FACTA UNIVERSITATIS (NIŠ)
SER.: ELEC. ENERG. vol. 21, no. 2, August 2008, 127-154

Digital Broadcasting and New Services

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Invited Paper

Abstract: The paper contain brief overview of a recent progress on digital broadcasting development. Main attention is given to the DVB-H standardisation and to possible services which can DVB-H offer. Also the DVB-H support to the IP data casting and IPTV in general is enlightened.

Keywords: Digital broadcasting, DVB-H, 3G mobile telecommunication, new services, IPTV.

1 Introduction

DIGITAL VIDEO broadcasting (DVB) is in all three derivations DVB-S (satellite), DVB-C (cable) and DVB-T (terrestrial) as the broadcasting standards are widely accepted and already used in some EU countries for terrestrial broadcasting. Even more, according to EU directive the analog broadcast system will be switched down in 2012 and replaced with DVB-T. The DVB receivers are already produced in large series of some million pieces per year, which leads to the conclusion that we are now witnessing extinction of analog TV systems and rising of digital TV era.

We are also witnesses of huge merging of telecommunication technologies. Digitalisation brings together classical telecommunications and computer data communications systems opening a palette of possibilities, which cannot be conceived in the analog systems. This gives possibilities to form services on demand including DVB at any time in any place. Many of those are already available with 2.5 G, 3 G and 3.5 G mobile networks, some of them – like DVB-T – are now on the way for wide spread implementation and use.

Manuscript received on July 1, 2008. An earlier version of this paper was presented at XLIII International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST2008, June 25-27, 2008, Faculty of Electronic Engineering of Niš, Serbia.

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For future of DVB is seems to be developing Internet Multimedia Services (ISM) leading to IPTV, a unified platform of New Generation Network (NGN) for plethora of services and new business models.

The article contains a brief overview of different aspects of digital video broadcasting with emphasis on new services and marked drivers issues.

2 Background technology

Basic enabling technologies of DVB are:

1. digitalised images and voice compression
2. forward error correction

and in the recent time more and more important role has

3. IP technology and protocols enabling services not known and possible in analog broadcasting.

2.1 Image compression

The efficient image/video coding-compression is noticeable for digital broadcasting as well as for storage of digital image/video on devices with limited memory capacity. There are a lot of compression standards. Among them the MPEG-2 is still prevailing in digital broadcasting. In sense of picture size, interlacing, picture rates it is adopted to existing analog systems, but considering frequency efficiency it is three times better.

2.1.1 H.264/MPEG-4

H.264 and MPEG-4 AVC (Advanced Video Coding) was recently standardized by the International Telecommunication Union-Telecommunication (ITU-T) as H.264 standard providing significant improvement in compression efficiency, up to 50 % in comparison to MPEG-2. It enables user friendly video representation for interactive applications, progressive and interlacing images presentation etc.

Compare to MPEG-2 the MPEG-4 AVC, i.e H.264, has two new blocks: deblocking filter and intra-frame prediction block (Fig. 1). The rough principle of encoding is as follows. The current frame of input digital video signal is divided into macro-blocks. Each macro-block consists of three components, luminance component Y and two colour components Cr, Cb. The chrominance signals are both subsampled by two in horizontal and vertical direction, because the human eyes are less sensitive to chrominance as luminance. The macro-blocks are coded in intra or inter mode. Intra mode prediction is made inside the same frame, inter mode prediction is based on motion compensation. Motion vector/data are assigned to each macro-block that refers to its position in preceding reference frame (image). The accuracy of vector displacement is improved to quarter of picture element (1/4-pel). Also multiple reference images can be used.

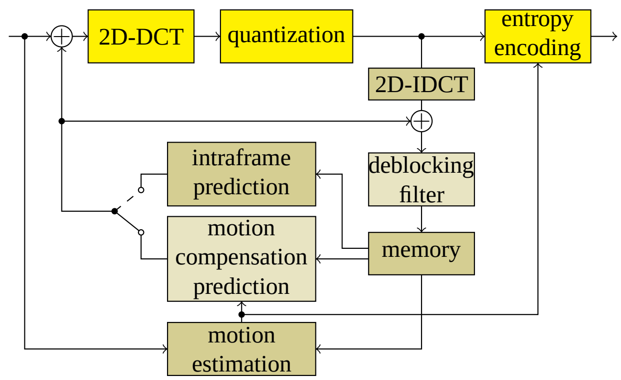


Fig. 1: Generalised scheme of hybrid MPEG coder.

Macro-blocks in MPEG-4 AVC are processed in groups called slices. Slices are processed in raster scan order. Five different slice-types are supported, i.e. I-, P-, B-, SI-, and SP-slices. In I-slice, only intra mode is used. In P-slice, macro-blocks are motion compensation predicted using one reference frame and in B-slice using two reference frames. SI- and SP-slices are used for efficient switching between two different bit streams. Also encoding of interlaced video is supported with two modes, which are frame mode and field mode. The prediction error signal, obtained as difference between current and predicted block is transformed using two dimensional discrete cosine transform (2-DCT) using integer calculation. The transformed signal is quantized and entropy encoded. Entropy encoder, contrary to MPEG-2, uses alternatively two efficient adaptive techniques incorporating context modelling. The first, with lower complexity, uses context-adaptively switched sets of variable length codes (CAVL), and the second context-based adaptive binary arithmetic coding (CABAC). For reducing the blocking artefact adaptive de-blocking filter is introduced in prediction loop in H.264/AVC, efficiently implemented only with shift and add operations.

At the decoder side the encoded quantized coefficients are first entropy decoded and de-quantized. Then inverse transform is used. Obtained signal is added to the prediction signal, which is already available at the decoder site. The result is the reconstructed macro-block. This macro-block is stored in memory for decoding the next incoming block.

2.1.2 Hybrid video coders

The standardised hybrid video coders can be used for different standardised coding schemes (MPEG-x, H.26x). Since this results in highly variable output bit-rate it has output FIFO (first in first out) memory. The size of buffer is limited by the communication delay, so that the rate control (RC) algorithm is needed to avoid buffer overflow/underflow, while producing desirable video quality.

RC schemes based on feedback. The rate allocation (quantisation parameters determinations) is made on the basis of the buffer occupancy or the bit-count for past image blocks. These schemes are simple and good solutions for low-cost implementations. Examples of bit-count feedback control schemes are the MPEG-2 TM5 (Test Model 5) rate control.

The MPEG-4 committee has adopted a quadratic rate-distortion model for video object coding using a smart and model based selection of quantisation parameters on the macro-block level. Beside this algorithm there are also others such as adaptive rate control for MPEG-4, which use regression method for estimation of quantisation parameters obtained with modification of TM5 with sum of absolute differences instead of mean absolute difference.

2.2 Forward Error Correction Coding

Apart from the modulation used, the FEC coding scheme is the most important part of a wireless digital communication system's transmission scheme. FEC codes add redundant information that allow errors to be corrected at the receiver.

The stronger FEC coding schemes enable higher data rates, lower transmitter powers, and more robust reception. In digital broadcasting FEC is implemented in more layers (Fig. 2). Underlay is convolution coding, upper layers has Reed-Solomon coders.

