TECHNICAL GUIDELINES

Project: Tackling the "Digital Divide" in SEE by using the capacity of DTT networks

Acronym: SEE TV-WEB

Version A-1.0; Date: 14.06.2013

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DOCUMENT HISTORY

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<td>Universal Service Obligation</td>
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<td>VBR</td>
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<td>Video on Demand</td>
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<td>W3C</td>
<td>World Wide Web Consortium</td>
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1 Introduction

These technical guidelines provide an overview of technical possibilities and background for the purpose of providing the services like the one proposed by the TV-WEB project. The document is explaining the initial idea to use DVB-T/T2 networks for delivering the Internet content to households without access to broadband and to the users who do not use personal computers. The TV-WEB service proposed by the project is targeting the population in rural areas and is aiming to reduce the digital divide and on the other hand support goals of the Digital Agenda. In order to enable proposed service, the internet content has to be selected and offered as a push service, without using the return channel, thus providing full local interactivity.

The structure of the document is based on two parts, with the first one providing the background and potential of using existing and new digital terrestrial broadcasting networks, while the second one is dealing with the middleware interoperability issues.

In order to aggregate a content which is to be distributed over digital terrestrial broadcasting networks without a return channel, certain adaptations need to be executed enabling end-users to have an interactive experience. The overall solution foresees adaptations in editing, creating TV-WEB content transport stream, multiplexing, transmitting and receiving, which is described in the first part, together with a short presentation of existing and future broadcasting services. On the other hand middleware platforms are rather complex, therefore initial analysis has been performed on open standards like OpenTV, MediaHighway, Liberate, Betanova, MHEG-5, MHP & GEM and HbbTV. The technical solution which is going to be used in pilot implementations all over the project area has been decided based upon this analysis. At the end of the second part, prerequisites for placing the internet content on the TV screens are presented, with display, control and other important requirements.
PART I: DIGITAL BROADCASTING AND SERVICES
2 Digital broadcasting

2.1 General overview

Broadcasting is the distribution of audio and video signals which transmit programs to the wide audience. The audience can be the general public or a sub-audience. Television and radio programs are distributed through terrestrial broadcasting, satellite or cable. Distribution of programs can be based on free-to-air services or subscription-based services which are a distribution of scrambled signals protected by an electronic code and require descrambling equipment in households.

There are several broadcast systems in use in the world today. Analogue broadcasting is based upon a transmission method of conveying voice, data or video information using a continuous signal which varies in amplitude, phase, frequency or some other property. In case of an audio and video broadcasting, transmission of an analogue source signal uses analogue modulation method. Digital broadcasting is using digital data rather than analogue waveforms to carry broadcasts over television channels or assigned radio frequency bands. It is becoming increasingly popular for television usage but adoption rate for radio is much slower.

Digital radio describes radio technologies which carry information as a digital signal, by means of a digital modulation method. The most common meaning is digital audio broadcasting (DAB) technologies, but the topic may also cover TV broadcasting as well as many two-way digital wireless communication technologies. The acronym DAB (Digital Audio Broadcasting) is synonymous with the Eureka 147 standard and is a one-way standard used for broadcasting. While digital broadcasting offers many potential benefits, its introduction has been hindered by a lack of global agreement on standards. The Eureka 147 standard (DAB) for digital radio is the most commonly used and it is coordinated by the World DMB Forum.

Digital Radio Mondiale (DRM) is a set of digital audio broadcasting technologies designed to work over the bands currently used for AM (amplitude modulation) broadcasting, particularly shortwave. DRM can fit more channels than AM, at higher quality into a given amount of bandwidth, using various MPEG-4 codecs (Moving Picture Experts Group). DRM can deliver very high sound quality, but on frequencies below 30 MHz (long wave, medium wave and short wave), which allow very-long-distance signal propagation. DRM is robust against the fading and interference which often plagues conventional broadcasting on these frequency ranges. DRM was enhanced to DRM+ (Mode E) which can be used within the VHF band III frequency range.

Digital Video Broadcasting (DVB) is a suite of internationally accepted open standards for digital television. DVB standards are maintained by the DVB Project, an international industry consortium with more than 270 members, and they are published by a Joint Technical Committee (JTC) of European Telecommunications Standards Institute (ETSI), European Committee for Electrotechnical Standardization (CENELEC) and European Broadcasting Union (EBU).

At the beginning of the nineties, Digital Video Broadcasting (DVB) was created as a European project. In the course of this project, several transmission methods were developed: DVB-S,
DVB-C and DVB-T. The satellite transmission method DVB-S has been in use since about 1995. Using the QPSK method of modulation and with channel bandwidths of about 33…36 MHz, a gross data rate of 38 Mbit/sec is possible with satellite transmission. With approximately 6 Mbit/sec per program, up to 6, 8 or even 10 programs can now be transmitted in one channel depending on data rate and content and when mainly audio programs are broadcast, more than 20 programs are often found in one channel.[22]

In the case of DVB-C, transmitted via coaxial cable, the 64QAM modulation also provides a data rate of 38 Mbit/sec at a bandwidth of only 8 MHz. Current HFC (hybrid fibre coax) networks now allow data rates of more than 50 Mbit/s per channel. DVB-C, too, has been in use since about 1995.[22]

DVB-T provides for data rates of between 5 to 31 Mbit/sec and the data rate actually used is normally about 22 to 22 Mbit/sec if a DVB-T network has been designed for roof antenna reception, or about 13 to 15 Mbit/sec for portable indoor use.[22]

In addition to DVB there are several different systems used in the different parts of the world. In North America ATSC system is used for terrestrial transmission and ITU-T J83B for cable transmission, In Japan ISDB-T system is used for terrestrial systems and ITU-T J83C for cable transmission and in China DTMB is standard for digital terrestrial broadcast.

Digital television has been extended to mobile reception with the development of standards for use with mobile telephones, designated as DVB-H (Digital Video Broadcasting for Handhelds) and T-DMB (Terrestrial Digital Multimedia Broadcasting) and CMMB (Chinese Mobile Multimedia Broadcasting)

2.1.1 Digital Video Broadcasting – Terrestrial

With emerging media market all over the world, DVB-T (Digital Video Broadcasting – Terrestrial) is offering technical, economic and societal benefits above and beyond those offered by the current analogue transmission system. Development of digital broadcasting infrastructure is enabling services that are more diverse, greater in number and of higher perceived value than in analogue environment (especially if such services are widely accessible). Uptake of digital broadcasting opens up new opportunities for business and governments but also for consumers and citizens.

Recently, the digital terrestrial broadcasting in the form of DVB-T or other standards adopted throughout the world is being introduced, while the analogue broadcasting is being switched off. Although analogue to digital switchover process is posing many challenges to the stakeholders at a national level, the digitalization is introducing many important advantages, especially concerning the use of frequency spectrum and services for the consumers. The particular needs of the mobile and portable reception have to be taken into account in network planning. On the other hand special arrangement called Single Frequency Networks (SFN) can be used in network planning to create precise and efficient network coverage to a desired area, while this has been impossible with analogue technology. In any case, the public authorities are required to
coordinate the actions of stakeholders from all parts the value chain and to execute the switchover plan as efficiently as possible.

The limited capacity of the terrestrial system, caused by scarcity of frequencies, requires a strong regulatory environment for controlling frequencies, must-carry, switchover, simulcast and eventually switch-off of analogue broadcasting. A short simulcast period is desirable to minimize the operating costs of two parallel networks. The frequencies released from analogue services can be used for new programs, new services (non-linear) or even new technologies, such as in the case recent decision that the 800 MHz band (digital dividend 1) will be used for wireless broadband technologies, to be utilized by LTE (Long Term Evolution).

In addition to all these benefits introduced through a very efficient coding standards (MPEG-4) and transmission standards (DVB-T and DVB-T2 [Digital Video Broadcasting-Terrestrial 2]), and with utilization of additional techniques such as statistical multiplexing, the digital terrestrial television is suitable for additional services that are using free capacity available either in existing multiplexes or in new networks built after the frequency spectrum is freed from analogue transmission.

2.1.2 Digital Video Broadcasting – Satellite

After early standardization work on transmission systems had been carried out in the DVB Project (Digital Video Broadcasting), first DTV (digital television) transmissions of pay-TV services started in the mid-nineties via satellite. The pay-services on satellite were soon followed by public and private free TV services. Digital satellite transmission allows a 6-8 times higher programme offer per channel (transponder) than analogue. Given the number of satellites and associated channels available, this provides an almost unlimited programme capacity. In addition, there are few regulatory constraints on the use of this capacity. This enabled a market-led environment with a large competing service offer. Consequently, digital switchover on satellite had already taken place and analogue services have been recently completely discontinued.

In addition, satellite transmission has been developed significantly over past years. The new standard has been introduced, with a second generation DVB-S2 (Digital Video Broadcasting – Satellite 2), defining interactive services, news gathering and other broadband satellite applications. Moreover, DVB-SH (Digital Video Broadcasting - Satellite services to Handhelds) was developed as well, defining satellite services to handheld devices below 3 GHz. There have been many different business cases developed and utilized in the past, when DVB-S (Digital Video Broadcasting – Satellite) was used as a distribution network for terrestrial broadcasting either for DVB-T or even for DVB-H (Digital Video Broadcasting- Handheld).

2.1.3 Digital Video Broadcasting – Cable

DVB-C (Digital Video Broadcasting – Cable) is the standard for the broadcast transmission of digital television over cable. This system transmits an MPEG-2 or MPEG-4 digital audio/digital video stream, using a QAM (Quadrature amplitude modulation) modulation with channel coding. The standard was first published by the ETSI in 1994, and subsequently became the most widely
used transmission system for digital cable television in Europe. It is deployed worldwide in systems ranging from the larger cable television networks (CATV) down to smaller satellite master antenna TV (SMATV) systems.

Cable systems are still largely analogue, although digital transmission is being available for many years now, with the first generation DVB-C transmission system and a second generation DVB-C2 (Digital Video Broadcasting – Cable2 ) system which was published in 2009. By using state of the art coding and modulation techniques, DVB-C2 offers above 30% higher spectrum efficiency under the same conditions as in DVB-C, and the gains in downstream channel capacity are higher than 60% for optimized HFC (Hybrid fibre-coaxial) networks. Numerically speaking, DVB-C2 allows transfer rates of about 80 Mbit/s and more per 8 MHz channel.

Cable networks have less capacity than satellite transmission but significantly more than terrestrial. A clear advantage of the cable transmission is that it can provide an integrated return channel via cable modem, thus enabling broadband Internet access alongside digital broadcasting. Switchover of the cable networks in many countries is thus linked to the terrestrial switchover.

From the consumer point of view, drivers for switchover in free TV cable networks differ from those in satellite and terrestrial networks. The number of existing analogue services in cable is typically so high that the introduction of new standard definition TV services may not be sufficient by itself to trigger consumers to buy digital receivers. Successful switchover in cable may be assisted by new attractive service offerings like HDTV (High definition television) content or easy-to-use interactivity. Depending on market penetration, which is quite high in some countries and metropolitan areas, simulcast is required over a certain period of the switchover, which may cause a capacity problem. The more heavily regulated nature of some cable networks means that switchover may not be driven automatically by market forces, as it did with satellite. If this is the case, a coordinated action of the various stakeholders in the value chain is then required to optimize switchover; concerning timing, cost and consumer protection and communication.

2.2 Digital Video Broadcasting – Terrestrial

As already mentioned, Digital Video Broadcasting (DVB) offers a number of technical, economic and societal benefits above and beyond those offered by the current analogue transmission system. Digital television reinvigorates broadcasting by improving programming, introducing new services, increasing reception capabilities and lowering need for the spectrum. Digitization is possible because television signals have more information than the human eye needs to correctly perceive an image, and this redundancy is exploited by digital compression techniques to reduce the amount of information generated in the digitization to levels suitable transport to enable high quality and economy of resources. The benefits of digitization include:

- More programmes / channels in a given frequency range, through the use of compression techniques that maximize the value of available resources
- Better picture quality, new programming and distribution formats
- Interactive services and enabling users to tailor the services they receive
• Links to other digital infrastructures (the Internet and fixed/mobile telecommunication networks) and delivery of new services or provision of alternative delivery of existing services.

