there must be local storage of information or a return channel to provide interactivity (Moreira, 2006). Some digital television sets include transcoders which make interactivity possible, although conventional sets are able to receive the content of digital TV and achieve interactivity by means of a device called a set-top box as shown in Figure 1.4.

The set-top box appears in the current scenario as an alternative to the costly digital television set. It is a decoder that receives the digital television content and converts it into analog format in such a way that the user may access digital technology. It also makes it possible to browse the web, using a return channel. And from such an initial contact with digital technology, the user may decide to change to a digital television device (Valdestilhas *et al*., 2005).

Figure 1.5 shows a model of an interactive digital television system. This model shows the broadcasting of television programs by the stations to users spread all over the country.

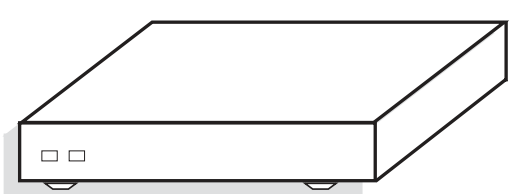

Figure 1.4 Set-top box model

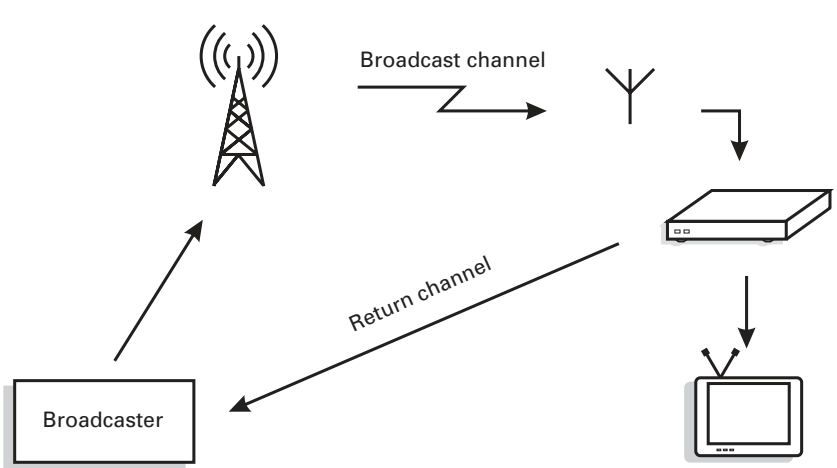

Figure 1.5 Model of interactive digital television system

The user receives the digital programs that are converted by the set-top box, which makes it possible to watch these programs on analog devices. The information coming from the station/broadcasting transmitter is sent through a broadcast channel, whereas the interactive information may be broadcast through the interactivity channel or even by the broadcasting channel. In addition, the user information is broadcast through the interactivity channel (Moreira, 2006).

The most basic kind of interactivity is called local interactivity, and uses the user's device or the set-top box. The data from certain interactive services are broadcast and stored on the device. This device may react to the user's queries without requiring data exchange throughout the network.

When it is wished to enable the user to respond to the interactive service in any way, in order for the broadcaster or network operator to capture such response and react to it, an interactive channel must be provided throughout the broadcasting network. This interactivity may be simple, as it is when one votes for a contestant on a television show. For this to happen, only one directional return channel from the viewer to the broadcaster is necessary.

If a higher level of interactivity is necessary, when the user needs a response (for example, in on-line shopping in which the buyer sends credit card data and receives confirmation of the purchase), a direct channel between the supplier and consumer must be implemented. The broadcast channel alone will not be sufficient if there is not an individual address, since such information is confidential and must be addressed solely to the relevant client.

If the information expected or requested by the interactive service user is more complex or demands a high broadcasting capacity, another level of interactivity must be achieved. This is the case, for example, when a potential consumer that, upon seeing an advertisement of a given manufacturer's product, asks for additional information. In that case, the direct interactivity channel must be broadcast. The interactive service is then akin to a two-way communication service with similar demands for the capacity and quality of broadcasting, in both the direct and reverse directions.

The addition of interactivity to the infrastructure of digital television requires the installation of the system be extended to include the components that promote communication between the end-user and the supplier of the interactive service. The high bit rate of the digital television broadcast channel may be used in the distribution of information to the user of the interactive service at rates of up to 20 Mbit/s per channel on land broadcasting networks, and up to 38 Mbit/s per channel on satellite or cable broadcasting networks. The transmission capacity of the interactivity channel will depend upon the type of network used for the transmission (Reimers, 2005b).