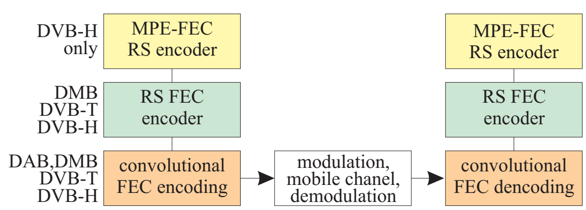


Fig. 2: Layers of forward error correction coding used in different digital broadcasting standards.

2.2.1 Convolutional Coding

DAB, DVB and DVB-H all use convolutional FEC coding with various code rates (implemented by puncturing the mother code).

By modern standards of FEC coding, convolutional coding on its own is an extremely weak form of error correction coding allowing only low data rates and requiring relatively high SNR (signal to noise ratio) at the receiver – i.e. requiring relatively high transmitter powers for a given bit error rate (BER).

DAB uses unequal error protection (UEP) for audio where the data that is more likely to cause errors that the listener will be able to perceive are protected more strongly. DVB and DVB-H use equal error protection (EEP), where a fixed code rate is used for all audio data.

2.2.2 Reed-Solomon Coding

Reed-Solomon coding (RS) is used as the outer layer of FEC coding for DMB and as the middle layer of FEC coding for DVB-H. RS coding fixes the weakness of convolutional coding.

The RS code, used by both DVB-H and DVB, uses packets (codewords) of 204 bytes, which is consist of 188 input bytes and 16 parity bytes (code rate is 188/204, i.e. the amount of redundancy added is only 7.8 %, which is very low), and can correct any 8 bytes that contain bit errors in a packet irrespective of the number of bit errors in each byte, i.e. all 8 bits can be in error, but that only counts as one of the 8 bytes that can be corrected.

The use of Reed-Solomon codes as the outer layer along with a convolutional code for the inner layer of an FEC coding scheme is a very good combination for wireless systems. This is because errors in wireless systems tend to occur in short, concentrated bursts which then overwhelm the Viterbi convolutional decoder. The benefit of using RS coding is that when the Viterbi decoder becomes overwhelmed due to there being too many errors, the Viterbi decoder itself produces a short burst of errors, which is exactly what RS codes are good for correcting.

2.2.3 MPE-FEC

DVB-H also uses a very strong outer layer of FEC coding called the MPE-FEC (multi-protocol encapsulation forward error correction), which allows DVB-H to use 16-QAM at reasonable C/N values at the receiver, and so allows reception of high data rates with just a single-antenna. The MPE-FEC also use a Reed-Solomon code, but here it can correct any 64 bytes out of a 255-byte codeword. This capability is achieved by use of erasures, i.e. bytes that are or thought to be in error. Those bytes are flagged as being unreliable (erasures). Because half of the error correction capability of an FEC code is consumed by locating the errors, the use of erasures informs the error correction decoder where the errors are and so help to the decoder to correct twice as many errors as when erasures are not used.

3 Active and potential drivers in digital video broadcasting

The era of analog broadcasting of any kind has comes to its end. According to many broadcasting regulators prognosis and their recent requests the analog services will be shutdown in a few years. Classical one way broadcasting service will be replaced with more adoptive and integrated services that are interactive and geared toward costumer needs and wishes.

Broadcasting also is no longer limited to wireless transmission of signals. The cable operators as well as telecom providers becomes very important and also global players in broadcasting. Their rich infrastructure of cables, phone lines, fiber-optics backbones as well as new technologies such as xDSL, fiber-to-home which by their nature give better environment for signal delivering and better position in integration of their existing services with new ones. This not only gives them important advantages in competition, but also brings new paradigm of broadcasting services – integrating different services into one bundle. Comparing to analog broadcasting the digital broadcasting enables:

- better utilization of frequency space
- better quality of voice and image
- better possibilities for author rights protection
- introducing new services in broadcasting
- integrating different services

Technical aspects of the first two features are briefly described in the previous section, rights protections is a story to itself, so the next subsections concentrate on services offered by digital television (DTV). First it is necessary to situate within the DTV broader context of digital broadcasting by describing the different service categories and benefits that DTV can offer.

3.1 Multi-channel television

Multi-channel television has been the main driver during the first phase of roll-out, primarily led by satellite pay television operators. Consumer benefits include greater programme choice, due to digital compression, which allows a greater number of programmes to be transmitted simultaneously in a given bandwidth.

Multi-channel is the key service offering of most national digital terrestrial television implementations. However, spectrum limitations reduce the number of services, which terrestrial can carry compared to satellite and cable. Digital terrestrial multi-channel services cannot compete successfully with the quantity of services available by satellite or cable. It is possible that the mobile and in-car reception possibilities of multi-channel services via digital terrestrial television could extend its market appeal, but this proposition has yet to be proved.

However, the appeal of multi-channel may already have reached saturation in many markets. There are indications that multi-channel appeals more to younger consumers, whereas improvements to picture and audio quality attract the 35+ age group even in markets where multi-channel has been very successful as a pay TV service. Moreover, in markets where analogue multi-channel is already well-developed, digital multi-channel digital television has no unique selling point to differentiate it from analogue multi-channel offerings. In smaller countries, limited and not elastic domestic programme production capacity may further reduce the role of multi-channel as a driver, given the importance of national and local programming for TV audiences.

3.2 Interactive television

Benefits are evolving and have yet to be fully realised. Interactivity can increase consumer involvement in conventional TV programmes through voting or by adding options, like a different commentary track or another camera angle. This type of interactivity does not require a return channel and is known as enhanced broadcasting.

The Electronic Programme Guide is the most important application, as it offers consumers greater control and management of their multi-channel TV offerings.

Interactive television can also offer bidirectional services, when receivers are equipped with a return channel. Some Information Society services like e-mail or home banking are already reaching the home and there is potential for further growth.

3.3 Improved visual and audio quality

The main consumer benefits of digital broadcasting are to improve the impact and realism of the programming. This includes a number of features, notably multi-track audio, marketed as surround sound. Transmitting programmes with higher bit-rates will deliver improved pictures, leading to greater impact and enhanced realism on bigger television displays, compared with lower bit rates. Use of the 16:9 aspect ratio widens the viewing angle so that it matches the human visual field better and ensures that films can be viewed at full video resolution, in the appropriate aspect ratio. Combining these two techniques with more picture information is called high definition television, high-resolution pictures intended for viewing on big displays.

Although digital television technologies were widely expected to provide improved quality and were promoted as such, the quality gains have largely failed to materialise through digital broadcasting, even for standard definition television. Broadcasters do not consider picture quality per se to be a driver or to provide differentiation from analogue TV. However, another group of players like DVD publishers has taken a different view of quality. They have found a way of differentiating digital quality and turning it into a driver, in particular by using the wide-screen format. Digital broadcastersX and DVD publishersX contrasting attitudes towards quality are very marked. DVD uses the same video compression technologies as digital television and was launched at about the same time. It has achieved a faster take-up in major EU member states than digital television. The success of DVD cannot be attributed exclusively to content since the same catalogue is available at lower prices on VHS cassettes.