To take full advantage of those benefits a smooth switchover from analogue to digital broadcasting process shall be ensured, while National Governments, Regulatory Bodies and other stakeholders need to be actively involved in enabling the process through following activities:

• Preparing **Analogue to Digital Switchover Strategy**, and decide on every important social, economic and technical aspect of digitalization. It is necessary to consider on potential extension of services and content offered on new platform (MHP (Multimedia home platform), PVR (personal video recorder), …) and technical standards to be used (SDTV-standard definition television/HDTV, MPEG2/MPEG4, DVB-T/DVB-T2, CA, interactivity, data casting, …).

• Analyse all stakeholders in the process and prepare **funding or other support schemes** which will endorse the A/D (analogue / digital) switchover process and stimulate active cooperation of potentially resilient stakeholders.

• Prepare and endorse execution of **Information campaign** in order to inform end users about the process.

• Protect the market from sub-standardized reception equipment through **National requirements** and **specifications for receivers** and thus assure compliancy of receivers entering the market. These requirements and specifications are used also as requirements for broadcasters and Multiplex operators to deliver the signal according to the specifications.

With switchover to digital television the most significant change in television broadcast was made since the introduction of television. With this revolution, significant improvement in the quality and diversity of services is evidenced. Although new technologies such as IPTV (IP television), wireless and fixed broadband are becoming increasingly popular, they are not perceived as viable alternatives to terrestrial broadcasting. New technologies may not be available in the sparsely populated areas, so DTT (Digital Terrestrial Television) is still the most important for distribution signal to a mass audience across large areas. In next years it is expected that the terrestrial broadcast platform will remain very important for radio and TV service, based upon following reasons:

- Free to air access
- Almost universal coverage
- Suitable for regional (local) coverage
- High reliability
- Legal obligations fulfilled (DTT is usually mandatory)
- Simplicity of use to the viewers
- Affordable costs for viewers (and broadcasters)

For this reason DTT has been chosen by a large number of viewers as the main receiving platform. With better use of bandwidth through digitization, the potential for introducing new services is becoming increasingly important in order to increase the competitiveness of the
terrestrial platform. Additional services such as pay per view, electronic program guide, internet access, interactive services and new innovative services shall be considered and implemented by the broadcast and network operators in order to attract consumers.

Until the August 2012 DVB-T standard has been deployed in 68 countries and in additional 47 countries the DVB-T or DVB-T2 have been adopted. With advanced trials and with serious deployment plans reaches to 120 DVB-T countries. DVB-T2 was introduced as DVB drew up Commercial requirements for more spectrum efficiency and updated standard due to the European analogue switch-off. DVB-T2 is at the moment the world’s most advanced DTT system which is offering high robustness, flexibility and very high efficiency, higher than any other DTT system.

DVB-T and DVB-T2 use MPEG2–TS (Transport Stream) and deliver same bit-stream to the receiver error free. The bits that form the payload of the transport stream it can be video encoded with MPEG-2 or highly efficient MPEG-4 video compression codec and audio encoded with MPEG1 level 2 (MP2), HE-AAC (High-Efficiency Advanced Audio Coding), Dolby Digital audio codec. With use of statistical multiplexing, the content can be stuffed into a single multiplex much more efficiently then in a standard way. In the same transport stream Subtitles, teletext, electronic program guides (EPG), firmware for receivers and other services can be transmitted as well. As a consequence, the digital terrestrial standards, compression techniques, additional features and flexibility allow broadcasters to provide more linear and non-linear services with less demand for capacity. This alone makes it more efficient for them to use the capacity which is free for new services, like the one promoted by the TV-WEB project.

In order to be able to correct errors introduced by the physical transmission channel DVB-T standard introduces the forward error correction (FEC) or channel coding allowing the detection and correction of transmission errors.

DVB-T is based on OFDM (COFDM) multicarrier modulation scheme in order to reduce effect of multipath reception which is very common in terrestrial mobile or portable reception: the delays of the indirect paths become much smaller than the OFDM symbol period. OFDM uses 2048 carriers (2K) or 8192 carriers in 8K mode for which the spectrum can be considered as virtually rectangular.

The DVB-T standard has been designed to be compatible with all existing TV channels systems in the world (6, 7 or 8 MHz) and to be able to coexist with analogue television transmissions thanks to good protection against adjacent channel interference (ACI) and interference from within the channel itself (co-channel interference or CCI).

Process of interleaving is introduced in order to adapt the bitstream to the OFDM modulation an in order to further increase robustness of the system while guard interval allows satisfactory reception in the presence of very long echoes of transmitted signal at reception. This means that is possible build wide area coverage networks using the same frequency – SFN network with distances of tens kilometres between transmitters.
In addition DVB-T standard has a possibility of hierarchical coding by means of non uniform QAM modulation of the carriers allowing the simultaneous transmission of high priority and low priority bitstreams.

### 2.2.1 DVB-T / DVB-T2

To meet the demands of television viewers, broadcasters must be prepared to launch new services in order to ensure the appeal and competitiveness of the DTT platform. In addition, broadcasters will want to retain sufficient flexibility to ensure that the DTT platform can evolve and provide new services as they become available.

Constrained by limited frequency capacity, the terrestrial television platform needed a new, more efficient, transmission system to meet the demands of the future and to allow for the launch of additional services. In March 2006 DVB decided to study options for an upgraded DVB-T standard. In June 2006, a formal study group named TM-T2 (Technical Module on Next Generation DVB-T) was established by the DVB Group to develop an advanced modulation scheme that could be adopted by a second generation digital terrestrial television standard, to be named DVB-T2. Building on the success of DVB-T, the DVB-T2 specification incorporates the latest developments in modulation and error-protection to increase the bit-rate capacity and improve signal robustness. To achieve these improvements, detailed changes have been made to the physical layer features and network configuration, and to optimize performance to match the propagation characteristics of the frequency channel. The DVB-T2 commercial requirements called for capacity increase of 30% compared with DVB-T in equivalent reception conditions.

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Code rate</th>
<th>Guard interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/4</td>
<td>1/8</td>
</tr>
<tr>
<td>QPSK</td>
<td>1/2</td>
<td>4.98</td>
</tr>
<tr>
<td>QPSK</td>
<td>2/3</td>
<td>6.64</td>
</tr>
<tr>
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<td>3/4</td>
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<td>5/6</td>
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<tr>
<td>QPSK</td>
<td>7/8</td>
<td>8.71</td>
</tr>
<tr>
<td>16-QAM</td>
<td>1/2</td>
<td>9.95</td>
</tr>
<tr>
<td>16-QAM</td>
<td>2/3</td>
<td>13.27</td>
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<tr>
<td>16-QAM</td>
<td>3/4</td>
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</tr>
<tr>
<td>64-QAM</td>
<td>7/8</td>
<td>26.13</td>
</tr>
</tbody>
</table>

**Table 1: DVB-T Useful Bitrates (Mbit/s) for 8 MHz channels [15]**

Compared to DVB-T, DVB-T2 COFDM parameters have been extended to include [24]:

- New generation FEC (error protection) and higher constellations (256-QAM) resulting in a capacity gain of 25-30%, approaching the Shannon limit.
• OFDM carrier increase from 8k to 32k. In SFN, the guard interval of 1/16 instead of ¼ resulting in an overhead gain of ~18%.
• New guard interval fractions: 1/128, 19/256, 19/128.
• Scattered pilot optimization according to the guard interval (GI), continual pilot minimization resulting in an overhead reduction of ~10%.
• Bandwidth extension: e.g., for 8 MHz bandwidth, 7.77 MHz instead of 7.61 MHz (2% gain).
• Extended interleaving including bit, cell, time and frequency interleaving.

To reach bitrates from the Table 12 presented below, which are higher than DVB-T, new technologies are used, forming the DVB-T2 standard:
- Constellation rotation provides more robustness for low order constellations
- Multiple Physical Layer Pipes allow separate adjustments of robustness for each service within channel to reach required reception conditions
- Alamouti coding is diversity method of transmitter that improves coverage in small-scale SFNs
- Extended interleaving is including time, bit, cell and frequency interleaving
- Future Extension Frames (FEF) allows the standard to be compatibly enhanced in the future.

DVB-T2 introduces a new technique to improve performance in channels with frequency selective fading. The IQ (In phase and Quadrature) constellation diagrams are counter clockwise rotated to achieve constellation points with unique values on I and Q axis. The information is therefore present on both axes. But what is the practical use of this technique? In DVB-T the data bits from carriers which are severely degraded (e.g. due to fading) are lost. The FEC (Forward error correction) has to recover those lost bits. This can lead to a significant increase in the minimum field strength required to decode the signal. Rotated Constellation is a way to significantly relieve the FEC. This technique results in more accurate detection of the data bits and therefore less errors that have to be corrected by the FEC. As a result it can use its capability for other channel impairments, e.g. noise. The trick is that the rotated constellation comes with Q-delay. After the constellation mapping the Q axis is delayed. Delay means in this context that it is shifted to the next cell (term cell is specific for DVB-T2 standard and has different meaning than “cell” in mobile communications) as depicted in Figure 2 (This figure is missing). Therefore the information is split into I and Q values with both carrying full information but being transmitted on different carriers. With the multitude of interleaver stages following this stage of the modulator both axes are transmitted on well separated carriers.
If some carriers get severely degraded only one axis is erased but the other axis is more likely to be still present. Of course, splitting the information in two parts makes each part slightly less robust than the combination of the parts. But overall the mechanism provides a significant increase of the robustness of the signal in severely degraded channels.
The data bits on such affected subcarriers are very likely to be lost. Only the FEC can recover those bits unless the rotated constellation technique is used. Instead of requiring a 2 to 5 dB higher minimum C/N (carrier to noise) than a Rayleigh channel it is about the same when using rotated constellations. Let’s take the concept one step further and see how rotated constellations relieve the FEC. The higher code rate of the T2-system (i.e. the less protection it has) the larger is the decrease of the required minimum C/N achieved by using this technique. The additional robustness can be used to increase the data rate by choosing a higher code rate (e.g. for a portable reception scenario) while keeping the same minimum field strength. The additional capacity can be used to improve picture quality or to provide additional services.

DVB-T offers a maximum transmitter distance of 67.2 km in a SFN. This assumes an 8 MHz channel using the 8K carrier mode and guard interval 1/4. For SISO (Single Input Single Output) operation of DVB-T2 which means each transmitter emits the same signal the maximum transmitter distance can be up to 159.6 km (8 MHz channel). At this distance significant earth curvature is present which further increases the opportunity to include more distant transmitters in the SFN.

### 2.2.2 Digital Video Broadcasting - Return Channel Terrestrial

In the year 2001 ETSI - EN 301 958 was introduced. DVB-RCT (Digital Video Broadcasting - Return Channel Terrestrial) is a platform where the DTT network can become a bi-directional, asymmetric, broadband and wireless path between broadcasters and consumers. DVB-T with DVB-RCT can be used for Interactive TV, interactive web sessions and for light IP (internet protocol) telecommunication services. This is one of alternative to increase the percentage of the population with access to the Internet. The system is able to provide higher degree of interactive service for Terrestrial Digital TV, using the existing infrastructure already used to broadcast DVB-T services. The Terrestrial Return Channel system is based on In-Band (IB) downstream signalling. Accordingly, the Forward Information path data are embedded into the MPEG-2 TS packet, themselves carried in the DVB-T broadcast channel. The Forward Information path is made up of MPEG-2 TS packets having a specific PID (Packet ID) and carrying the Medium Access Control (MAC) management data. The Return Interaction path is mainly made up of ATM (Asynchronous Transfer Mode) cells mapped onto physical bursts. ATM cells include Application data messages and Medium Access Control management data. The MAC messages control the access of the RCTTs (Return Channel Terrestrial Terminal) to the shared medium.