1.4.1 Interactive services

The term interactive service may describe a number of different types of services that call for a variable level of interaction between the user and the supplier of the service or

network operator. Some of these services that are already available, or that will soon be, include (Resende, 2004, Crinon *et al*., 2006):

- Electronic programming guide (EPG): this may be the oldest mode of interactivity on television, and allows the user to keep up with the programming of hundreds of channels, making the choice of a desired program easier.
- Enhanced television: this is an evolution of the television programs that already use interactivity; the difference lies in the format through which the user interacts with the station, which is no longer via the Internet (through a computer) or via a telephone, but through the digital television set itself.
- Individualized television: in this type of service, users will have at their disposal a level of interactivity similar to that of a DVD player (it will be possible to set cameras, sound, and subtitles at will).
- Internet television: this service makes it possible to access the Internet on the TV screen.
- Video on demand (VOD): this is an interactive application for which there has been great demand in recent years; it offers users a selection of films or TV shows that are available at that moment. VOD differs from EPG by allowing the user to search for a program in a databank with thousands of alternatives, to see if the program is showing and if so on which channel.
- Commercials: these can be incremented with the option of providing details if the user is interested in the product announced. There are also applications in which the user makes direct contact with the salesperson, with the possibility of purchasing the product through the television. A similar application is already available on shopping channels.
- Purchase of MP3 files, films or educational products that can be downloaded from a supplier immediately after the transaction.

Besides the interactive services, other services are available on digital television (CPqD, 2005):

- Monoprogramming: the showing of a program, with associated video and audio content, on a frequency exclusively designated for the station/programmer. This option, not obligatory in the environment of land digital television, is being used in some countries for the transmission of HDTV.
- Multiprogramming: this offers a multitude of simultaneous programs through only one frequency channel. Thanks to the encoding of video/audio and data signals, it is possible to broadcast between four and six simultaneous programs in SDTV.
- Mobility/portability: this allows the reception of digital television signals by the user in different movement conditions (stationary, moving, or even within a speeding vehicle). The reception may be by means of television sets on vehicles, television receivers integrated in cell phones or palmtops (Faria *et al*., 2006a, Itoh and Tsuchida, 2006).
- Multiservices: these simultaneously combine several broadcasting and telecommunication services on the same digital television platform.

1.4.2 Television on mobile phones

Some mobile phone operators have launched handsets with digital television reception. Although the system is still of low resolution, it may become another success story for a product associated with the mobile phone, just as it was with the transmission of messages and the digital camera.

The Scandinavians and the Koreans are already using television on mobile phones. The Nordic operator Telia Sonera believes that this will be the next big trend in the mobile world. The giant Nokia launched its activities in this area with a major event in Singapore in the second quarter of 2005.

North American Strategy Analytics estimates that the mobile phone networks will have close to 51 million television users around the world by 2009, generating a total income of US$ 6.6 billion.

Korean SK Telecom launched, in May 2005, a satellite TV service on mobile phones which offers 12 channels of video and audio. The Korean operator has also integrated TV and mobile Internet services on mobile phones. South Korean LG Electronics has a display that processes 30 image frames per second, an evolution of the 20 frames per second on earlier handsets.

There is competition in relation to two standards, Digital Video Broadcasting Handsets (DVB-H), and Digital Multimedia Broadcasting (DMB). LG prefers the DMB standard, which transmits twice as much data as DVB-H and does not discharge batteries so quickly. The Japanese, the Koreans, and Sweden's Ericsson support the DMB standard. Taiwan's Samsung has a DMB handset which was used in the satellite TV service on mobile phones from SK Telecom. Nokia is interested in the DVB-H standard.

In Europe, the telephone operators Vodafone and O2 are implementing plans in this direction. In the USA, a country in which the process is more advanced, Cingular has launched the MobiTV service with 22 channels, and Verizon Wireless has launched the VCAST service with CDMA 1xEV-DO technology. Qualcomm launched the MediaFLO service on its own frequency band of 700 MHz which can accommodate from 50 to 100 broadcasting channels with up to 15 streaming channels.

In Brazil, Bandeirantes Television Network (Band) has an agreement with the telephone operators for broadcasting news. Globo TV Network is awaiting the definition of the market and legislation before deciding what action to take. It does not want to give up control of the content. However, the possibility of broadcasting soap opera compacts and news is certainly tempting (Alencar, 2005a).

A study shows a world panorama of the experiences of the introduction and exploration of land digital television, in some of the countries pioneering its use. The data are presented in Table 1.1. The table relates to other services besides the interactive ones: monoprogramming, multi-programming, services based upon mobility and portability, and in multi-service environments (CPqD, 2005).

The mobility of the handset is an undeniable advantage of the DVB and ISDB systems when compared to the American ATSC. Consumers have already become used to the portable telephone and may be interested in a TV set that can be carried to the stadium, used in automobiles, or even in city and intercity bus fleets. A new market niche may

Table 1.1. Interactive services and business models for digital TV in some countries (CPqD, 2005)

	Germany	Australia	South Korea	Spain	USA	Finland	Netherlands	Italy	Japan	United Kingdom	Sweden
Services											
Monoprogramming		•	•		•				•		
Multiprogramming	•	•		•	•	•	•	•	•	•	•
Interactive:											
(without return channel)	•	•	•	•	•	•	•	•	•	•	•
(with return channel)			•			•		•	•		
Mobility/portability			•			•			•		
Multiservice	•	•		•	•	•	•	•	•	•	•
Business models											
Open TV	•	•	•	•	•	•		•	•	•	•
Cable TV				•	•	•	•			•	•
Pay-per-view								•			

appear, surprisingly not predicted by the Americans, who have invested so much in mobile communications in the last three decades (Alencar, 2002b).