3.4 High Definition television (HDTV)

The main technical characteristic of HDTV is that it offers between four and five times the resolution of a standard definition television system. HDTV is intended for viewing on displays of over 1 metre diagonal. This transforms television from an objective viewing experience X staring at a small screen X to a subjective viewing experience, i.e the eye wanders within the frame to different elements. This significantly enhances realism and impact and thereby the enjoyment of the work. HDTV has the potential to maximize the differentiation between analogue television and digital television.

3.4.1 Compression techniques

HDTV reduces the potential for multi-channel as it normally 15-20 Mb for a single service using the current MPEG2 technologies. However, new compression systems offer a twofold improvement in compression efficiency over MPEG-2.

This is significant for two reasons. Clearly, if HD transmission could be coded at 5-10 Mb using MPEG-4 AVC standard, which would be a significant incentive for broadcasters to reconsider HD as an option, even on terrestrial networks. With it the HDTV would become spectrum-efficient with reduced transmission costs, more HDTV services and programmes could be carried in a given bandwidth or be mixed with standard definition ones, making the trade-off between the number of services and resolution less stark than it is today.

3.4.2 HDTV image formats

The original cinema aspect ratio was 4:3. This was defined by one of Thomas EdisonXs technicians in the 1890s as a consequence of the decision to use film with a 35 mm gauge obtained by halving the Eastman 70 mm film gauge used for still pictures. Use of the 4:3 aspect ratio maximized the picture area on 35 mm film, an important consideration given the low resolution of early film stock.

Apart from some experiments with wide-screen formats in the late 1920s, 4:3 was used for all films till the 1950s, when different wide-screen aspect ratios were introduced, including $1,66 : 1$, $1,85 : 1$ and $2,35 : 1$ (Fig. 3). Television had already

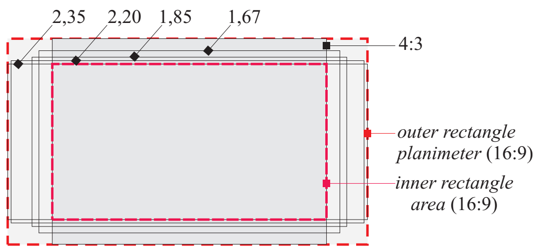


Fig. 3: Cinemas and HDTV images formats

adopted the 4:3 format, to be followed by the computer industry thanks to use of a common manufacturing base for cathode ray tube monitors.

The 16:9 format was agreed by all broadcasters and consumer electronics manufacturers for the future of television, including high definition, in the 1980s. This format is a compromise between the many different aspect ratios used in the film industry. Its mathematical relationship to these and the 4:3 format facilitates the shooting, conversion and display of all programming material (Fig. 3). Moreover, 16:9 ($= 1,77 : 1$) is very close to the Golden Section of $1,618 : 1$.

3.4.3 HDTV image resolutions

The Grand Alliance HDTV standard supports multiple formats (Table 1) which are designed to be primarily compatible with computers rather than existing NTSC, PAL or SECAM televisions.

Table 1: Various HDTV image resolutions

active lines	active horizontal pixels	aspect ratio	frame rate in Hz
720	1280	16/9	progressive 24, 30 or 60
1080	1920	16/9	interlaced 60
1080	1920	16/9	progressive 24, 30

3.5 Multi-service operators (MSO)

Historically, MSO has stood for “Multiple System Operator”, referring to a cable television service providers that operates multiple systems. This antiquated term meant to define separate geographic operations and unconnected networks with disparate, analog, broadcast-only systems. With interactive and cohesive digital networks capable to deliver an array of services, it is time to update the MSO acronym to more appropriately stands for Multi-Service Operators.

MSO enterprisers are moved on wave of customers expectation and demand for an integrated, personalized blend of video, Internet, and voice services that can be accessed using TVs, PCs, and mobile devices with unmatched reliability and ease of use (Table 2).

Table 2: MSO: "All Services on All Screens"

	Video	Internet	Voice
TV, PC	DVT VOD (SD + HD) PVR and NPVR IPTV PVR access Gaming	E-mail and web Instant messaging Internet video Internet audio	Voice mail, caller ID on TV, call-log access Click-to-dial Service management IPN
Mobile	DVT VOD Remote PVR access Portable video content Gaming	E-mail and web Internet video Internet audio	Dual-mode phones Unified voice mail and call-log access Push-to-talk Instant messaging

As an example that MSO enterprisers are possible even in small countries, the Slovenian experiences let be mentioned. Momentary two Internet providers, Amis, fast growing private enterprise and state owned SiOL, a Slovenian Telekom daughter company, provide triple play services advertised as "3 in 1" what should emphasise that one service bundle contains about 100 digital video channels (i.e. multichannel TV services), Internet access (with bit rates between 10 and 20 Mb/s and VoIP.

4 Internet Broadcasting

Internet Protocol Data Casting (IPDC) enables data packet distribution (Data) over broadcasting (Casting). It is core technology for IP Multimedia Systems (IMS) and can be implemented on cable networks as well on wireless networks (Fig. 4). By it the broadcasting is able to become one of network's services with all benefits of bidirectional communication capabilities if IP networks. This gives new dimension to broadcasting since the interactive TV, Video-on-Demand and similar services are simple implement.

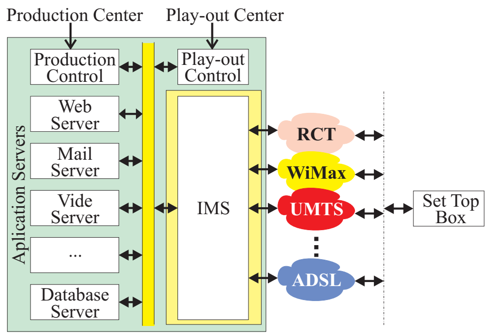


Fig. 4: Integrated multimedia services enabled by IPDC.

At broadcasting the video content is proceeded to IPCD as real-time data stream. IPDC services convert this stream to datacast service. Further there are generated ESG for each program network. This data is then delivered through multicast routers to access points of end users.

4.1 Session Initiation Protocol (SIP)

SIP is just a protocol, of course, not a scalable, interoperable application and service infrastructure. Recognising this, players in the mobile market decided to form the 3rd Generation Partnership Project (3GPP) and bridge the gap by developing the IMS specification. IMS has been embraced by other important standards bodies like ETSI, as well as by major carriers and vendors worldwide.

4.2 Internet protocol Multimedia Subsystem (IMS)

Using an access-agnostic control plane, IMS creates a flexible and extensible platform for IP multimedia services across cable, DSL, fiber, WiFi, and mobile networks. IMS also provides links into legacy mobile and PSTN networks, helping to bridge the packet and circuit, wired and wireless domains. The layered IMS approach enables complex applications to be created and deployed more quickly, reducing development costs and accelerating time to revenue for service providers. Additionally, because IMS is an open, interoperable standard, carriers can select among a range of vendor partners and avoid proprietary solution lock-in.

In IMS nomenclature (Fig. 5), the session control engine is called the Call Session Control Function (CSCF). It works with the Home Subscriber Server (HSS), a database with subscriber service parameters that is accessible to all IMS applications. This is a vast improvement compared to legacy data models. In those cases, each application has its own database, without a consistent method of inter-application communication for sharing subscriber information. The Breakout Gateway Control Function (BGCF) is the interface for interconnecting IMS with legacy networks.