A system reference model for interactive systems is presented in the next Figure:
Characteristics of DVB-RCT in view of response that offers a wireless interaction channel for real time DTT services:
- low cost, powerful and provides a flexible Wireless Multiple Access based on OFDM (Orthogonal frequency-division multiplexing) technique
- can serve large cells, up to 65kms radius, providing a typical bit-rate capacity of several kilobits per second, for each TV viewer, even at the edge of the coverage area
- can be employed with smaller cells, to constitute denser networks of up to 3.5km radius cells providing to the user a bit-rate capacity of up to several Megabits per second per user
- can handle very large peaks in traffic, as it has been specifically designed to process up to 20,000 short interactions per second
- is able to serve portable devices; bringing interactivity everywhere the Terrestrial Digital broadcast signal is receivable
- can be used around the world, which uses the different DVB-T system: 6, 7 or 8 MHz channels
- does not require more than 0,5W RMS transmission power from the User Terminal or STB to the base station

Consequently, in 2004, the DVB-RCGPRS (Digital Video Broadcasting - Interactive channel through the General Packet Radio System) was introduced with interaction channel through General Packet Radio System (GPRS). Despite all these facts, the standard RCT (Return Channel Terrestrial) was not deployed on the market according to the expectations, since it has not been widely recognized as the technology to utilize successful interactive services. One of the most relevant reasons for unsuccessful utilization lies in the fact that the business model for providing interactive services includes more than one player, which is not the fact when providing merely linear services by the broadcasters.
2.2.3 Statistical Multiplexing

In addition to program reception using directional roof-top antennas, terrestrial digital television offers the possibility of portable and mobile reception with non-directional antennas, although calling for higher received signal energy. Quite independently of this, for economic reasons, providers obviously want to broadcast as many programs as possible in a single UHF (Ultra-high frequency) channel, with the best possible quality of service, and over as large an area as possible coverage area. As the total data rate is a function of available channel capacity, one has to try to keep the data rate for the individual programs as low as possible. This is contrary to the fact that the picture quality of a compressed program tends to be inversely proportional to the compression factor. In addition, the scene material, i.e. the content of the pictures to be coded, influences picture quality. In other words, scenes containing pictures with a lot of detail and fast movement (often the case in sport broadcasts) need a higher data rate than scenes where pictures are low in detail and movement is slow (as in animated cartoons) in order to create a comparably satisfactory, subjective impression of quality in the eyes of the viewer.

The TS contains the 188-byte-long transport stream packets, containing video, audio and data signals. Depending on the data rates, packets of one or the other ES (elementary streams) will occur more or less frequently in the TS. For each program there is one encoder which encodes all elementary streams, generates a PES (Packetized elementary stream) structure and then packetizes these PES packets into TS packets. The data rate for each program is usually approx. 2 - 7 Mbit/s but the aggregate data rate for video, audio and data can be constant or vary in accordance with the program content at the time. This is then called “statistical multiplex”. When statistical multiplexing is used, a lower data rate is allocated when the video is easy to encode, such as a head and shoulders shot of a news presenter sitting in a studio. A higher data rate is allocated when the video becomes more difficult, e.g. a sports clip within the news programme. The benefits obtained through use of the statistical multiplexing are greatest when there is a large ratio between the minimum and the maximum bit-rate required to give constant video quality. All the programs are then combined in a multiplexed data stream to form a single TS which can then have a data rate up to 40 Mbit/s. There are often up to 6, 8 or 10 or even 20 programs in one transport stream. The data rates can vary during the transmission but the overall data rate has to remain constant. A program can contain video and audio, only audio (audio broadcast) or only data, and the structure is thus flexible and can also change during the transmission. To be able to determine the current structure of the transport stream during the decoding, the transport stream also carries lists describing the structure, so-called “tables”.

Use of the statistical multiplex despite low data rates is a very promising approach to producing good subjective picture quality in MPEG-coded programs, while using much less multiplex capacity. It is based on the assumption that it is fairly unlikely that all programs comprised in the same multiplex will consist of critical scene material at precisely the same time. Therefore it is conceivable that an intelligent multiplexer will drive the output data rate of the encoders so that the one whose program momentarily makes the highest demands on the MPEG coding process is always instantaneously allowed the highest output data rate. This assumption is even truer, the larger the number of independent items of picture information (program data streams) that are added to a transport data stream in the multiplexer.

This is a condition that can hardly be met in a terrestrial DVB broadcast. Although the DVB-T standard permits transmission rates up to about 30 Mbit/s, one has to assume that as a rule total data rates from 11 to 22 Mbit/s will be common for DVB-T. Enormous increases in capacity were forecast in part for cable and satellite channels through using this technique. More recently, serious investigations show that statistical multiplexing of eight programs produces a clearly perceptible quality improvement, especially where critical picture scenes in programs are concerned.
The improved coding efficiency due to sharing the multiplex capacity increases with the number of channels, as the peaks and troughs of bit-rate demand across the channels average each other out better. To a first approximation, the savings are independent on whether the content is all SD (standard definition) or all HD (High definition) and whether the compression is MPEG-2 or H.264/AVC.

The exact efficiency gain is dependent on both the nature of the video content and the details of the implementation, but gains can be typically expected to asymptotically approach a value between about 25 and 30% for large numbers of channels. The graph below is indicative of the typical benefits that can be expected, based on statements from encoder manufacturers and the author’s own experience.

![Typical Coding Efficiency Benefit due to Statistical Multiplexing](image)

Statistically multiplexing a mix of HDTV and SDTV content is also possible, but this is likely to give significantly less benefit, as a demand peak on the HDTV channel will require several SDTV channels to reduce bit-rate to compensate. A particular case to avoid is multiplexing an HD and an SD version of the same programme on a single multiplex, as the peaks of demand will coincide.

Non video content in statistical multiplex is also an option. Capacity for low priority, opportunistic data becomes available during periods of time when several channels in a statistically multiplexed group are carrying relatively easy to encode video. Since the availability of this capacity cannot be guaranteed, it is not suitable for the carriage of any time-critical data. However, it could be usefully employed for the carriage of non-time-critical services, such as downloading non real-time audio-visual content onto the hard disk of a PVR for subsequent playback. It could also be used to temporarily enhance the performance of some text or interactive services that had a guaranteed minimum delivery bandwidth.
Figure 4: Slovenian multiplex content – statistical multiplexed [8]

2.3 Broadcasting network

2.3.1 Typical digital terrestrial broadcasting network

The typical broadcast network consists of following main elements: Head-end, Distribution network and Transmission network. In the Head-end, each service received from the studio or other platform (retransmitted) which will be transmitted is encoded to the chosen format and scrambled if needed. Inclusion of other services like EPG, subtitling, etc. shall be done at this point as well. The bundle of services will then be multiplexed into a common Transport Stream at
the configured bit rate using CBR (Constant Bit-Rate) or VBR (Variable Bit-Rate) and prepared for transmission via SFN adapter (in case of DVB-T) or DVB-T2 Gateway (in case of DVB-T2).

The Distribution network is being used to distribute the signal from the Head-end to transmitting locations all over the area which is to be covered. The distribution network is in most cases based on using microwave network, optical network or a combination of both. In some particular cases with lack of existing microwave or fibre network or very high investment needed to cover bigger areas, use of satellite distribution network is economically more justified.

The Transmission network is used to deliver the signal to the households. In order to provide a signal to households, a comprehensive network designing and planning shall be performed, with use of high power, medium power and low power transmitters and repeaters.

![Diagram of digital terrestrial broadcasting network]

Figure 5: Typical digital terrestrial broadcasting network

### 2.3.2 Adaptation of the broadcast network for the ‘TV-WEB’ service

Figure 6 represents a ‘TV-WEB’ end-to-end network and it is designed for many different usages. Architecture can fit in scenarios from stand-alone solution with smaller RF transmitter to cover small local area (or laboratory testing) and up to national level networks. Communication between network segments, management and in some cases also content distribution is made through IP network. To preserve security issues some necessary security recommendation have to be obliged with usage of encapsulation, IPsec tunnel, point-to-point connections or other solution that network owner uses to maintain security level. Routers, switches, firewalls and other IP network equipment is part of IP network segment and it’s not covered in this architecture separately.
Figure 6: End-to-end ‘TV-WEB’ network

Pilot infrastructure in

Figure 6 is full option and covers all cases proposed by the TV-WEB project, with minor adaptations in for each particular case. Workflow on

Figure 6 also indicates source of TS parts and it is in compliance with Figure 8 where functional components of HbbTV (Hybrid Broadcast Broadband TV) system is presented. The whole system is divided into 5 segments:

1. Editing
2. Creating TV-WEB content transport stream
3. Multiplexing/Re-multiplexing
4. Transmitting
5. Receiving and usage (end-user)

Editing

Content delivered over the TV-WEB platform have to be adopted to ensure the best performance possible on different TV sets and to achieve good user experience. At the pilot implementation stage the appropriate content will be chosen and adopted (technically and visually) for delivery over the TV-WEB platform. Editing segment consists of editing terminals (with internet connection) where a CMS (Content management system) based editor application is installed, providing a number of suitable templates and a content transcoding engine. Web application will
be implemented as a service on a web server running dedicatedly developed software for this purpose. TV-WEB server application is a web based application with no need for additional software on the editor side.

Editing application has 2 roles:
- import, editing and management of content
- storage and play-out

Although all additional content provided by data carousel is treated as non-linear, all content is transported in the same way as linear but it’s about a cyclic play of chosen content. Since interactivity is supposed to be achieved virtually by locally stored content repetition time shouldn’t be too long in the range of a few minutes. The total amount of all content is in this case very important and it is directly proportional to bandwidth allocated for TV-WEB content.

_Creating TV-WEB content transport stream_
Transport stream will be created and adopted on a IRT Broadcast server (IRT). Output from the server will be ASI (Asynchronous Serial Interface) or IP based to assure proper output for different scenarios in case that infrastructure provider has free ASI or IP inputs on their own multiplexer. This segment consists of:
- **Hardware:**
  - 1 computer with local and remote management for TS creation and I/O cards
  - ASI/IP card like DTA 2160 (to ensure ASI or IP output for transport stream)
  - A/V (audio/video) card like BlackMagic DeckLink studio Duo (to provide additional ingest of audio/video content)
- **Software**
  - Broadcast server (like IRT Broadcast server with AIT editor)
  - Encoding program (like DtEncode with options for all I/O cards and support up to full HD)
  - TS player like StreamXpres and TS analyser like StreamXpert
  - DVB analyser SW
  - Full remote access software (like TeamViewer to support remote connections even if server will be located in private LAN (Local area network) network – behind router and NAPT)

With the broadcast server all necessary tables are created while content provided by the editor server is adopted and inserted in transport stream. System should allow for changes while playing out the content, which is essential for TV-WEB scenario. Nevertheless, even though this is in general supported by the server and the standard, some issues were detected on set-top-boxes and TV sets during the refreshing of a changed DVB transport stream content (structure changes).

_Multiplexing / Re-multiplexing_
Pilot systems are supposed to be implemented in different environment cases therefore the powerful multiplexer is necessary to cover all varieties. Minimal 2 ASI and 3 IP inputs and ASI and IP output are basic requirements. Multiplexer shall support easy creation and adaptation of
SI (service information) and PSI (program and system information) table with local and remote control. Suitable HW (hardware) could be Harmonic ProStream 1000 or CableWorld CW-4856.

With different cases, different implementation scenarios are expected in dependency of network owner equipment but generally there are 2 cases predicted:

- using network owner multiplexer
- using own multiplexer and output from network owner’s multiplexer as an input

Multiplexer is extremely important part of the whole solution from suitability and stability point of view. It is crucial part of the system since pilot system shouldn’t interrupt linear content provided by broadcasters and shall provide stability and conformity with standards. Adding HbbTV content into multiplex shouldn’t interrupt existing content in the particular multiplex.