1.5 Return channel for digital television

The interactivity channel is seen as a subsystem that makes it possible for each user, individually and independently from the others, to interact by forwarding or receiving information and requests from the networks (Manhaes and Shieh, 2005). That is, the return channel is the medium through which the networks and the television announcers directly reach the viewers. It is through this channel that a direct connection is established between the user and the seller of a given product. The subscriber may choose a program that is different from the one showing, or change the angle of the camera broadcasting the show.

In addition to having the benefits of the regular display of the network's programs as well as the major interaction with subscribers, viewers might decide to follow a court case through an e-government service, to check if their salaries have been credited to their bank accounts through home banking, or even call upon their children for an on-line French class. All these possibilities might seem intangible in the short run, although such advances are possible by means of the interactivity channel of digital TV.

The model shown in Figure 1.6 illustrates a generic system of interactive services. The downlink establishes communication between the network and the viewers; it can happen through broadcasting (open and available to all users/subscribers) or be individualized. The user is enabled to interact with the network by means of an uplink or return channel, expressing preferences and opinions. The return channel may be implemented

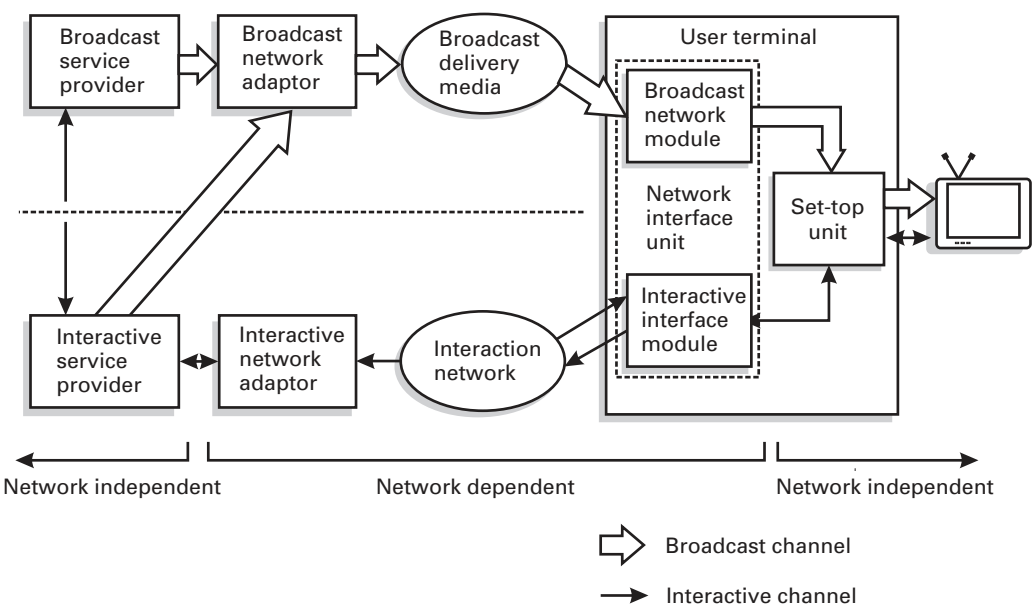

Figure 1.6 Model for a generic system of interactive services (Reimers, 2005b)

by any communication technology which establishes a connection from the users to the networks (Manhaes and Shieh, 2005).

Figure 1.6 shows that two channels are established between the users and the supplier of the service. The network adapter provides the connectivity between the supplier of the service and the network, while the interface unit connects the network to the user. The supplier of the broadcast service distributes the MPEG-2 stream of transport from the unidirectional broadcast channel to the user's set-top box. The supplier of the interactive service offers an interactive channel for the bidirectional communication which is divided between the interaction route in the direct direction, to the downstream, and the return route in the reverse direction, to the upstream.

In order to offer high-speed services to the user, the supplier of the interactive service can choose the broadcasting link to fit the data on the MPEG-2 transport stream. In that case, the broadcasting channel may contain data application or communication control, in such a way as to connect to the distribution network. The user may, for example, use a cable modem instead of a set-top box. A bidirectional control application and a communication channel will also be required from the different services suppliers, with the intention of obtaining synchronization (Reimers, 2005b).

It is worth mentioning that the interactivity channel may be designed to send data through the broadcasting channel networks or by means of a specific channel.

The introduction of a return channel, however, is not an easy task. Table 1.1 shows that the interactivity channel is well established in only four countries: South Korea, Finland, Italy, and Japan (CPqD, 2005). In the UK, despite being available since 2003, the interactivity channel did not appeal to the population and so did not reach the desired