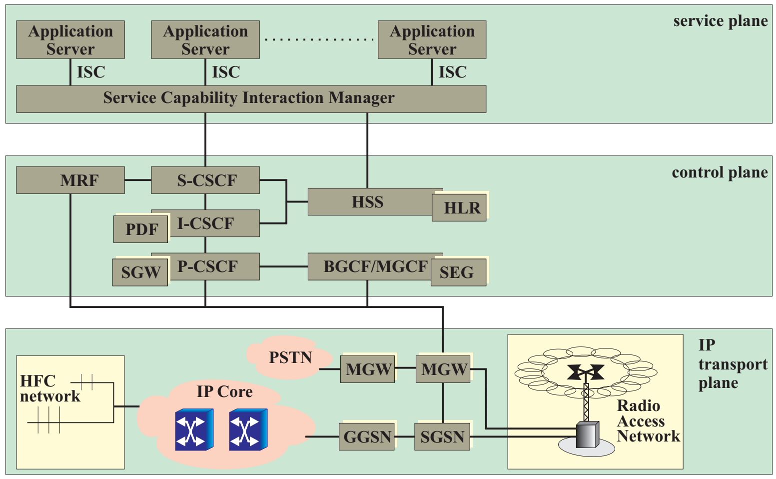


Fig. 5: IMS reference architecture. Abbreviations meaning are:

ISC: IP Service Control

MRF: Media Resource Function
S-CSCF: Serving Call Session Control Function
I-CSCF: Interogating Call Session Control Function
P-CSCF: Proxy Call Session Control Function
PDF: Policy Decision Function
SGW: Signaling Gateway

HSS: Home Subscriber Server
BGCF: Border Gateway Control FN
MGCF: Media Gateway Control Function
HLR: Home Location Register
SEG: Security Gateway

MGW: Media Gateway
GGSN: Gateway GPRS Suport Node
SGSN: Serving GPRS Support Node

In a nutshell, the CSCF is a SIP server that controls multimedia sessions, with several functional elements. The Proxy-CSCF (P-CSCF), a SIP proxy, is the first stop for a SIP client requesting service. It works with the Interrogating-CSCF (I-CSCF) to query and register the user for services. The Serving-CSCF (S-CSCF) accepts and authenticates user registrations, and then routes SIP sessions to users. All of this is done in concert with the HSS, which hosts the subscriber and subscription data needed to authenticate users and applications. Additionally, the HSS plays a critical role in coordinating DNS and security functions.

5 DVB-RCT

The DVB-RCT is based on OFDM technology. Thus, it retains the robust features of the DVB-T in terms of high capacity, efficient spectrum use and immunity against interference and jamming. DVB-RCT makes use of various error correction schemes (convolution and Reed Solomon coding) and different modulation constellations (M-QAM). Added to that is the employment of various adaptive strategies on the base station side such as, dynamic resource allocation (BoD) to users (n Sub-Channels), selection of optimal modulation order (M-QAM) and coding scheme which best fit the requirement for maintaining a reliable communication between the user and the base station. The RCT standard provides three operational modes – Burst Structures (BS) – that give various combinations of time and frequency diversity, thereby providing various degrees of robustness, burst duration and a wide range of bit-rate capacity to the system (Table 3). Depending upon the transmission

Table 3: RCT burst structures: Maximal data rates per sub-channel achieved on various operating modes for 2 k adjacent carriers and 8 MHz bandwidth.

operating modes (burst Structures)	number of subchannels	Data Rate per subchannel (kbit/s)
BS1	1710	16,15
BS2	427	58,86
BS3	59	471

mode, the total on-air signal ensemble is made up of 1 k or 2 k adjacent carriers that are being shared among the users according to burst structure and their bandwidth demand:

- BS1 uses one carrier (defined as one Sub-channel) to carry the total data burst.
- BS2 uses simultaneously four carriers (defined as one sub-channel), each carrying, over time, quarter of the total data burst.
- BS3 uses simultaneously twenty-nine carriers (defined as one sub-channel).

Each user can be allocated to one or more sub-channels to support his data rate requirements starting, in case of BS3, from 471 kb/sfor one sub-channel up to several Mbit/s. The maximum aggregate data rate on the return channel can reach 27.78 Mb/s using 8 MHz bandwidth, 64 QAM and 3/4 coding rate in a fixed roof antenna reception. For mobile reception, the maximum aggregate bit rate will be lower, down to about a quarter of the 27.78 Mb/s.

DVB-RCT can be deployed in large cells. Typically, these large cells will closely match the coverage area of the Digital Television broadcast signal in the forward direction. DVB-RCT can also be deployed in denser networks with smaller cells with user bandwidth of up to several Megabits per second. The system is specifically designed to handle very large peaks in traffic X each sector of each cell can process up to 20 000 short interactions per second. All three burst structures can be employed in the same cell.

Operating mode BS3 is specifically designed to support DVB-T cellularisation and its deployment in small cells. Each base station equipped with 6 sectoring smart antennas can provide simultaneous services to 354 users with average data rate of 471 kb/s for each user.

6 DVB-UMTS

UMTS is the third generation cellular mobile system designed to offer also multimedia/Internet access to portable-mobile terminals. With the target of carrying high-capacity bi-directional multimedia services via radio, UMTS networks are typically characterised by small cells, especially in densely populated areas. The main advantage of UMTS over GSM is the capability to deliver higher bit-rate multimedia services, such as Internet pages and video clips, to portable phones and other types of mobile terminal. Therefore UMTS networks and terminals are able to deliver audio services and low-resolution video services to mobile terminals. Advanced modes of UMTS will also support restricted possibilities for multicast and cell-wide broadcast.

For integration of DVB and UMTS five scenarios are prepared by consortium of 17 broadcasters, network operators, manufacturers of professional and domestic equipment and research centres, lead by T-NOVA (formerly Deutsche Telekom BERKOM).

6.1 Integration on the terminal level

It assumes integration on the terminal level only. The user can receive information (Fig. 6) either over a broadcast or a mobile network. The broadcaster provides be-

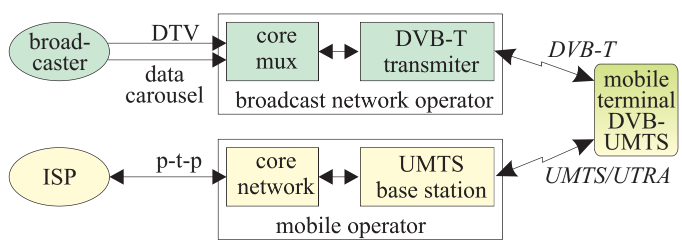


Fig. 6: Scenario 1: integration on the terminal level

sides TV a data carousel on a DVB-T multiplex. The data carousel can comprise all kind of information, e.g. an online service, the download of files, software, videos etc. The data carousel enables hyperlinks which route to other pages or files in the data carousel or – if not available – will enforce the terminal to approach an ISP via

UMTS. Even without an UMTS link, the service is usable (and covered by existing DVB specifications). If the broadcaster likes to provide local information, i.e. news, traffic announcements and events, the content can be put on a (second) data carousel for a local DVB-T chain. In this scenario there is no definite requirement for a co-ordination of both networks related to the services and applications. The user has the choice to select the service of DVB or UMTS to get the requested information. However, it will not be easy for him to see which is the most convenient and cost efficient way. So far a co-ordination at least at the service level would be beneficial for the user.