**Transmitting**

Transmitting depends on the case chosen for implementation. Two major options are predicted:

- modulator and transmitter are part of network owner’s equipment
- modulator and transmitter are part of pilot system

Within the first option, the pilot system doesn’t interact with transmitting part and only provides proper TS as an input into modulator (ASI or IP). In the second option, small MFN (multi-frequency network) DVB-T cell will be realised with transmitter which is a part of the pilot system. Proposed equipment supports ASI and IP feed (with support for tagged traffic input), DVB-T and DVB-T2 options, IP management and as a solution it is again divided into two sub-parts:

- modulator with low power output for closed areas and laboratory testing and simple indoor antenna system
- modulator, transmitter (amplifier) with the maximum output power of 100W, RF (radio frequency) cabling and simple outdoor RF antenna system

Transmitter stability is not so crucial since in this case, pilot modulator continuous transmitting is not required because it doesn’t interact with content provider’s content nor it is crucial from the user perspective. Tests and evaluations in this case will be done in closed and controllable areas.

**Receiving and usage**

Different scenarios are expected in the end-user environment. For indoor tests and implementations in various locations at least 5 full completes (indoor antenna, STB (set-top-box), TV set) are proposed and additional 25 – 30 STB for installations in households in testing areas. STB’s have to be HbbTV compliant with supported standard 1.5, while fulfilling other prerequisites which will be determined during development of applications and services proposed by the project. List of appropriate and recommended STB sets will be accomplished by testing and development during the project and are not determined at this stage. Adding HbbTV content into existing multiplexes shouldn’t interrupt existing STB's at households and in case of evaluation and testing at households STB’s will be offered to the end-users as temporarily replacement for their own STB’s or as additional terminal equipment to their TV set.
Pilot integration cases
As mentioned above, many different integration steps will be possible depending on the network stage and other possibilities tailored by the network owners. All subsystems are remotely managed via IP interfaces to manage and control the whole system from laboratory premises. In some cases IP or ASI distribution is not determined due to unknown state of existing network (free capacities distances, etc).

2.4 Broadcasting services
Digital technology enables interaction among three functions: broadcasting, communication and storage. Digital broadcasting services provide multiple video channels and data channels; data broadcasting affords a service similar to internet web browsing. Interactive broadcasting service is realized through the use of communication circuits as return channels. The combination of communication and storage is realized as in a PC (personal computer) environment, where people can download and store information through the internet. Data broadcasting and interactive broadcasting services have been available in digital satellite television and subsequently in digital terrestrial television since many years.

Due to development in ICT (Information and communications technology), large capacity storage has matured for home use, TV programs are automatically recorded in digital format, and additional information to program "metadata" enables a new form of broadcasting such as automatic storage and search and digest-viewing. The combination of broadcasting and storage function realizes a new service referred to as "Server-type broadcasting". The broadband network will allow additional transmission media to radio wave. Radio permits the broadcast of certain range of data broadcasting; however, for those who require further information, combination service with data broadcasting and internet will enrich the value. In the near future, television will become a comprehensive home information terminal, fusing broadcasting and communications to provide a home gateway to the IT (information technology) society.

2.4.1 High quality linear program services (HDTV, 3D TV, UHDTV)
HDTV is a digital TV broadcasting format where the broadcast transmits widescreen pictures with more detail and quality than found in a standard analogue television, or other digital television formats. HDTV is a type of Digital Television (DTV) broadcast, and is considered to be the best quality DTV format available and implemented at this point of time. Types of HDTV displays include direct-view, plasma, rear screen, and front screen projection. HDTV requires an HDTV tuner with support for high definition formats (720p, 1080i, 1080p).

3D TV (3D television) is a television standard that conveys depth perception to the viewer. Several techniques are available: 3D display, 2D plus depth display, Stereoscopic display, multi view display. New 3D television sets use an auto stereoscopic system for 3D effect without the need of glasses. As demand for 3D TV increase the new technologies are being implemented: Visible light communication and WindowWalls. With latest improvements in digital technology, 3D movies have become more practical to produce and display, putting competitive pressure behind
the creation of 3D television standards. The entertainment industry is expected to adopt a common and compatible standard for 3D in home electronics within next few years.

UHDTV (Ultra High definition Television) was prototyped in 2003 and in 2012 the first transmission took place 2.6 miles over-the-air via the UHF band. Ultra high definition television will be implemented in two digital formats: 4K UHD (2160p) and 8K UHD (4320p). 4K UHD will be used for displays presenting native video at minimum 3840 x 2160 pixels resolution. This is 8.3 megapixels resolution and that is 4 times of 1920 x 1080 pixels. On the other hand, the 8K option is represented by 16 times 1080p resolution. A full two-hour movie at 60 fps would take up to 43 terabytes space in 8K UHDTV, so new compression methods are necessary. 8K UHD is similar to an IMAX cinema format, and scenes are so realistic that people have experienced slight nausea while watching action movies.

![Figure 7: Graphical representation of SDTV, HDTV and UHDTV resolutions [57]](image)

### 2.4.2 Pay TV

Pay television, premium television, or premium channels refers to subscription-based television services, usually provided by digital cable and satellite, and also increasingly via digital terrestrial television. Subscription networks are most concerned with providing content that will make people want to subscribe as well as renew subscriptions rather than who is watching and when this viewing is taking place. Premium television services are commonly devoid of traditional commercial advertising, therefore programs on most pay television channels are uninterrupted by television commercials with breaks inserted between programs.

### 2.4.3 EPG

Electronic program guide (EPG) provides users of television a continuously updated menu where broadcast programs are displayed in schedule form for current and upcoming programs on all available channels. Advanced form of the EPG, associated with both television and radio broadcasting, is Interactive Program Guide (IPG). IPG allows television viewers to navigate scheduling information menus interactively, selecting and discovering programming by time, title, station, or genre using an input device such as a keypad, computer keyboard, smart phones,
tablets or TV remote control. The value of an EPG/IPG to the user is to be informed about most interesting programmes that fit his viewing criteria. Now the user can see if chosen programme is available within the next few days and on which channel. Or the user can select to be informed about best programmes by means of the rating that information provider has associated with the programme data. Similar attributes such as the language of the programme, subtitles and audio description or the indication of the unsuitability of the programme for viewing by children can be included as well.

2.4.4 VoD

Video on Demand (VoD) is an interactive media system where the user has option of selecting program content from a large database and can watch different programs as and when desired. Some of the VoD applications are providing video films on demand, News and Weather, Music, etc. In the VoD system, a feedback mechanism is installed at subscriber device that aids the Video on Demand service engine controlling the rate of data transfer over the network. Since it is possible to send one specific video stream to only one user at the time this service is mostly used in TV over IP systems, so the whole network is not occupied with this required stream.

2.4.5 PVR

Personal Video Recording is an interactive service known also by the name Digital Video Recorder (DVR), PVS - Personal Video Station and many more. PVR could be a part of subscriber service which is offered for monthly fee or as free service. PVR can record a program and replay it almost immediately with a slight time lag or recorded content is stored for a few days for delayed playback. The service enables functionalities such as searching for shows according to the type (sport, education…). This type of PVR is mostly in use in IPTV systems.

Second type of PVR functionality is based on old VCR (video cassette recorder) functionality. In this case a PVR is represented as hardware (set-top-box) with recording and playback option. A PVR records the television program in digital format to a hard disk drive, USB drive or on local or network drive and plays it back when desired. Video recording have become an essential part of modern set-top-box functionality. The ability to capture programming and view it whenever the consumer desires, has become a must-have function.

2.4.6 MHP

Multimedia Home Platform – MHP is a compatible set of middleware specifications developed by DVB Project. With migration from analogue to digital TV the one of the opportunities is to deliver interactive applications to the viewers. In the early years of digital TV the only solutions available for the APIs necessary to run such applications on set-top boxes were proprietary systems, and therefore not conducive to the development of horizontal markets.

MHP was designed to work across all DVB transmission technologies. Use of an open standard for interactive TV middleware means that receiver manufacturers can target multiple markets rather than developing products to the specification of a particular broadcaster. Equally applications based on MHP can be developed by multiple service providers, enabling a horizontal
market in that area. Three versions of MHP have been published; each adding new features useful in a broadband world. In all versions, a broadcast-only profile can be supported, although most modern deployments include broadband connectivity. MHP can be described as a set of instructions that tells the operating system on a digital TV receiver how to deal with an interactive TV application it has received. MHP also defines the form in which the applications are delivered at the receiver, including the service information that signals that interactive applications are present in the transport stream.

MHP was superseded by HbbTV which is based on a number of existing standards such as Open IPTV Forum, DVB, W3C (World Wide Web Consortium) and CE-HTML. HbbTV specifications are standardised by ETSI (ETSI TS 102 796). A hybrid terminal (receiver) can be connected to the two networks in parallel. On one side it can be connected to a broadcast DVB network (e.g. DVB-T, DVB-S or DVB-C), while on the other side the hybrid receiver can be connected to the Internet via broadband interface allowing bi-directional communication with the content provider. Broadband connection allows delivering of nonlinear A/V content. Within the broadcasting interface the option of using DSM-CC (Digital storage media command and control) object carousel is used mainly for application data and stream events.

MHP applications come in two flavours. The first types are DVB-HTML (Digital Video Broadcast HyperText Markup Language) applications. These are not very popular, partly because the specification for DVB-HTML was only completed with MHP 1.1, and partly because many broadcasters, box manufacturers and content developers find it too complex and difficult to implement. The second, and by far the most popular flavour are DVB-J (DVB-Java) applications. These are written in Java using the MHP API set and consist of a set of class files that are broadcasted with a service. DVB-Java applications are known as "Xlets" where concept is similar to applets for Web pages that have been introduced by Sun in the JavaTV specification.

The MHP set-top boxes may provide a backchannel for applications that wish to communicate with the outside world, for example a voting or shopping application. Typical upstream backchannels are phone line or broadband Internet connection.

The largest deployments of DVB-MHP are in Italy (DVB-T), Korea (DVB-S), Belgium (DVB-C) and Poland (DVB-S) with trials or small deployments in Germany, Spain, Austria, Colombia, Uruguay and Australia. MHP was offered also in Finland but without success since it was believed that MHP never gained »critical mass«.

In the beginning of 2009 Austrian ORF has improved MHP. A new look and more information are part of the make-over of the enhanced television service, which is now called OK-MultiText. According to ORF, there are some 185,000 MHP set-top boxes in the market, both for DVB-T and DVB-C. The text service is now also optimised for usage on widescreen 16:9 television sets. ORF OK-MultiText offers a wide choice of information, ranging from detailed programme information to live updates of arrivals and departures at Vienna Airport. When viewers access the service, the live broadcasts stream remains available in a corner of the screen. The complete MHP delivery in Austria was stopped in June 2011.
2.4.7 HbbTV

HbbTV (Hybrid Broadcast Broadband TV) is a dynamic industry standard which provides an open and business-neutral technology platform, seamlessly combining TV services delivered via broadcast with services delivered via broadband. It also enables access to internet-only services for consumers using connected TVs and set-top boxes. Prior to HbbTV, the only two adopted interactive TV standards present apart from proprietary operator deployments were MHEG-5 and MHP. With the inclusion of internet connections on DVB receivers, the introduction of Smart TV platforms by manufacturers and the desire for broadcasters to leverage Connected TV, the HbbTV standard was conceived. The basis of HbbTV is CE-HTML: a subset of XHTML designed for the reduced platform capabilities of consumer electronic platforms. On top of this, HbbTV (via the OIPF specification) defines a set of JavaScript APIs which transforms a static web page into an application environment. This allows, amongst other things, interaction with the broadcast environment (e.g. to see the channel list, initiate recordings etc) and media streaming over IP. Crucially, HbbTV is specifically designed to link these applications to DVB broadcasts. The broadcast streams contain AITs (Application Information Tables) which associate applications with broadcast services, which may be triggered upon zapping to a service. Applications can be distributed over IP through URL links in these tables, or for receivers with no IP connection, may be carried in the broadcast streams themselves using DSM-CC. If an IP connection is present, applications can make use of internet services, for example catch-up services.
The aim of the HbbTV standard is to merge classic television service and Internet into one user device (connected TV) offering the full user experience through broadcasting network and broadband Internet connection. But there will be a proportion of viewers without Internet connection and the aim of the TV-WEB project is to present a solution which would bring the flavour of Internet also to this group of viewers. In other words, to extend the use of DSM-CC object carousel to deliver nonlinear A/V content as well as selected web services. The project could be further developed to include limited back channel provided to each citizen by the Universal Service Obligation (USO) Directive. This connection could provide a way to request application data from the servers of an application/content provider although it will not be used to actually receive nonlinear A/V content.

### 2.5 The future of digital terrestrial broadcasting

Broadcasting has been undergoing major changes in the recent years. Terrestrial distribution was historically the first to reach mass audience with linear programmes, followed by satellite and cable distribution. Recently also IPTV is becoming increasingly important in distribution of programmes, especially in urban areas. The following Figure represents distribution of different...
types of reception in EU27 households. It can be concluded from this Figure, that the terrestrial platform is still the most common platform used in EU and is traditionally used also in cases of second or third TV set in the household.

![Figure 9: Type of reception in EU27 households (Data from Eurobarometer 362, 2011) [55]](image)

With transition from analogue to digital transmission an unpredicted increase in frequency capacity became available in the UHF band. Radio spectrum and especially the UHF band is one of the things which attract a lot of attention since with transition from analogue to digital television broadcast, the spectrum gained is referred to as ‘digital dividend’. The spectrum gained with this process will be available not only within the whole UHF spectrum but predominantly in the 800MHz (and subsequently also 7000MHz) band which is offering better signal propagation. The digital dividend is attracting market players such as broadcasters, network operators, mobile service providers and others, to be involved in this transition process as they all want to use the available spectrum for implementation of their services.

Recent decision worldwide has led to the fact that the 800MHz will be used for wireless broadband and this frequency spectrum is already lost for the broadcasters. Moreover, further discussion is on-going for the allocation of 700MHz band (called digital dividend 2), for which mobile operators and broadcast operators are fighting for.

Independently of what the future decision will be, it is a fact that the digitalization process enabled extended offer of linear programmes and supporting features and new services. As a consequence, HDTV, possibly in the future also 3DTV and Ultra-HDTV will be utilized more and more. For this reason terrestrial distribution has been chosen by large numbers of viewers as their mean of reception. Quite contrary to what protagonists for further allocation of UHF band to the wireless broadband are saying, the digital terrestrial broadcasting has a spectacular growth based upon following facts [55]:

- Development from just a few channels per country (analogue) to more than 50 digital channels including HDTV and 3DTV
- DTT in Europe serves 275 million people and provides 1800+ TV channels
- Variety of business models: Free-to-Air Public Service, Commercial TV and Pay-TV
- About 200 Million DTT enabled receivers sold in Europe
- Many TV sets served: Kitchen-TVs, Bedroom-TVs, Second Homes, Caravans etc represent an additional significant share
- Simple to use and install, reliable and universally available
- Demand for linear TV is growing – quite the reverse of common myths

Broadcast technology is constantly evolving and with advent of digital technology, the production and distribution side are greatly accelerated. But on the other hand, Internet has great influence in the broadcast sector as well, since it is emerging as new platform for audio-visual services delivery. Internet today offer linear programmes streaming and also non-linear services as time-shifted, on-demand programmes. With fast internet connections, wireless broadband networks are capable to deliver media content to fixed devices, portable devices and mobile phones so the internet has big influence to the way people are using services.

If we would like to predict the future of broadcasting, one needs to understand a broader picture about future services. It is a long known fact in media services: ‘the service is king’. From the service point of view, typical broadcasting can be characterised as a service providing linear media, which is consumed in a ‘shared’ way. The following Figure is showing a positioning of typical broadcasting. Although broadcasters are able to provide higher quality video (HDTV, 3DTV UHDTV), attractive programming bundles and additional features, they are still quite limited in their ability to attract more consumers.

![Figure 10: Benchmark of typical digital terrestrial broadcasting](image)

If we follow actual trends in this domain, broadcasters should offer (besides higher quality) hybrid or connected TV/Radio, which is opening the possibility to offer a whole new set of interesting non-linear and interactive services (see Figure 11).
Hybrid TV as described earlier (under HbbTV) is a system where media content is delivered with hybrid distribution. Broadcast network are optimized for linear content delivery to large audience and broadband networks are suited for on-demand, interactive and other services. These services require a return channel connection for which fixed broadband internet connection could be used or wireless broadband connection in case of mobile reception. Hybrid TV delivery is expected to grow in the future and that is very important for broadcasters. Additionally, the second screen and additional media applications could be introduced which provide personalization. This move forward means also that the broadcasters shall cooperate with broadband operators more intensively, while providing a consumer a whole new experience. The main concern in interactive services is that various proposed solutions on the market are mutually incompatible, which could lead to fragmented markets and significantly reduce the benefits of Hybrid TV.

Now, if we go even further, it might be speculated that the future of broadcasting is shown on the Figure 12.
If we consider the importance of broadcasting as a platform, its technical characteristics, efficiency in signal distribution, economical background and the capacity offered, the most obvious prediction is that the broadcast technology will be fitted and more clever integrated with broadband networks and devices, thus filling-in the disadvantages of broadband technologies in order to more efficiently realize future services.

As the project TV-WEB is concerned, we can easily position the proposed solution using the same principle as above. The aim of the TV-WEB project is namely to deliver Internet content to those who do not usually use Internet services and who have no broadband connection. The idea is to use the free digital terrestrial television broadcasting frequency spectrum capacities for transmitting selected Internet content (such as news, e-services etc.) and ensure a sort of Internet experience via TV devices to certain less advantaged segments of the population, or those in rural areas without broadband access. The proposed concept differs from the services provided by technologies such as Hybrid TV/Connected where the Internet experience is ensured by connecting the TV to the Internet. Instead, the SEE TV-WEB project foresees delivery of Internet content to the homes solely using the DTT spectrum.

The positioning of the TV-WEB solution is depicted in the following Figure.

![Figure 12: The future of digital terrestrial broadcasting][56]

---

**Figure 12: The future of digital terrestrial broadcasting [56]**

<table>
<thead>
<tr>
<th>MEDIA - SERVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINEAR MEDIA (audio - video)</td>
</tr>
<tr>
<td>NON LINEAR (VOD, PODc, PVR, ...)</td>
</tr>
<tr>
<td>MULTIMEDIA/SOCIAL (web, social, pers, ...)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEDIA - CONTEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHARED (lean backward)</td>
</tr>
<tr>
<td>PERSONAL (inside a ‘box’)</td>
</tr>
<tr>
<td>MOBILE (outside)</td>
</tr>
</tbody>
</table>

1 | 2 | 3 |
---|---|---|
4 | 5 | 6 |
7 | 8 | 9
Figure 13: TV WEB solution
3 Interactivity and local interactivity in broadcasting

Interactivity is defined as dialog that occurs between human being and (computer) program. Human interaction with devices and interactivity is becoming one of the most interesting fields of research to improve user experience and speeding up adaptation of new technologies and to encourage customers to invest in new digital TV appliances. While we are all used to control switching between programs within broadcast service there are unrevealed options of using applications and internet pages on TV sets. One of major issues concerns limited remote control (usually still classic TV remote control) without mouse or QWERTY keyboard. Interactivity in most cases requires return channel but in case of TV-WEB project basic assumption is that we don’t have broadband access or even no access to the internet at all – so there is no return channel.

3.1 Interactivity vs. local interactivity

The absence of return communication channel limits or inhibits interactivity as such in its prime manner. Some new HbbTV applications and services are developed to provide interactivity without return channel but in case of transmitting web content through DVB-T network some adaptations are necessary to achieve at least local interactivity. To provide local interactivity content has to be chosen and edited by editor to be usable on TV sets besides that the 10-foot user interface guidelines should be used. Since all content is not appropriate to be delivered and presented on TV sets selection has to be made with care and appropriate planning. Content which will be delivered to the end user should also consider end-user population (such as local news, content for elderly, etc.).

3.2 Interactivity standards in DVB

DVB project released few standards to replace missing return channel (DVB-RCT – Digital Video Broadcasting – Return Channel Terrestrial, DVB-RCC - Digital Video Broadcasting – Return Cable Channel, DVB-RSC - Digital Video Broadcasting – Return Satellite Channel) for acquiring true interactivity. Without return channel, only virtual interactivity (through locally stored content – local interactivity) could be provided and in case of using HbbTV stack and delivery of data through DVB networks (in our case DVB-T or T2) memory limitations are major obstacle to increase local interactivity.

Interactivity has already taken place in ITTI project (Interactive Terrestrial Television integration) [42] with the idea of integrating return channel on the same technology basis than carrier of forward channel. Physical parameters of DVB-RCT are presented in Table 4.

TV-WEB project assumes absence of return channel what consequentially means that interactivity can be achieved only by prediction and locally stored web pages (content).
3.3 Local interactivity

Recently there have been few services and features offered to TV viewers, without need of return channel like Data carrousel or Electronic Programmes Guides (EPG). These are examples of implementation of “Local Interactivity”.

In the case of local interactivity all content offered to the consumers must be included in data carousel or with other words in transport stream. In dependency of available bandwidth for data carousel repetition time could be quite big. If repetition time is too big, the service can become unusable because users wouldn’t wait several seconds or even minutes for one page to be loaded. This barrier could be eliminated by caching the content in the local memory. One of possible solutions could also be in using external memory but at the moment tests have shown that the usage of local external memory is not so trivial (for usage with carousel applications). Although local memory is limited and tests have shown that limits are quite low and further test are necessary to determine how this issue could be solved in best possible way from user experience and technical perspective. Some improvements are expected with support for HbbTV 1.5 which adds DRM. Anyway some improvement proposal for STB’s firmware will be produced to increase functionalities and emerging local interactivity.

Table 4: Physical parameters of DVB-RCT [58]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream Channel (DS)</td>
<td>OFDM, ETS 300 744 (DVB-T) compliant</td>
</tr>
<tr>
<td>Return Interaction Channel</td>
<td>Multiple Access OFDM (MA-OFDM)</td>
</tr>
<tr>
<td>Forward Interaction Channel (US)</td>
<td>Embedded in DS, compliant with ETS 300 744 (DVB-T)</td>
</tr>
<tr>
<td>OFDM Carrier set</td>
<td>1024 (1K), 2048 (2K)</td>
</tr>
<tr>
<td>OFDM Carrier spacing (CS)</td>
<td>~1KHz, ~2KHz, ~4KHz</td>
</tr>
<tr>
<td>Transmission modes</td>
<td>6 modes (as combination of 3 CS and 2 Carrier set)</td>
</tr>
<tr>
<td>Carrier shaping</td>
<td>Nyquist, Rectangular</td>
</tr>
<tr>
<td>Guard Interval</td>
<td>1/4, 1/8, 1/16, 1/32 (for Rectangular shaping only)</td>
</tr>
<tr>
<td>Transmission Frames</td>
<td>TF1, TF2</td>
</tr>
<tr>
<td>Data randomization</td>
<td>PRBS with polynomial: 1+X^2+X^15</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK, 16QAM, 64QAM</td>
</tr>
<tr>
<td>Encoding rates</td>
<td>½, ¼</td>
</tr>
<tr>
<td>Useful data payload per burst</td>
<td>18, 27, 36, 54, 81 bytes (1 burst = 144 modulated symbols)</td>
</tr>
<tr>
<td>Channel codes</td>
<td>Turbo or concatenated (Reed-Solomon + Convolutional)</td>
</tr>
<tr>
<td>Interleaving</td>
<td>Random Interleaver – PRBS with polynomial: 1+X^2+X^15</td>
</tr>
<tr>
<td>Burst Structures</td>
<td>BS1, BS2, BS3</td>
</tr>
<tr>
<td>Frequency hopping</td>
<td>for BS1 only (optional)</td>
</tr>
<tr>
<td>Medium Access Schemes</td>
<td>MAS1, MAS2, MAS3 (as combinations of BS and TF)</td>
</tr>
<tr>
<td>Net bit rate / carrier (range)</td>
<td>0.6 Kbps – 15 Kbps (depending on the mode)</td>
</tr>
<tr>
<td>Maximum bit carrier per user</td>
<td>No limit (in the case of Rectangular Shaping)</td>
</tr>
<tr>
<td>Service range</td>
<td>Up to 65 km (cell radius)</td>
</tr>
<tr>
<td>Channelisation</td>
<td>6, 7, 8 MHz channels are supported</td>
</tr>
</tbody>
</table>

**PROTOCOLS incorporated in DVB-RCT**

- **Medium Access Control (MAC)**: Specifications mostly derived from EN 200 800
- **Access options**: Fixed rate access, Contention access, Reservation access
- **Security**: Supported (derived from EN 200 800)
PART II: MIDDLEWARE INTEROPERABILITY
4 Middleware interoperability

4.1 Background

Middleware can be functionally compared to a high level operating system with graphical user interface. There are many different middleware systems, some of them are proprietary the others are open standards. The last promoted open middleware system by EU Commissioner for Information, Society, and Media Viviane Reding was MHP (Multimedia Home Platform). Later on in the Communication on Reviewing the Interoperability of Digital Interactive Television Services the Commission expressed certain disappointment with the uptake of MHP. “The demand for interactive TV applications has proved to be less than many forecast some years ago, and the commercial success of interactive television remains limited. The most successful applications have been in the area of quiz shows, sport, gambling and reality television; governments have yet to find ways to exploit the technology successfully as a means of communicating with citizens.”