6.2 IP services on coordinated UMTS and DVB networks

This scenario is technically similar to scenario 1, but now a service provider (e.g. ISP) offers a non-broadcaster related IP service on both networks (Fig. 7). A

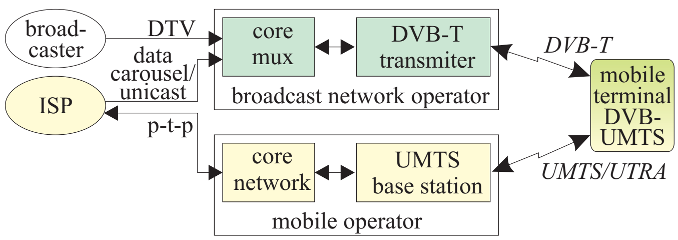


Fig. 7: Scenario 2: integration on the service level.

coordination of both networks is implemented on the network basis to provide new features. A service provider uses a part of a DVB-T multiplex (e.g. leased from a broadcast network operator) to provide a portal for an Online service. He uses a data carousel as above to transmit the most relevant pages or files to the user. Links to the WWW have to use UMTS in the normal retrieval mode. The benefit for the user and the service provider is that a part of the traffic is transported by DVB-T to multiple users. This reduces the traffic load on UMTS as well as the access time to frequently used pages (if stored in the terminal) and improves therefore economics and performance.

A control channel is needed to provide signalling for the use and allocation of these channels (e.g. handover or roaming for DVB-T and UMTS). Thus the user can tune to (one of) the DVB-T Online channel(s), indicated via UMTS or vice versa. This control channel can inform the user that a combined service is available and configures the receiver to use the service. The user should not be forced to make the configuration itself. Thus a co-ordination at the network level sup ports the use of the service.

6.3 UMTS as an interaction channel

This scenario (Fig. 8) uses UTMS as an interaction channel for interactive broadcast services. It provides the same interactive services as with a GSM return channel (dial- in access). An alternative to dial- in is to contact the broadcaster via the Web, using the access to an ISP. This may be more efficient, as the always-on capability of UMTS fits better to the interaction channel in digital broadcasting. The terminal receives with the digital TV program one or more URL(s), e.g. via SI (service information), which are related to the specific interactive program, and enables the terminal to get connected to the server of the broadcaster.

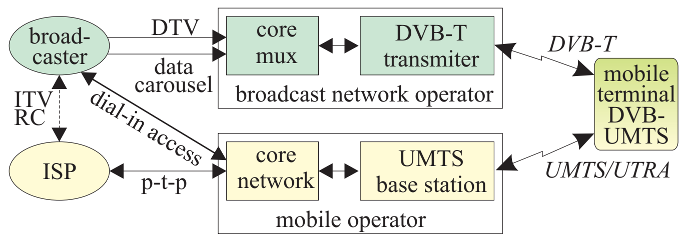


Fig. 8: Scenario 3: UMTS as a return channel for interactive TV.

6.4 Delivery of DVB content via UMTS.

Planed are two subscenarios:

- *Scenario 4A* supports the delivery of DVB content via UMTS (Fig. 9). Because of limited resources (bit rate and capacity) it is not feasible to provide broadcast quality TV services in a normal mode via UMTS. Therefore the TV service via UMTS has to be adapted in terms of resolution, bit-rate and probably coding format. A straightforward approach to provide video services to UMTS terminals is that a service provider (an ISP or the broadcaster itself) offers the content to a mobile operator in an appropriate form

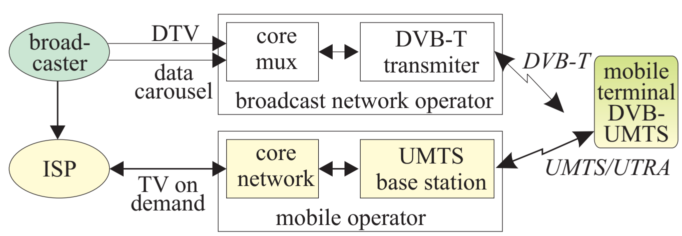


Fig. 9: Scenario 4A: DVB content via UMTS.

and that the TV program is accessed in a retrieval mode by an individual user (i.e. TV on demand).

- *Scenario 4B: DVB content over B-UMTS.* It is planed future extension of scenario 4A for a mobile network operator or a broadcast network operator might be based on the coexistence of two superimposed UMTS networks, each one operating on a separate frequency band (Fig. 10):

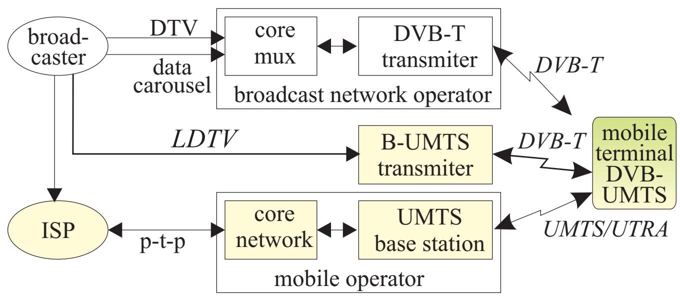


Fig. 10: Scenario 4B: DVB content over B-UMTS.

1. an uni-directional "broadcast-UMTS" network (B-UMTS), characterised by high power transmitters and wide coverage, for broadcast services (radio, television and multimedia)
2. a bi-directional UMTS cellular network, for the interactive services (e.g., telephony, Internet access).

6.5 UMTS with integrated DCB-T downlink.

This scenario is a modification of the scenario 2 which enables the ISP or a mobile network operator to deploy a UMTS network with a DVB-T downlink (Fig. 11) The DVB-T downlink as part of the UMTS network is now used as an extension

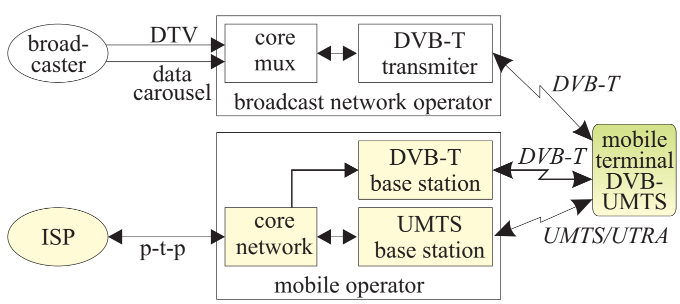


Fig. 11: Scenario 5: UMTS with integrated DCB-T downlink.

pipe to the UMTS air interface (UTRA) to increase the downlink capacity. The DVB-T transmitter can be collocated with the UMTS base station. In this scenario DVB-T is used only as a technology in a mobile network. Sharing spectrum with DVB-T broadcast is required. The DVB-T cell size can be the same or greater than the UMTS cell, depending on the service mode.

7 IPTV OVER WIMAX

Future IPTV services will strongly depend on coise of correct transmitting technologies, but it is even more critical to identify the key success factors for launching a successful IPTV service.

7.1 Key Success factors for IPTV over WImax

7.1.1 Economy of Scale.

Economy of scale characterizes a production process or service operation, in which an increase in the number of producing units may cause a decrease in the average fixed cost of each unit. By optimizing the economy of scale for operating IPTV services, one can minimize the risks and secure the early advent of ultimate success. This translates to the need of an access network technology that can support more subscribers and mobile TV for future requirements.

7.1.2 Scheduled Live Content and Quality Assurance.

Quality of service and quality of experience for end users have been identified as critical requirements of IPTV services. In the long run, watching IPTV content will be just like surfing different Web sites over the Internet. Watching unmanaged live or on-demand content offered by different service and media providers in the world would provide the true value of IPTV services to customers. However, an IPTV channel is still critical to ensure comparable TV quality and experiences similar to those of the conventional cable, satellite, or digital TV services. Offering managed and scheduled SDTV programs with a quality guarantee is required to secure a head start and the success of IPTV service.

7.2 Why IPTV over WiMAX

WiMAX should always be included to facilitate the previously mentioned success factors for the IPTV services due to the following factors:

7.2.1 Maximize the Number of Subscribers

Obviously, the success of the launch of IPTV services is determined by the time and volume of profitable operations. Getting the maximum number of subscribers as soon as possible for a newly launched IPTV service program is a clear goal for any service provider. It has been reported from time to time that xDSL and cable broadband access is not available in some areas due to geographical distance and user-density. Meanwhile, the deployment of xDSL and cable wiring overhead is not as easy and scalable as that of WMAN technologies.

As an alternative to the conventional wired access network technologies, WiMAX offers the ease of deployment similar to other wireless technologies, but with larger service coverage and more bandwidth. The cost for infrastructure deployment and for service provision can be dramatically reduced. Delivering IPTV services over WiMAX to complement the current IPTV deployment can capture the maximum number of subscribers under the same infrastructure and provide even better accessibility to the same pool of video content for mobile users in the future.

7.2.2 Converged Wireless Broadband Access Net

Telecoms arc actively seeking ways to offer triple or quadruple play services. WiMAX is considered a very good candidate to provide new services such as wireless broadband access and mobile voice over Internet Protocol (VoIP) telephony. Launching IPTV over WiMAX can further achieve economy of scale in terms of more services and better service availability under a common infrastructure.

7.2.3 Supporting the Future Trends

We have enumerated the emerging trends of IPTV for the aspects of mobility, accessing unmanaged content, and supporting high-quality video, such as HDTV. WiMAX offers benefits for such promotion with its reservation-based bandwidth allocation, cost-effective and infrastructure-free deployment, and stringent QoS support for the four types of service: unsolicited granted service (UGS), real-time polling service (rtPS), non real-time polling service (nrtPS), and best effort (BE) traffic.

Enabling rtPS in the wireless broadband access can support perfectly the bandwidth requirements of managed content of the IPTV service providers, especially for paid HDTV and SDTV. With more and more portals available in the Internet core that offer a great deal of rich and free on-demand video content, it is a very attractive approach to allow not only home IPTV users, but also mobile users to access this unmanaged content without affecting the quality and performance of other paid live content. The incorporation of rtPS and BE services can be manipulated to support these demands, such that the best flexibility and economy can be achieved without losing much quality in content delivery. The extendibility for supporting the future trends of IPTV services over common WiMAX access infrastructure creates long-term and growing economies of scale to the state-of-the-art IPTV operation.

8 DVB-H

DVB-H is the latest development from the DVB Project targeting hand-held, battery powered devices such as mobile telephones, PDAs, etc. DVB-H combines broadcasting with a set of measures to ensure that the target receivers can operate from a battery and on the move. The DVB-H specification was developed in June 2004 for accessing DVB services on handheld devices.

Note, the DVB-H technology is upgraded DVB-T considering specifics of hand held terminals (HHT) and their use:

- limited power source of supplying batteries,
- high noise and interferences surrounding,
- Doppler effect caused with fast moving of terminals,
- seamless handover from cell to cell,
- flexibility in use of different bandpass widths and different frequency range (UHF, VHF).

To cope with above requirements the DVB-T specifications have been upgraded with the following (Fig. 12):

1. Time-slicing mechanism, which has two functions: **(i)** to spare energy consumption, and **(ii)** to allow smooth handover between cells.
2. Additional Forward Error Correction (MPE-FEC) for improving carrier to noise ratio (CNR), reduction of influence of the Doppler effect, and improving the impulse interference tolerance.
3. DVB-H signaling superimpose service and cell identifier information by modulation of the TPS carriers. It enables fast network detection and faster service and cell identification.
4. To DVB-T 2K and 8K modulation systems (the first one enables higher receiver speed, the second one for large, but slower SFN networks) the 4K modulation is added as compromise for both demands.
5. Additional 8K symbol interleaving of 4K system gives higher robustness in mobile and impulse noise surrounding.

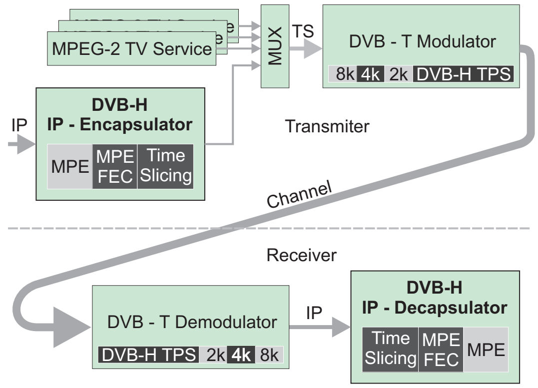


Fig. 12: DVB-H block diagram

8.1 Channel capacity

Existing television channel raster is accommodated for analog television system. Unfortunately this is not the same around the world, because it depends on the used television system. In Europe prevails nominal image resolution 625×625 which together with audio channels require 7 MHz channel bandwidths in the I., II. and III. frequency range, and 8 MHz in IV. and V. frequency bands.

8.2 Number of channels

The DVB-H technology is designed for lower image resolution, which require far lower bit rate in video stream (Table 4). Consequently DVB-H can settle in one

Table 4: Image quality, frame rate and channel stream bit rate.

image format	frame rate	bit rate
QCIF (176×144 pixels)	15 frame/s	128 kbit/s
CIF (352×288 pixels)	15 frame/s	384 kbit/s

DVB-T channel up to 50 channels. Since this channels are transmitted in bundle, the DVB-H on transmitter side require the same channel capacity as DVB-T.

8.3 Time-slicing

Time-slicing is actually a TDM system with important differences only on the receiving side. A transmitter continuously transfers slice after slice, but HHT with help of the superimposed channel and cell information can fast detect selected channel and in-time invoke sleeping receivers circuits. The end of belonging slice puts the receiver in the sleep mode. From HHT point of view data arrives in burst modes with DVB-T bit rate, so the bit rates given in Table 4 are average bit rates.

Time between the selected channel slices HHT can be used for measurement of the neighborhood cells signal power. If it detects one with a higher power than that, which in use, the handover occurs.

8.4 Error correction

DVB-T and specially DVB-H are planed for rush environment, so effective measures for error-free receiving are undertaken. To the DVB-T channel coding DVB-H has added a new layer in the multiprotocol encapsulation (MPE) phase. MPE-FEC is performed in the MPE phase. The parity bits are spread in MPE section. This coding consumes the variable part of the channel capacity. Practice shows that the system consuming 25 % of channel capacity with transmission of parity bits has the same receiver quality as HHT with diversity antenna.