The most important part of the software for ensuring complete interoperability between different operators of digital TV bouquets (beyond the simple passive reception of TV programs compliant with the DVB standard) is what is generally referred to as “middleware” or sometimes “interactivity engine” or, less often, just API (Application Programming Interface). In fact, the term “middleware” is rather vague and does not mean anything more than that it is situated somewhere between the hardware and (application) software. The term API points only at the interface between an application and the software layer immediately below it. It is essentially made of a predefined set of function calls of the middleware.

The middleware can be functionally compared to a high-level operating system with graphical user interface (GUI) such as Windows, which is very different from a low-level real-time operating system (RTOS, such as pSOS, vxWorks or Nucleus to cite just a few), on which the middleware is based. One of the crucial functions of middleware is to make the application independent of the hardware platform on which it is run, assuming it has sufficient resources (processing power and device functionality).

In order for the same hardware platform to relatively easily support many middleware, which not only differ from one another by their upper API (to the applications), but also by their interface to the lower layers of the software (which we will name “middleware API”), the set-top box manufacturers most often interface the middleware to their own API (which we will name “platform API”) through an adaptation layer. Figure 7 illustrates the different software layers of a set-top box using a middleware in comparison to the layers of a personal computer (PC).
Figure 14: Comparison of the software layers of a set-top box and a PC

Quite a few different middleware are in use in Europe. Some providers are using proprietary middleware solutions and others rely on open standard middleware. Because applications are not portable between different middleware platforms they must be adapted for each middleware independently.
5 Open Standards Analysis

5.1 OpenTV

OpenTV is a middleware proposed by a company bearing the same name. It was originally a joint venture between Thomson Multimedia and Sun Microsystems (Sun Interactive Alliance formed in 1994). In 2010 OpenTV became a fully owned subsidiary of the NAGRA Kudelski Group. A number of OpenTV middleware versions have been released of which Open TV 2 and Open TV 5 are of the greatest importance. OpenTV has deployed over 170 million devices worldwide.

Figure 15: OpenTV logo

5.1.1 OpenTV 2 middleware

OpenTV 2 middleware is widely deployed in Europe. Since its first deployments in 1997 the OpenTV has created a footprint covering 100 countries, more than 50 network operators and 40 set-top box manufacturers and has been deployed in 100 million digital set-top boxes and televisions in 2008.

The Core TV components (figure 16) provide the base functionality of OpenTV, which is utilized by different application environments:

- **Spyglass HTML Browser**
  Supports HTML 4.01 and XHTML 1.0, JavaScript 1.6, CCS1, CSS 2.1 and elements of CSS 3, DOM 0, DOM 1, DOM 2, and elements of DOM 3 relevant to television interfaces, AJAX, XML handling with E4X and DOM2. The Spyglass browser also includes a range of extensions for TV functionality including stream playback and control for live TV, RTSP VOD, over-the-top video, and home networking. In addition, it supports the Hybrid Broadcast-Broadband TV standard HbbTV 1.1.1 (ETSI TS 102 796).

- **OpenTV’s Virtual Machine (Interpreted C)**
  OpenTV applications can be written in C, using compiler gcco, which outputs o-code (conceptually comparable to byte code of Java), which is then run on the set-top box by means of a virtual machine (interpreter).

- **Adobe Flash Lite**
Additional application environments can be added to OpenTV through a published API. The different environments require different levels of STB resources (i.e. processing power and memory).

Applications that provide Internet services can either be resident within the set-top box, downloaded via broadcast transmission (e.g. DVB-T), or downloaded over broadband IP connection.

5.1.2 OpenTV 5 middleware

OpenTV 5 is the latest generation of OpenTV middleware. It is built on the Linux operating system and Internet technologies, such as HTML4, HTML5, CSS3, SVG and JavaScript. Applications can be either resident within the set-top box, downloaded via a broadcast carousel, or downloaded using a broadband connection. OpenTV 5 applications can take advantage of rich OTT support (HTTP progressive download and streaming, Apple HLS adaptive streaming, Microsoft Smooth Streaming, etc.) and use implemented DirectFB (Direct Frame Buffer) or OpenGL ES 2 (Open Graphics Library for Embedded Systems) libraries. HbbTV applications are also supported and additional application runtime environments can be added through a published API.
5.2 MediaHighway

MediaHighway was developed in 1993 by the R&D department of Canal+ and first debuted in 1995 Napaka! Vira sklicevanja ni bilo mogoče najti.. It is currently developed by the NDS Group, which acquired it from Thomson SA in 2003. In 2012 Cisco acquired NDS Group. According to the NDS Group the MediaHighway middleware has been integrated on more than 30 different chipsets and has been shipped in more than 195 million set-top boxes by over 50 operators [38].

Figure 18: MediaHighway logo

Many versions of MediaHighway exist, which correspond to a DLI (Device Layer Interface) number. The DLI is in fact the interface of the middleware to the lower layers of the software. The hardware platform together with its operating system and its drivers must comply with the DLI specification, generally via an adaptation layer. The DLI defines the functionalities supported by the middleware and ensures an independence (or abstraction) from the hardware platform and RTOS (real-time operating system) used.
Recent versions of MediaHighway are based on “MediaHighway virtual machine” which can execute applications developed under many different standard languages (Java, DVB-MHP, HTML, HbbTV, MHEG-5, etc.) by loading the appropriate interpreter.

![MediaHighway middleware architecture][39]

**Figure 19: MediaHighway middleware architecture**

### 5.3 Liberate

Liberate Technologies is a provider of interactive TV software to Digital TV network operators. The Liberate middleware solution is based on the Java-based Liberate software engine that is called Navigator Standard. The TV Navigator is a customizable component that is used to match the individual needs of the network operator, supporting a limited number of interactive applications. Although Liberate is designed to work with both Satellite and Cable its main market lies with the Cable delivery of DTV.

### 5.4 Betanova

Betanova middleware was developed by BetaResearch, the market leader in digital DVB set-top boxes in cable and satellite networks in German-speaking countries. The Betanova middleware is truly dependent on the D-Box set-top box platform. Hence both Betanova and D-Box have found themselves limited to the German market. The D-Box is a set-top box platform being used for broadcasting TV services as well as interactive services in Germany and is based on the DVB and MPEG-2 standards. The first version of the Betanova middleware was based on the C/C++ programming language. In 1999 BetaResearch deployed the worldwide first Java based middleware called Betanova 2.0.

### 5.5 MHEG-5

The MHEG-5 (Multimedia and Hypermedia Expert Group) middleware, standardized under the ISO/IEC 13522-5 reference (licence-free), is a subset of MHEG-1 particularly dedicated to digital
TV receivers (STB or iTV) with limited processing power and memory size [40]. It is practically the only MHEG version in real volume usage. MHEG-5 is mainly used to provide interactive services for digital television in the United Kingdom.

The MHEG is a descriptive language of multimedia presentations, comparable to HTML for hypertext pages. It is based on an object-oriented multimedia exchange format independent of the hardware and software (OS) platform on which it is executed. It is a declarative, as opposed to a procedural, language (such as Java).

```mheg
{:Application ("/startup" 0)
 |:Items
 |
 |:Link 1
 |:EventSource 0
 |:EventType IsRunning
 |:LinkEffect
 |
 |:TransitionTo ("/scene.mheg" 0))
 |
 {:Scene ("/scene.mheg" 0)
 |:Items
 |
 |:Text 1
 |:Hook 10
 |:OrigContent "Hello world..."
 |:OrigBoxSize 200 50
 |:OrigPosition 200 100
 |
 |:Link 2
 |:EventSource 0
 |:EventType UserInput
 |:EventData 104
 |:LinkEffect
 |
 |:quit ( { */startup" 0 } )
 |
 |}
 |
 |:InputEventReg 3
 |:SceneEntry 720 575
 |
 }
```

**Figure 20: Hello World application written in MHEG language**

MHEG-5 applications are constructed from sets of scenes and objects that are common to all scenes. Scene composition consists of a group of objects used to present information, textual, graphical, and so forth and descriptions of those object behaviours based on events. Navigation in an MHEG-5 application is achieved by the transitioning between scenes. MHEG-5 engine on the user’s terminal is responsible for interpreting the MHEG-5 script and displaying the extracted multimedia objects as instructed by the script.

For a long time MHEG-5 applications could only be delivered to the user’s set-top box via broadcast connection or loaded from a CI (or CI+) module. Work by the DTG in the UK led to the development of the connected TV MHEG-5 Interaction Channel (MHEG-IC), which enables an extension to broadcast services (and content) to be delivered via an IP (broadband) connection.

MHEG-5 has been selected as the mandatory interactivity engine for CI+ (Common Interface) compliant devices.
5.6 MHP & GEM

MHP (Multimedia Home Platform) and GEM (Globally Executable MHP), are two related sets of Java based open middleware specifications developed by the DVB Project. MHP was designed to work across all DVB transmission technologies whereas GEM is a platform-independent environment that can be adopted across a range of delivery systems including packaged media. GEM is thus a common core engine on which interactive applications can run; implementing GEM requires the definition of how those applications actually connect with that core [41]. Both MHP and GEM are published as open standards by ETSI (European Telecommunications Standards Institute).

MHP defines a generic software interface (API) between the interactive applications coming from different service providers and the terminals on which they should be run, independently of their hardware and software implementation. The performance level of these terminals can vary greatly.

The MHP architecture has three levels: resources, system software, and applications.

Resources include all the essential parts of the set-top box: MPEG decoding, input/output devices, host processor, graphics subsystem, etc.
System software enables presentation of an abstract view of the platform to the applications. It includes a navigator (or application manager), which takes control of the platform, and applications that are run on it. The software kernel of MHP is called DVB-J (DVB-Java), based on the Java Virtual Machine defined by Sun Microsystems.
MHP applications access the platform through the MHP API. A number of software interfaces required to make use of specific resources of the hardware platform are implemented by means of extensions. The task of any practical implementation of MHP is to ensure correspondence between the API and the hardware resources of the platform.
Three profiles have been defined for the MHP platform, by order of increasing functionality, which imply an increasing need for processing power and hardware complexity:

- Enhanced broadcast profile makes use of unidirectional broadcast services only.
- Interactive broadcast profile adds support for interactive services requiring only a low speed return channel.
- Internet access profile adds the supplementary functionalities brought by Internet access within the limits of TV screen display. It requires a higher speed connection.