8.5 Signaling

If MPE-FEC and/or 4k modulation is used, DVB-H uses signaling for identification of the time-slices channels, cells and information.

With signaling a fast and simple recognition of slices that belong to a channel is achieved. This is an important feature since based on which most of receivers' circuits can sleep until the arrival of the next slice in the channel.

8.6 Modulation

DVB-H to the modulation used in DVB-T, e.g. 8k-OFDM with 6817 carriers spaced for 1116 Hz per symbol (6048 of them are used for data transferring, others serve for synchronization) and 2k-OFDM with 1705 carriers spaced for 4464 Hz (1512 used in data transferring) add the 4k-OFDM.

To combine mobile services together with a fixed reception application the DVB-T group introduced a *hierarchical encoding*. This encoding calls for a special DVB-T 64-QAM modulator which is fed by two transport streams (Fig. 13). One of them controls the 16-QAM signal (Low Priority Stream), and the other controls in which quadrant the 16-QAM constellation (High Priority Stream) is placed (Fig. 14). The benefit of the hierarchical encoding is that the system allows one program for DVB-H application together with service supporting programs to be pick up in stationary application – DVB-T.

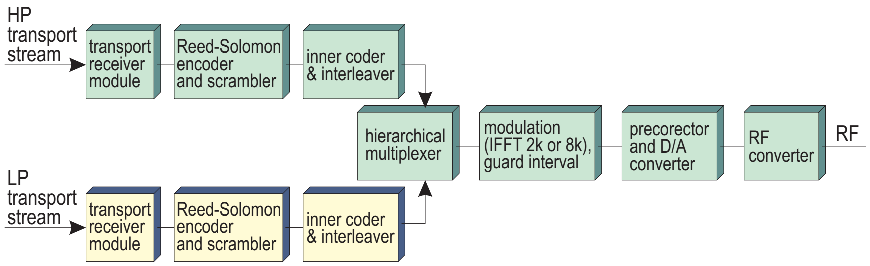


Fig. 13: Block diagram of the hierarchical modulation.

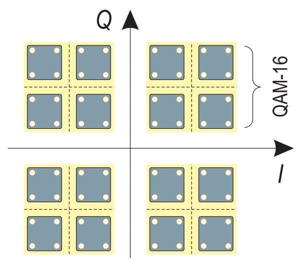


Fig. 14: Constellation diagram of the hierarchical modulation. To the 4-QAM belongs squares (one in each I-Q quadrant), content of these squares are further detailed by 16-QAM, which belongs to LP stream. In the worse environmental condition it is replaced with 4-QAM. Joined 4-QAM and 16-QAM give 64-QAM, and joined 4-QAM and 4-QAM yields to 16-QAM.

8.7 Internet Protocol Data Casting

The mobile IPDC (Fig. 15) need mobile terminals, which beside GSM/GPRS or

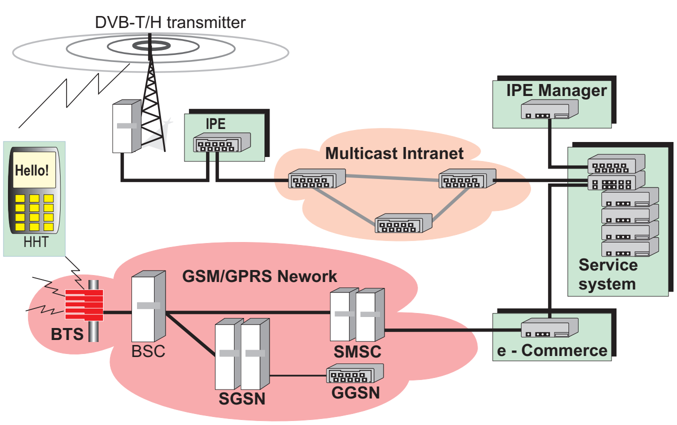


Fig. 15: Basic IPDC configuration.

UMTS functionality have DVB-H receivers. With DVB-H receiver users can watch

DVB accommodated with handheld capabilities. For program selection and other services ESG (Electronic Service Guide) is used. It controls distribution of content through intranet. In order to save available terminal's battery energy, DVB is distributed in time-slices, i.e in discontinuous mode. This is very important feature of the DVB-H standard. It is enabled by IP encapsulation (IPE).

In DVB-H the IPDC consists of two channels:

1. Channel for content transmission by means of DVB-H network (upper part of Fig. 16) ,
2. GSM/GPRS network, which enables IPDC services as well as classic mobile phones services (lower part of Fig. 16).

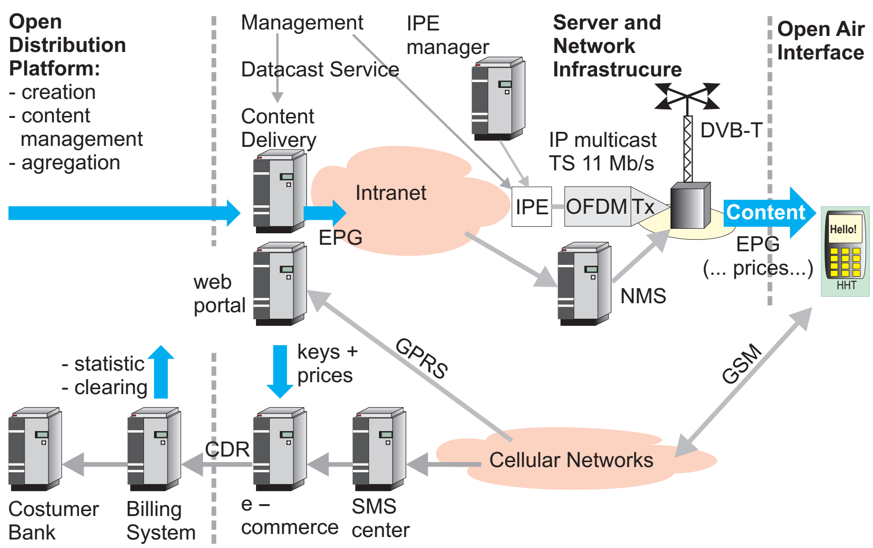


Fig. 16: IPDC network and system.

Each channel consists of number of building blocks enabling functionality of IPDC. First among them in the first channel is *Datacast server*. There video signals are stored in the form, which is simple to edit, process, store and link to the content prepared for distribution. You can also find there added information about the content (like TV programs), metadata about content etc.