![MHP Profiles](image-url)

**Figure 23: MHP Profiles**

MHP had not met the expected success in most countries where DTV has been launched, except in Italy where MHP interactive receivers have been strongly subsidized. But even there the interest has decreased after reduction of the subsidy after one year. The main reason was a significant cost increase, due to the hardware resources (higher processing power and memory size) required by the Java virtual machine. MHP’s relatively steep licensing fee also limits its general adoption.

### 5.7 HbbTV

The HbbTV specification is based on existing standards and web technologies including OIPF (Open IPTV Forum), CEA, DVB and W3C. The standard provides the features and functionality required to deliver feature rich broadcast and Internet services. Utilizing standard Internet technology (HTML, XHTML, CSS, JavaScript including AJAX) it enables rapid application development. Products and services using the HbbTV standard can operate over different broadcasting technologies, such as satellite, cable, terrestrial or IPTV networks. Version 1.0 of the HbbTV specification has been approved by ETSI as ETSI TS 102 796 v1.1.1 in June 2010 [43].
HbbTV evolved in 2009 as a joint project between France and Germany, and it is those two countries along with Spain and the Netherlands that have made the early running with HbbTV deployments. In Germany, at least eight broadcasters are now offering HbbTV applications over terrestrial or satellite networks. HbbTV has also won over the Nordic region (Denmark, Finland, Iceland, Norway and Sweden), which originally was planning to build hybrid broadcast around the alternative MHP developed by the DVB. HbbTV has replaced MHP as the common API for hybrid digital receivers within its NorDig digital TV specification. HbbTV is expected to launch also in Switzerland, Austria, the Czech Republic and Poland [44].

The success of HbbTV can be put down to three factors: its flexibility; foundation on existing standards that are being implemented anyway as part of OTT and IPTV deployments; and support from industry groups, notably the European Broadcast Union (EBU), whose influence extends outside the continent.

The key component for OTT that has been adopted by HbbTV is the OIPF’s (Open IPTV Forum) Open Internet Profile, based on its Declarative Application Environment (DAE), which is a browser for TVs with support for various presentation mechanisms including HTML4, HTML5, SVG, and CE-HTML.
HbbTV addresses the following types of application [45]:
- Broadcast-independent application (i.e. not associated with any broadcast service). This type of application is downloaded via broadband and accesses all of its associated data via broadband.
- Broadcast-related application (i.e. associated with one or more broadcast services or one or more broadcast events within a service) that may be launched automatically ("autostart") or explicitly upon user request. This type of application may be downloaded via broadband or broadcast and may access its data via either method.

5.8 Suitability and argumentation
Comparison of standards reveals many benefits of HBBTV standard. It brings many benefits and besides that is also adopted in many countries within EU and also in the USA. Figure 19 shows current state of HBBTV standard adoption some additional information can be found in Table 5. In August 2012 standard version 1.5 was introduced with DRM implementation and possibilities of AAA (Authentication, Authorization and Accounting). Even more version 2.0 is under development and topics discussed to be implemented are:

- Currently working on requirements
- Topics being discussed / raised as a topic HbbTV should address
  - HTML5
  - Companion screen / 2nd Screen
  - Synchronizing Broadcast & Broadband
- Design paradigm identical to phase 1
- HbbTV has to address immediate market needs
- Leverage mature existing technical components / specifications
- Aspects relevant to time line:
  - Quick technology development in Internet domain
  - Content providers must be able to address rapidly growing legacy customer base

HbbTV platform is already opening new opportunities and upgrades for many advanced applications and services for usage on TV screens and beyond. HbbTV platform is dynamic and provides an open and business-neutral technology platform and in addition its development and wide adoption also brings international market and development communities.
Country | HbbTV Deployments and Adoptions
--- | ---
Germany | HbbTV has been deployed for some time in Germany, both on satellite (e.g. Astra HD+) and Free-To-Air (FTA) terrestrial. It is carried by cable operators such as Telecolumbus and Primacom, as well as supported in the Kabelkiosk package.
Austria | ORF is running an HbbTV portal on its satellite service and a roll-out is planned next year on the DVB-T2 pay TV platform.
France | The French public broadcaster, France Television, has deployed an HbbTV-based video-on-demand (VOD) service. Eutelsat has adopted HbbTV for its FranSat satellite platform. Additionally, the new TNT2.0 platform complete with DRM will be launched in the summer of 2012 with the introduction of MyTF1. TNT2.0 is based on HbbTV 1.5 incorporating MPEG-DASH adaptive streaming and supporting the Marlin or PlayReady DRM systems. A test suite is available from Digital TV Labs to test platform conformance against the TNT2.0 specification.
UK | In the UK, the DTG-driven CTV project specified in D-Book 7 Part B heavily references HbbTV 1.5, but is yet to be adopted by any platform operator. Intellect, the organisation for manufacturers, has released a rival specification which is wholly based on HbbTV. Freesat G2 uses HbbTV.
Switzerland | Radio Télévision Suisse (RTS), which serves the French-speaking part of the country, will be the first SRG affiliate to test an HbbTV service, with the other affiliates following in 2013. The planned services include applications such as a multimedia teletext with news and sports reports, a VOD service and dedicated offerings for people with disabilities.
### Table 5: HbbTV deployment [59]

<table>
<thead>
<tr>
<th>Region</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>Dutch broadcasters SPS, NPO and RTL have adopted HbbTV for connected TV services. NPO has been conducting trials on the Canal Digital DTH and Ziggo cable networks.</td>
</tr>
<tr>
<td>Scandinavia</td>
<td>The NorDig standards organisation has dropped MHP and selected HbbTV 1.1, with the imminent NorDig Specification version 2.4 to include HbbTV 1.5. Public service broadcaster, DR, has been running a pilot of its catch-up service on HbbTV with great success.</td>
</tr>
<tr>
<td>Poland</td>
<td>TVP and TVN have been conducting trials, and recently launched services to coincide with the European Football Championship.</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Czech public broadcaster CT has been conducting recent trials.</td>
</tr>
<tr>
<td>Spain</td>
<td>Abertis is launching TDTCOM, a connected DTT platform for pay-TV services using HbbTV 1.5 platforms.</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Test services are expected to be soft-launched in the near future.</td>
</tr>
<tr>
<td>Turkey</td>
<td>The latest DVB-T2 receiver specification for the imminent launch of DTT services specifies HbbTV.</td>
</tr>
<tr>
<td>USA</td>
<td>ATSC is in active liaison with HbbTV to use the technology as part of ATSC3.0.</td>
</tr>
<tr>
<td>ASEAN Region</td>
<td>Malaysia and Vietnam have adopted HbbTV as part of their new DVB-T2 standard and other ASEAN countries are actively considering.</td>
</tr>
</tbody>
</table>
6 Terminal equipment analysis

Nowadays many new TV sets already support HbbTV applications and there are also many HbbTV set-top-boxes. All supports basic applications combining broadcast and broadband but since this project initiates new perspective with absence of broadband there are some limitations. Local interactivity can be accomplished only with storing data on local media (memory) so in this case usage of local memory is expected. But tests done so far had shown that although this scenario is supported in standards many STBs and TV sets doesn’t support all functionalities. Some changes are expected with new standard 1.5 which upgrades functionalities with DRM functions.
7 Broadcasting internet content – prerequisites

7.1 Internet content on the TV screen

It is very important that the user interface of Internet services is adapted to the device on which the services are used. Because users interact with TV differently as with computers we cannot simply expect them to use the same user interface as they use on the computers. For example, browsing ordinary web pages on the TV is very tiresome for the user, if the pages are not properly adapted. The main differences, which must be taken into account, are:

- No direct pointing to page elements, but hand-held remote controlled navigation with only four navigational buttons (up, down, left, right), confirmation key (OK) and back button. Additional navigation is possible with standard colour buttons (red, green, yellow and blue), number buttons, and playback buttons (play, pause, rewind, etc.).
- The usual distance between the user and the TV is approximately 3m.
- Light conditions in a living room may be different to a desk situation.
- The user is typically browsing passively (Lean backward) in comparison to interacting/searching actively (Lean forward).

When designing user interface for Internet services that are intended for use on the TV, the 10-foot user interface guidelines should be used. These guidelines are dedicated for user interfaces that are displayed on big screens (televisions) and are approximately 10 feet away from the user. "Ten foot" is used to differentiate the GUI style from those used on desktop computer screens, which typically assume the user's eyes are less than two feet (60 cm) from the display. The 10-foot GUI is almost always designed for being operated by a hand-held remote control (not through touch or mouse). The 10-foot user interface has extra-large buttons with menu fonts that are easily read and navigated. Guidelines recommend that because of the greater viewing distance the minimum font size used should not be smaller than 18px (even bigger fonts are preferred). Best readability is generally achieved with anti-aliased fonts. Mixing of different fonts is highly discouraged.

The goal of 10-foot user interface design is to make the user's interaction as simple and efficient as possible, with as few button presses as possible while still having an intuitive layout, in terms of accomplishing user goals – what is often called user-centred design. Graphic design may be utilized to support its usability, however the design process must balance technical functionality and visual elements (e.g., mental model) to create a system that is not only operational but also usable and adaptable to changing user needs.

Other guidelines for 10-foot UI include:

- Text on the TV screen requires greater line spacing compared to the text written on paper for maintaining the same readability. Designers must be aware of this fact and take it into account while designing the UI.
- Single-pixel thick horizontal lines or static UI elements with single-pixel detail should be avoided as older televisions and low-resolution displays may simply not display such fine detail, and content will flicker if running on an interlaced display mode since a single row of pixels will be visible only half the time.
- Researches have showed that it is easier for people to read light text on a dark background.
Any displayed screen should contain as limited amount of text as possible (some researches have showed that the maximum limit should not exceed 90 words).

Example of web page that has been adapted for use on the TV (10-foot UI) is shown on Figure 27 and Figure 28.

Figure 27: Web page designed for use on the computer

Figure 28: Adapted web page for use on the TV
7.2 Data Carousel, Object carousel

Services can take a place in MPEG-2 transport stream on several types. One of options is data/object carousel in DSM-CC (Digital storage media command and control). DSM-CC is a toolkit for developing control channels and asynchronous data transmission in MPEG-2 stream - this protocol enabling the downloading of applications to the digital receiver. For MHP is often used DSM-CC in User-to-User communication protocol, but in TV broadcast which is one-way network this is solved with broadcasting all of objects from server to client. Every file in the file system is broadcasted periodically, and the receiver waits for the file it wants. File operations on the receiver tell it which files it should look for in the broadcast. The best example of this kind of solution is a teletext system: each page has a unique number, and each page is transmitted in turn. When the user enters a page number, the TV must wait for that page to be broadcast before it decodes and displays it. This type of solution is known as a carousel - every page goes round it turn, and the receiver must wait for that page to come round again in the broadcast before it can use it. In DSM-CC, data is transmitted in blocks called modules rather than in pages, but the principle is the same. The data to be transmitted is split up into modules, some description of that module is added and then each module is transmitted in turn.

Data carousels work well for a teletext system or for a simple application, but it has some limitations. Basically let’s to transmit chunks of data over an MPEG-2 connection, but it says nothing about what that data actually is: the application that is reading the data carousel has to know the format of what is contained in the data carousel and how to deal with it. For MHP applications, this is a big problem since the file and directory structure is such an important way of organising files and is needed to distinguish application code from assets. The solution to this is the Object carousel which is built on top of the data carousel model, but it extends to add the concept of files, directories and streams. This allows the carousel to contain a true file system - a set of directories and files that contains a directory structure like on a PC. In fact, it goes one better than that - Stream objects allow an object carousel to refer to elementary streams that are part of the broadcast, and Stream Event objects allow a receiver to know about specific synchronization points within a stream. In Object carousel can be carried following message types:

- **File messages** represent real files. They contain the actual data that makes up the file.
- **Directory messages** represent logical containers for a set of file messages. Each DSM-CC directory contains a number of files (just like directories in a real file system), and a DSM-CC directory message contains a set of references to the files that are within that directory.
- **Stream messages** are references to MPEG-2 streams, often containing video or audio data. Each stream message can either refer to a single MPEG-2 program, or to one or more elementary streams.
- **Stream Event messages** describe a set of synchronization points (called stream events) that are contained in a stream. The stream events themselves are described by specific descriptors, but Stream Event messages tell the receiver what stream events are present in the stream and associate them with a textual name.
- Service Gateway messages represent a concept that is similar to a directory (and in fact Service Gateway messages are almost identical to Directory messages). The main difference is that Service Gateway messages identify the root directory of the object carousel. This means that every object carousel will have one and only one Service Gateway message.