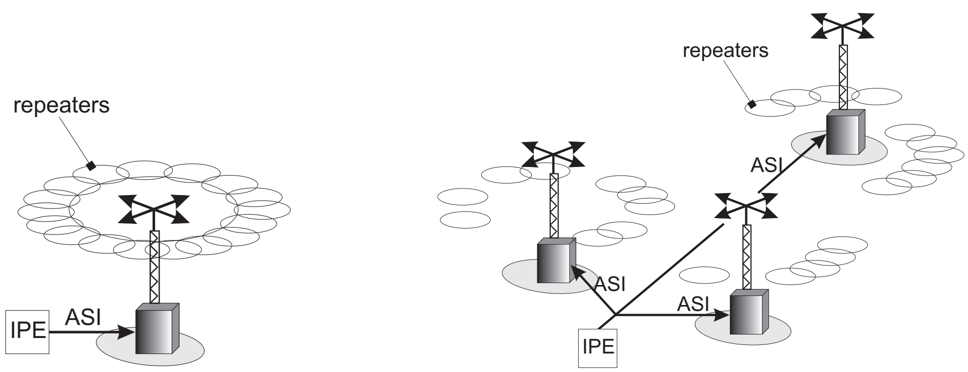
8.8 DVB-H networks

DVB-H uses Single Frequency Network (SFN) systems due to the lowest costs, terrain coverage and channels utilization. This means that broadcasting is performed from many points, forming cells on the same frequency. Consequently, the HHT can simultaneously receive many synchronously modulated signals and thus gain signal/noise ratio. The bad side of SFN are interferences caused by difference in signal propagation from cells transmitters. The *guard interval* introduced in DVB-T serve as protection against them. If delays are longer than group delay, delayed signal causes additional noise. Power of those noises is time depended.

Further advantages of SFN over Multi Frequency Network (MFN), a typical SFN case is a GSM network of cells, which is a far more effective terrain of signal coverage. If somewhere the signal level is under the acceptable threshold, it can be recovered by simple adding of more transmitters or repeaters to the same frequency. No additional frequency space, i.e. channel allocations, is necessary. This means that the DVB-T signal sources power can be lower and that the signal power distribution over the terrain has smaller power variation as in the case of MFN.

All the above mentioned SFN benefits are paid by demanding transmitters synchronisation.

The cell size depends on the terrain obstacles and density of population. In rural areas one higher power transmitter with number of repeaters on cell's boundary is typically used (Fig. 17a). The use of repeaters lower the network installation



(a) rural case:
1 DVB-H transmitter,
10 to 20 repeaters

(b) urban case:
1 – 6 DVB-H transmitters, 5 – 10 repeaters

Fig. 17: DVB-H cell network

costs, because they don't need to be connected to some primary signal distribution network. In urban areas the transmission infrastructure is more sophisticated due to the buildings and other obstacles. It needs a number of transmitters linked to some primary network (Fig. 17b). Transmitters should have well synchronized (by means of GPS) modulators. Small power repeaters are used only for covering gaps or shadows inside the network.

In both cell types the cell shape field is not relevant. It is determined by antennas configuration and covers only selected direction, for example section of highways. Maximal distance depends on modulation and it is limited to 60 km.

Cells in some area are connected to intranet (Fig. 18). The input router must

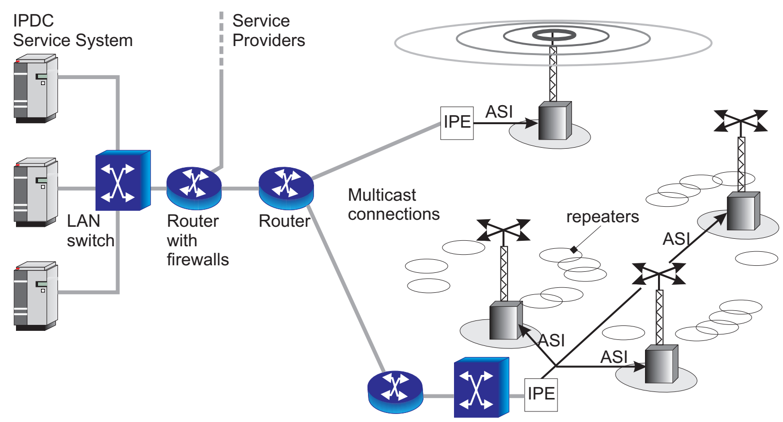


Fig. 18: Intranet connection to the transmitting stations

have firewalls for protection against unauthorized assess. Intranet topology, elements and traffic organization should support multicast traffic and have acceptable small jitter. For DVB stream transmission, the SDH networks due to their time division multiplex nature are very well situated.

A cell with many transmitters has only one IPE delivering encapsulated DVB stream to all transmitters over coaxial or fiber cables or radio links.

8.9 IPDC service management

Basic IPDC service is broadcasting, not user controlled multicast. Therefore the IPDC operator should allocate the network capacity to all service providers in fair amount. This is done by controlling the IPE process (Fig. 19).

8.10 Services

IPDC offers many new services. A huge potential among them has usage and implementation of different portals, news services, and delivering of multimedia contents. Another very important field is advertising, such as public information about traffic, weather, job positions etc, and other type like information regarding shopping, restaurants, care services etc. All these can be geographically sensitive.

From all possible services the following two bundles should be emphasised:

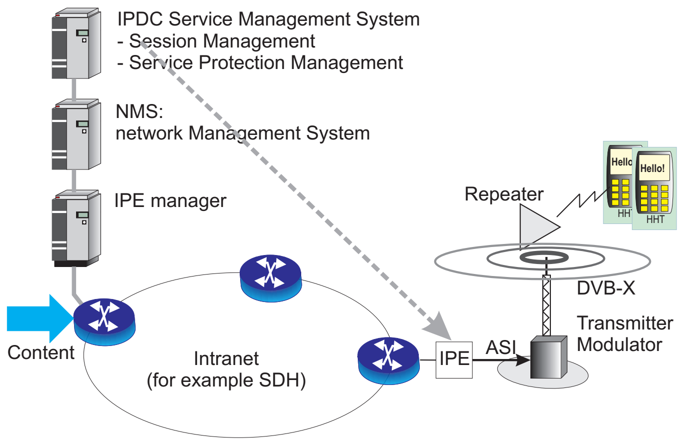


Fig. 19: IPDC management system

1. **Interactive services** which may includes:

   - *Online shopping*. It can be supported by catalogs, brochures.
   - *Chat*. This is an online forum, where users can send messages. They are delivered to all IPCD users. Since there is a small amount of data, many chat rooms can be established simultaneously.
   - *Online ticket purchasing*. There is an idea that user beside classic information (time schedule, price, available places ...) can see a snaps of movie, theatre or concert performance etc.

2. **Non-interactive services** which are similar to well known teletext's services:

   - Traffic news with snaps of actual road reports, stock exchange news, weather forecast, actual events ...;
   - Profiled news according to the interest groups;
   - electronic newspaper;
   - radio and television guide.

9 Conclusion

Since digital broadcasting far better utilises frequency space than analog transmission, it gives better video and audio quality, easily provides multimedia services and also enables services, which cannot be conceived in analog systems such as interactivity. All this can be done at affordable prices and that makes digital broadcasting a very important player in all kinds of data transmission to broad audience.

The full potential of digital broadcasting can be exploited in convergence with other telecommunications technologies. But technological convergence as well as development of specific convergence technologies are no guarantee that business convergence will eventually take place. Other drivers such as market, regulation, competition, motivation must exist to make it all happen.

Another important issue in digital broadcasting is users terminals. Their potential can be exploited with new terminals such as HHT with DVD-H capability, new generation of Set-Top-Boxes, which integrate functions of communication nodes with DVB and DAB receivers, new sets based on Multimedia Home Platform merging personal computer and TV set in one device as well as different kind of personal computers.

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