Each object carousel consists of a directory tree that is split into a series of modules, which may contain one or more files or directories. Each module may contain several files with a total size smaller than 64 KBytes - storing several files in a module larger than 64K is not allowed. Splitting files across more than one module is not allowed, so files larger than 64K must go in their own module, which will contain only that file. Files in a module can come from any part of the directory tree to be broadcast, and need not come from the same directory.

These modules are broadcast one after the other until they have all been broadcast, at which point the process starts from the beginning and the first module is broadcast again. In order to access a file, the receiver must wait until it receives the module containing that file, at which point it can parse the module and access the file. This may not be efficient when the total amount of data being broadcast is quite large, but most receivers will cache some data. This caching may either be done at the module level, or at the individual file level. Some modules are transmitted more often than others in order to improve access time for commonly used data.

Simply broadcast DSM-CC carousels or streams as part of service is not enough. A receiver needs to know what data is present and how to find it. Like any other stream in service, DSM-CC streams must be listed in PMT. The DSM-CC specification defines several descriptors that are used by the receiver and the DSM-CC implementation to resolve references within DSM-CC and to make it easier for the receiver to associate an object carousel with a particular service. The carousel identifier descriptor is carried in the PMT (program map table) for the service containing the object carousel, and helps the receiver to associate a particular carousel with that service. Also the presence of applications must be announced, with the Application Information Table (AIT), which is a DVB table especially introduced for this aim. Once the receiver has signalled an application in the broadcast stream, it may start to download it. Once the application is downloaded, the application has access to this so-called remote file system.

7.3 Display

Interactive TV application needs to draw/display some user interface (UI) on the screen. DVB adopted for MHP an existing solution for UI display – HAVi Level 2 GUI (Home Audio/Video interoperability), which can be generalized for other interactive standards like HbbTV for example:

- The main building blocks of HAVi in MHP are widgets. These provide functionality to set up a flexible user interface by means of presenting text, providing buttons containing text and graphics, scrollbars, sliders, lists and user entry’s and even graphical animations. The flexible nature of widgets is a consequence of the fact that each widget uses a mechanism to present its content; this mechanism is called the ‘look’ of the widget. The look of a widget may differ from one device to the other, while its contents stay the same.
This provides for the ability to change the presentation of the user interface at run-time: Together with the application, the looks can be downloaded into the device, allowing for content providers to give the same application a complete different presentation. This allows for easy customisation of the application by the developer. However there are many other things that we should take care at developing DTV application:

- Aspect ratio: Display aspect ratio may be either 4:3 or 16:9. But an image in one aspect ratio can be displayed on a TV of another aspect radio in one of several ways. The aspect ratio of the display and the way how the picture is mapped may be changed either by the user or by the TV. In both cases when image or graphics is not designed for desire aspect ratio can be very unfavourable because image is stretched or squashed.

- Pixel aspect ratio: Here we have problem with different resolution, with square and non-square pixels which are typically used in video and TV applications and with layers which use different pixel shapes.

- Colour space: it is an issue how to use RGB colour space used by Java on the TV signals where YUV colour space is used.

- No free moving cursor: Navigation could not be done with pointing device for i.e. a mouse, but must be carried out with arrow keys and few other buttons.

- No window manager: Because window managers are too complex, there should be used different approach to this problem – application needs the way of getting some screen real estate it can draw on.

An important part in the structure of graphics model plays hardware in receiver, because there is not enough processing power to do all the work in software. Graphic model we can split in three logical layers: background, video and graphic layer.

The background layer is a simple colour behind every graphics on the screen and it will fill any areas which are not covered with video in case, if we scale video so, that is displayed in only part of screen. This layer will let us display also a still image but there are several limitations. In front of background layer is video layer, where the video content is shown. Because receivers usually do some scaling and repositioning video may not cover entire screen. In MHP standard is written that receiver should be able to display video at full-screen resolution or at quarter-screen resolution in position in one of four quarters of the screen.

The top layer is the graphics layer, which consist any AWT (Abstract Window Toolkit) widgets that application wants to display. MHP receivers are required for support a resolution 720 x 576 pixels with minimum 256 colours. These are minimum values. If higher resolution is supported it can become to a problem because a pixel in graphics layer will not map directly onto a pixel in video layer. Some receivers can have more than one graphics layer e.g. a separate layer for cursor or two graphics layers with some transparency between them. In base, only one logical graphics layer is in MHP and so it is on middleware to decide how this gets mapped to the underlying hardware. Each of these layers can be produced by separate parts of the hardware and that’s why also configured separately. It is important to change only those parts of graphics configuration which really have to change. An application must be flexible when dealing graphics and video configuration and it may not always get what it needs. Important is also, it must not disturb other running applications unless this is necessary.
Sometimes a screen configuration is wanted to be changed in order to get some specific option. Alternatively, you might want to query a device to see if it supports a specific configuration or to see how close it can get. In these cases, configuration class is used associated with each type of device. Each screen device class has an associated configuration class and this class has a name that matches to the device. An alternative approach is creating a configuration template where an array of templates and middleware is used to try to get the best match.

The graphic layer is required to support only non-square pixels. Optionally, MHP receivers can support graphics devices with square pixels at resolutions 768 x 576 (for displays 4:3) and 1024 x 576 (for displays 16:9). Also, aspect ratio 14:9 on emulated devices need to be supported in order to provide acceptable output on either 4:3 or 16:9 displays. In practice, means usage of the 14:9 aspect ratio that text will be the same width (pixels) on 16:9 and 4:3 displays because of the pixel-to-point ratios MHP specifies for text at different ratios. With this solution, any problems with text rendering interfering with a graphical layout are avoided.

Working with graphics on DTV receivers can get very complicated due to the hardware limitations of the receiver, so development of graphic designs and applications need to consider a lot of things. As it is already mentioned, the different shapes of video and graphics pixels may mean that the video and graphics are not perfectly aligned and even layers may not be the same resolution. Some settings in configuration templates can give good results at aligning the two layers of the display, but there is no guarantee a receiver can actually support this. Next can be a problem with Overscan. This means that only the central 90% of the display is visible and only central 80% of the screen is distortion-free - only at 4:3 TV set. 16:9 displays have different areas that may be hidden or distorted. To avoid problems, development should stick to the graphic-safe (title safe) area. In PAL standard this area in centre of the screen that will always be visible without distortions is at 562 x 460 pixels. With producing 4:3 signal, which is shown on 4:3 TV set, with display mode switched to 16:9 aspect ratio, another big problem occurs, because none of application in receiver can't control users aspect ratio TV settings. On a TV the problem with small text and thin horizontal lines which will flicker can occur – Interlacing. Also very saturated colours in UI are not desirable so web-safe pallet should be used for nicely display.

Almost every application will need to display text. The basic techniques for displaying text are well-known, and MHP applications can use the standard Java methods for drawing a string. There are some problems we face it when displaying large amounts of text in an application. The first problem is that reading text on a TV screen is difficult - TV displays typically have low resolution and low contrast, which makes text harder to read from a typical TV viewing distance. Choosing the right font is part of the answer to this problem, which is why MHP specify that the **Tiresias** font is the standard font used in receivers. This was specifically designed for readability on a TV screen, and will be much more legible than other fonts. Font sizes also play their part: since text is viewed from much further away, and the resolution is much lower, the recommended font size for text on a TV screen is much higher than for PC applications. Each pixel in a TV screen is treated as one point, so 18-point text will take up 18 lines on the screen. Because of the low resolution and poor contrast of a typical TV, this is really the smallest text that should be used in an application. These factors all affect the amount of text that can fit on the screen at
once and in general they all tend to reduce the amount of text that we can use. The second problem is navigation. If a piece of text is too long to fit on screen (or in the area of screen that is available to it), the user will need some way of moving around the text. While scrollbars work well on a PC where the user has a mouse to control the scrolling, this is not a good choice for a digital TV application. ‘Jump scrolling’ or paging through the text is a much better solution that is easier to navigate with a remote control. Option is also vertical scrolling, but the need for horizontal scrolling should be avoided. Care should also be taken to make sure that the method for navigating around a long piece of text does not clash with the method for navigating around the rest of the application.

Low level text rendering is named process for managing details about: how should the text be aligned? What margins should be applied? What happens if the text is too big for the assigned area? When application uses the usual Java methods for drawing strings the application is responsible for managing all of these details. It's up to the application to check if the string is too wide and to split it across multiple lines, and to work out where to split the text. It's up to the application to manage the line spacing, and to take care of every other aspect of rendering a piece of text.

DVB took the functionality of text layout managers: DVBTextLayoutManager class. This provides some additional layout rules, allowing the application to control a number of other layout factors. These include the orientation of the text, horizontal and vertical alignment, and the starting corner for the text. Using these extra rules gives applications a little extra flexibility in laying out text. High level text rendering in MHP is using a text layout manager to render text. There are no significant differences in the process of text layout between high level rendering and low level rendering, except that in high level rendering, text layout managers hide all of the complexity involved in rendering the text. High-level rendering is less flexible in some ways (e.g. the line spacing for the entire block of text will be the same), but this is unlikely to be a problem in most applications and high-level rendering is usually the best choice for displaying more than couple of words of text.

While the text layout manager may be enough for many purposes, it does not always offer the flexibility that an application may need. In these cases very well-known HTML can be used. The problem is that many MHP receivers do not support HTML. Luckily this is not as big a problem as it may first appear: many companies sell HTML rendering components or HTML browsers written in Java, and these can be incorporated into an MHP application relatively easily. Downloading a simple HTML browser or renderer is not significantly more difficult than downloading any other application, and the advantages far outweigh any problems. Using HTML or XML can give applications far more flexibility than other approaches, although it does make the application more complex.

Fonts: receiver will use the Tiresias font unless the application specifically sets another font for a piece of text. Unfortunately, even though the font is the same, the font metrics (e.g. spacing between letters or lines, the height of a line, and other similar parameters) may not be the same and so different receivers will display text slightly differently, with some receivers fitting more text into the same area of screen. Text may fit inside the area allocated to it on once receiver, but...
overflow that area on another. The only solution is to download a custom font as part of the application, which will have the same font metrics on every platform. The disadvantage of this approach is the extra time and complexity needed to load the font, as well as licensing issues related to the font.

7.4 Control

In MHP, a graphical user interface on the television screen provides interaction with the user. Typical MHP receiver use instead mouse and keyboard for input a remote control unit. When talking about user interaction in MHP, it is important to understand how the MHP device handles incoming inputs from the user. It is also important that UI is designed in way that user can easily navigate around it using just the arrow keys on remote. This means setting sensible navigation targets for each component in UI, but it also means using shortcuts where possible. Sometimes information need to be present on several different screens and the user should have a way of moving among those screens easily.

The MHP specification recommends that applications without an obvious user interface should only use the coloured keys or the teletext button, and that all other buttons should be left for the navigator. This allows developers to build applications that are activated with a single key stroke while still preserving the interaction model that people expect. Applications that want to use other keys must display a user interface that covers at least 3% of the screen area.

HAVi defines a number of classes for use to handle user input and help solve some of navigation problems. Most commonly is used “HRcEvent” class which extend the AWT “KeyEvent” class. It defines constants for keys that will be typically found on a remote control unit and MHP define common subset of these that will be present on every remote. Every receiver must support basic set of key controls. It is unlikely that remote will actually support all of the keys defined in HAVi because that kind of remote would be too complicated for usage.

Much of UI is graphical and as aid to navigation a representation of a key could be a drawing on the screen. This could be very helpful because one receiver manufacturer may name key as OK and another may use SELECT and the graphical representation of a key as it is drawn on the remote may also differ between receivers.
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